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Thesis Title

CONCEPTUALIZING SUSTAINABILITY DYNAMICS:
A FRAMEWORK FOR INTERFACE OF COMPLEX DYNAMICS AND SUSTAINABILITY IN HUMAN-NATURAL SYSTEMS

(サステイナビリティダイナミクスの概念の明確化：
人間–自然システムにおける複雑系ダイナミクスとサステイナビリティを繋ぐための枠組み)

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A Dissertation

by

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論文の内容の要旨

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(サステイナビリティダイナミクスの概念の明確化：人間−自然システムにおける複雑系ダイナミクスとサステイナビリティを繋ぐための枠組み)

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Sustainability is an evolving concept in an age of complexity. Human–natural systems where unsustainability issues appear are highly complex and dynamic. Sustainability or unsustainability conditions in these systems are diverse and change across space, time, and organizing relationships. The diversities and changes are not readily visible, which makes observing and evaluating sustainability in them a challenging task. Sustainability also has a significant conceptual diversity. Incorporating both holistic and context-specific conceptual understanding is necessary for interpretations of sustainability. Failing to do so could result in specific but not generally representative interpretations, or overly simplified or generalized interpretations. These challenges also extend to frameworks and methodologies used for evaluating sustainability. Often sustainability-evaluation frameworks and methodologies tend to focus on interpretations of a static state of a system. Further, they also support the analysis of parts and the specific processes that can scrutinize individual aspects of complexities. In contrast,

they can also produce generalized overviews that aim to reduce the complexities. However, the conceptual nature of complex dynamics demands that the frameworks and methodologies should adequately internalize both these ends. It means that in the face of complex dynamics, the observation process plays a key role in sustainability evaluation. Observing sustainability involves a cognitive process of organizing the knowledge related to human–natural systems' evolutionary paths, general sustainability principles, system-specific sustainability or unsustainability conditions, and complex dynamics involved in the observation process. In the field of sustainability, there have been milestone works to address the complex dynamics of human–natural systems along with their implications of sustainability in those systems. However, sensitivity to the process of observation of sustainability and sustainability change seems to still be lacking, which subsequently adds up to erroneous and incomplete interpretations and evaluations of sustainability.

This thesis explores the complex dynamics linked to sustainability in human–natural systems, and proposes a framework that embeds a methodology to reflexively observe and evaluate complex dynamic sustainability contexts by using the concept of 'sustainability boundaries'. The framework is developed by incorporating basic ideas of complex dynamics linked to human–natural systems, and the complex dynamics linked to observing sustainability and sustainability changes in these systems. Two complementary methods are proposed to observe sustainability contexts and sustainability boundaries. First, by utilizing a 'system and background' unit as an observation unit, the layer view-based method places the foundation to recognize sustainability contexts in a relatively fixed time frame. The observation process supported by the method is grounded in key ideas of complexity, which makes it a complex dynamic process in itself. Second, the 'system and background' units are examined through a set of dimensions that represent general and contextual principles of sustainability to recognize explicit sustainability or unsustainability conditions and their changes over the time. The proposed dimensions are, (i) sustainability-linked knowledge (ii) sustainability-linked worldviews (iii) resource limitation/availability (iv) well-being views (v) policies, rules, regulation, and governing practices (vi) new creations, innovations, and artifacts. They are considered to be relatively independent dimensions in terms of their role in forming and changing sustainability boundaries, yet with mutual interaction, collectively reinforce the sustainability or unsustainability path of a system. By combining these two complementary methods into an observation methodology that support a reflexive and iterative understanding process, the framework enable us to see multiple different sustainability contexts and their changing patterns and mechanisms. In overall, the methodology supported by the framework represents an integrated differentiation, analysis, and synthesis process that translates sustainability contexts to sustainability boundaries.

In order to illustrate its applications, the framework is supported with two case studies—one addressing the dynamics of a global-level unsustainability issue, and the other addressing historical sustainability change of a local-level village-forest socio-ecological system. In both cases, applying the framework led to holistic interpretations and evaluations, and in addition, made these interpretations and evaluations change-conscious. The framework also highlighted the drivers of change that had brought the systems from one sustainability state to another. Among these drivers, sustainability-linked worldviews seems to have played a synthesising role in emergence of new sustainability states that could transform itself. The case evaluations with the framework also have strengthened the previous understanding that sustainability resembles a dynamic process and a path than a static state.

In overall, the complex dynamics linked to the process of observing and evaluating sustainability change in human–natural systems are referred to as 'sustainability dynamics' in this thesis. The framework was developed to reflexively explore sustainability dynamics of human–natural systems by utilizing observation metastructures that support holistic interpretations and evaluations of sustainability and sustainability change. Together with those interpretations and evaluations, the thesis explores the patterns and mechanisms of sustainability dynamics.

DEDICATION

I dedicate this thesis to my family and my close friends.

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1. INTRODUCTION

Sustainability is a concept for the age of complexity.

The systems around which the discourse of sustainability is woven, shows complex dynamic evolving patterns. The planet we know today is a highly complex system where different types of systems interact with one another to form incredibly complex patterns and relationships[1]. These relationships spread across different units of different scales such as individuals, societies, villages, cities, countries, and the earth. The systems are interconnected with diverse spatial, temporal, and organizing relationships that continuously evolve these human–natural systems.

Further, there is a significant diversity in the way the concept is perceived adding complexity to the concept. These diversities are reflected in both general understanding and scholarly debates of sustainability. General understandings are predominantly shaped by the complexities related to the unsustainability issues that the systems go through. One example is how resource limitations are experienced by societies. In many places imitations of natural resources have placed stresses on the economic and social paths that human societies are collectively heading. The limitations seen for a particular society (for instance the workforce draining that is happening in many places as urban sprawl and the linked disappearance of many of the cultural values, tacit knowledge etc) are not confined to those remote locations. Countries and regions go through similar resource limitations, and the way the resources are allocated can no longer depend on the scarcity or the abundance of the resources. Consuming excessively one resource can have environmental and ethical implications that do not limit only to that particular place but across a wider terrain. Taken globe as one single system, the regenerating rate of natural resources is less than the current consuming rate highlighting that complexity of the issue stretch beyond current space and time. Further, over the years sustainability was heavily debated for its conceptual orientation for aspects such as, the human role of planet's sustainability and related diverse ethical standpoints. Significant aspects behind these debates are the diversity in interpretations and the changing and evolving nature of those interpretations. Sustainability in a deep sense is a concept that has surfaced and stands upon such diverse interpretations. These interpretations have

[1] We use the term system to mean an interdependent group of items forming a unified pattern.

paved for multiple possible conceptual pathways of sustainability. Even though its well recognized milestone in 20th century, the concept of sustainable development, is much known and cited in earlier developments of sustainability literature, factors such as the essence of facing the challenge of survival, the suitable way of existence, the sense of continuity, and multiple pathways to the future have always hovered in the background in all eras of human history in different parts of the world. Further, these interpretations have grounded upon individual and collective beliefs and perceptions, formal and informal knowledge that represent economic, social, ecological, technological, ethical etc aspects, and sometimes have evolved in to ideologies and philosophies. Stressing on such hard conceptual side in modern discussions on sustainability is now often regarded as perspectives of strong sustainability. Further, because of the complex nature of these macro level interpretations, sustainability as a concept has remained as a vague and ineffable concept. Despite such vagueness, sustainability interpretations also carry the desperation of reaching tangible or physical grounds, so that goals can be set easily within existing structures of research, policies, engineering etc. This strong inclination to frame the concept has lead to approach sustainability from a viewpoint that suits a particular application, goal, or a target. Such efforts have been challenged for their danger of over-simplification tendency, but also not completely eliminated mainly because of the existing vagueness and ambiguity in the macro-level definitions. However, linked with the unavoidable confusion made by highly specified approach to integrate sustainability's conceptual value in to policies, research, actions etc., instead of basing a foundation in a viewpoints that capture its inherent complexity and the complexities associated to the systems that the concept stands upon, very often sustainability is implied as a future state or a target, which is not quite clearly defied, yet since known as good, to be followed or even raced to reached through available means (Satanarachchi and Mino 2009[a]). Part of this pattern has been due to the fact that early dialogues, especially the scholarly ones, seem to have rooted from significantly two deviating branches of perspectives. One is the policy-oriented perspective of sustainability. And the other is a deep philosophy-oriented perspective of sustainability. Scholars are conceptualizing the present situation in history in different ways; some call it the tail 'end of modernity' where 'time and space compression' takes place. In these conceptualizations, sustainability/unsustainability of a system could be visualized as an isolated local phenomenon, as a part of a global phenomenon, and as an interconnected whole across different spatial, temporal, and organizational scales. Such visualization across different scales is a reflection of the diversity of humanity's understanding and awareness of itself and its surrounding, which are subjected to change and transform. Further, in a complex dynamic world there are numerous aspects that would lead us towards or away from what we understand as sustainability, which too is being shaped by the very process of observing, understanding, and interpretations[2]. Further that awareness itself reshapes the way we think and give new interpretations of sustainability to our systems. Thomas Berry, taking classical cultures of Eurasia, Africa, and Americas points out that these classical cultures came in to existence when human kind's experience on earth was predominantly spatial, while today we are given the mandate of transitioning to an understanding of the world in an ongoing evolutionary perspective (Lazlo E and Combs A., 2011). While the argument taken alone out of context may hide the perspectives such as history being internalized to those early societies through folk stories, cultures etc, it also embodies a further point with regards to the challenge we face in observing the surrounding amidst of complexities in today's world. It urges us to look at sustainability—a concept that gains its meaning through human interpretations—as a concept that has internalized various forms of complexities and dynamic changes associated to them. With conscious/unconscious decisions made in the interface of complex dynamics and sustainability, a system's path that joins its past, present, and future is formed, and would decide whether the system appears sustainable/unsustainable at a certain point in history.

With complex dynamics we face challenges for evaluating sustainability. Sustainability-evaluations, whether based on qualitative or quantitative interpretations, are essential to make decisions and plans for our systems. The challenges in evaluation could be seen as twofold. First, sustainability is closely tied to human–natural systems and their complex dynamics. Therefore the evaluations of sustainability of a system cannot be far from complexities and changing nature of the systems. Second, to solve issues and make plans in these systems, the evaluator's ability to recognize the complex dynamics and interpret the system's sustainability in a way that reflect those complex dynamics plays a key role. In this process evaluator's way of observations may have a crucial importance. The process that leads through the steps of preliminarily observations, interpretations, and finally rigorous evaluations of sustainability/unsustainability in itself appears to be a complex dynamic process. Further, because we as observers and evaluators are part of the systems (human–natural systems) that we observe and evaluate by deciding what constitutes as sustainability or unsustainability in the system (e.g. by recognizing issues as unsustainability issues), the evaluation process does influence how different systems and system entities experience sustainability, and based on those experiences, how they interpret sustainability in future. The resulting differences in interpretation across space and time of the system are often characterized by the use of the term 'context'. The contexts highlights the 'differences' associated with complexity. However, being only sensitive to differences does not lead us to understand general patterns that would have been visible if

[2] The process of trying to understand the system that human are part of, may metaphorically resemble the process of an individual trying to be aware of their own thought process.

systems were taken collectively, nor they allow us to see how these specific contexts are affected by such general patterns and further the change mechanisms behind those patterns. Even with varieties of differentness in trying to address sustainability in the form of problem solving or planning, many commonalities and continuations in terms of understanding and practices are always sought after. Without the sensitivity to the real complex dynamic nature of human–natural systems, these problem solving and planning activities could become erroneous (by relying on too simplistic and obvious assumptions), or ad-hock practices (by relying on only specificities and not on general patterns that can connect groups, places, projects across space and time)[3]. In fact the philosophical and scientific use of the term complexities does not imply being aware of differences alone, even though often the general use of the term may resonate a meaning close to 'complicatedness'. A deeper theoretical understanding of complexity—as would be shown in subsequent sections of this thesis—emphasises the importance of the differences, specificities, and contexts that reflect such differences and specificities, and, further the commonalities and general implications in a situation where extremely high amount of interactions are taking place. This is necessarily the case for any human–natural systems that we observe in sustainability evaluations. Human–natural systems are comprised of subsystems of different scales, and are connected to other external similar systems. They create system and environment relationships that affect the system's sustainability interpretations and evaluations, and further that may generate complex dynamic changes significant for sustainability evaluations. Evaluation can be done explicitly using specific indicators and measures. At the same time, some form of an evaluation is implicitly done in almost all decision points with the basic judgment of what is sustainable and what is not sustainable for a given context. Therefore, in sustainability evaluation there is undoubtedly the need for exploring the interface of complex dynamics and sustainability[4] and to come up with an understanding based evaluation than an add-hock or a mechanized procedure. For that, each observer needs to be sensitive to the complex dynamics linked to the evaluation process. Being sensitive to them, opens up new dimensions with which sustainability can be observed by exposing new contexts of sustainability. It also eliminates simplistic understanding, and as a result, is likely to make the decisions made for these systems more informed and accurate. In addition, they may also allow us to recognize patterns out of the complexities.

However, starting to address sustainability in human–natural systems in this manner also generates new challenges with respect to 'observing' complex dynamics. Usually evaluation and observation are not apart from each other. Observation of systems and the issues in those systems

[3] A similar idea is attached to the terms top-down and bottom-up approach that we follow in sustainability practices.
[4] At this point we do not go in to details as what the 'interface of complex dynamics and sustainability' would mean, how ever once a deeper discussion is made around these two entities and how they are interrelated, at the end of the literature review we would provide a more elaborated explanation.

is the entry point for sustainability-evaluation. In the face of complex dynamics, no longer the sustainability observations and evaluations could be based on fixed views nor could they be too narrow or too general. In usual evaluations, we tend to focus either on the specific parts of the system—which leads to focused evaluations, or on the whole of the system—which leads to generalized evaluations. They alone are often incomplete and further would hide distinctive change patterns that may be only visible if both ‘parts’ and ‘wholes’ were considered. These concerns extend for the frameworks and methodologies that we use in sustainability. The very conceptual nature of complex dynamics demands that the frameworks with which we observe and interpret our surrounding, also to have adequately internalized these characteristics to the observations and evaluations that they support.

In overall, we could say that the complex dynamics linked to the general evolutionary patterns of human–natural systems that make them sustainable/unsustainable, and the complex dynamics linked to the observation process that leads to sustainability interpretations (and subsequent evaluations) of those systems, would make sustainability appear as a dynamic process. If we collectively call these aspects as sustainability dynamics, then addressing the dynamics would be a significant aspect to make our interpretations and evaluations more accurate. To address them we would have to step back and explore complex dynamics in detail. Not only explore them as a separate study, it would be worthwhile if we could incorporate the exploring ability of them to our frameworks, so that our interpretations would naturally address dynamic patterns related to sustainability change, and further, would enable us to recognize the change mechanisms behind those patterns.

With such basis, this thesis aims to propose a framework to observe and evaluate sustainability in human–natural systems in a complex dynamic context. We recognize that internalizing complex dynamics is one requirements of such a framework. The thesis follows a combined exploratory, explanatory (for conceptualization), and analytical (for case illustration) approach in its development. The contents are arranged to first include a background review and a detailed review on theoretical implication of complex dynamics and other useful theories (Chapter 2). Then the stepwise process of developing framework is illustrated (Chapter 3), which is followed by an exploration of its applications with empirical observation (Chapter 4). Finally a discussion is made on the proposed framework focusing on its strengths and weaknesses to address what we at the end illustrate as sustainability dynamics.

2. EXPLORING SUSTAINABILITY IN A COMPLEX DYNAMIC CONTEXT

Overview

The chapter aims to explore the early developments in sustainability science. The literatures that are summarized here may not always be directly linked to the core part of the thesis work, that is the conceptualizing process to come up with the final evaluatory framework, however they pave the way by providing the background, by justifying the relevancy of the topic, and highlighting the room for research. Others include the key studies in both mainstream sustainability science filed and other related fields, especially the ones directly linked to its early developments where complex dynamics and concept level sustainability discussions were still closely connected. Since this study was inspired and informed by those works, it was considered as worthwhile and appropriate to illustrate them here. Also the discussions made in this section are intended to pave the path to an in-depth theoretical review that follows.

2.1 SUSTAINABILITY AND COMPLEX DYNAMICS: A GENERAL INTRODUCTION

Sustainability is a concept whose roots are grounded in the history of human evolution (Mebratu 1998; Kidd 1992). Why specifically human evolution, is mainly for the fact that sustainability gains its meaning with human system's interpretation of it. The term has become popular with widely cited definition from *'Sustainable Development'* by Bruntland Commission (WCED 1987). Sustainable Development has had a clear objective significance. It was interpreted and enriched with diverse research perspectives, that eventually also lead to a slightly different concept of 'sustainability', which encompasses the subjective and normative characteristics in a somewhat wider scope. A rich description for how the concept has evolved over the years can be found in Kidd (1992) and Mebratu (1998) in their historical and conceptual reviews. In addition, the article *"Sustainable Development: Mapping Different Approaches"* by Hopwood et al. (2005) gives a comprehensive review on multiple dimensions advanced within the concept that reflect its pragmatic to normative and strong to weak ends.[5] Lots of other authors also have constantly addressed the diversity of perceptions the concept of sustainability has attracted over the years (e.g. Niemeyer 2003; Bills and Morse 2005; Espinosa et al. 2008). Also there have been attempts to frame or categorize this diversity; the most famous example is the three-pillar view of sustainability (in some instances referred to as dimensions of sustainability) with ecology, economy, and society, for which later the scholars argued for the necessity for integrating some external dimensions of institutions, ethics, culture etc. (Hawkes 2001; Gibson 2001, 2006; Gibson et al, 2000; Barlett, 2008). In addition to the three-pillar approach, the journal of Sustainability Science explicitly states that its focus is on understanding the interactions within and between global,

[5] For more details on weak and strong sustainability please refer to Ayres, 2006.

social, and human systems, the complex mechanisms that lead to degradation of these systems, and concomitant risks for human wellbeing and security.

These and similar frames of understanding of sustainability are mainly based on how the boundaries between different systems were identified and how the relationships between those identified systems were perceived in different settings. Hacking and Guthrie (2008) describes sustainability as an entity to be perceived in relation to an integrated system having ecological, economical, and societal significance, and that the overlapping regions represent graphical enclosing bodies for the transactions, feeds, movements taking place between theses three perceived systems. However, often this particular graphical interpretation highlights more of flat surfaced interactions, than giving any inference on the systems' complex dynamic interactions. In the article by Komiyama and Takeuchi (2006), the importance of dynamic interactions of the three systems that appear in the latter model is highlighted. In their alternative view, the human system is stated as the sum total of factors effecting the survival of individual beings, while the social system has identified to be comprised of political, economical, industrial, and other structures created by human beings that generate the societal base for fulfilling human needs. They identified global system to be comprised of the entire planetary base for human survival, the geosphere, atmosphere, hydrosphere, and the biosphere. One remarkable aspect in terms of complex dynamics in this interpretation is the acknowledgement of the viability. Viability implies hierarchically interlinked systems with complex dynamic characteristics, and is also reflected in the general perception of holism (Bill and Morse 2002; Warburton 2003; Kalland 2002; Otto and Bubandt, 2011; Ramos 2010).

Depending on which disciplinary stream one would approach the concept from, there have been varying conceptual interpretations of sustainability (Espinosa et al, 2008; Kates et al 2001; Clerk and Dickson 2003; Meppem and Gill, 1997; Berg 1996; Stacy, 1993; Mihelcic et al, 2003; Robinson, 2003; Espinosa et al, 2007; Swart et al, 2004), and further, of its close link to complex dynamics. For instance, taking an economic resource related view, Norton (1992) argues that "sustainability is a relationship between dynamic human economic systems and larger, dynamic, but normally slower hanging ecological systems, such that human life can continue indefinitely, human individuals can flourish, and human cultures can develop— but also a relationship in which the effects of *human activities remain within bounds* so as not to destroy the health and *integrity of self-organized systems* that provide *environmental context* for these activities." It is possible to see the somewhat anthropocentric grounds the concept have emerged from (Baker presents a useful distinction between an 'anthropocentric and eco-centric paradigm of sustainability, Please refer to Baker et al. (1997)). Constanza (1992) stresses that sustainability implies a system's ability to maintain its structure or the organization, and functions (vigor) over time in the face of external stresses. In the process of maintaining the structure and functions many systems also are observed to go through cyclic behaviour. Holling (Holling, 2004; Holling et al, 1998) with the conceptual model of Panarchy (which would be explained in detail again) has explicitly explained such cyclic behaviour in relation to ecological and socio-economical systems. Early works, such as of Gumilev (1990), who identified the cyclic behaviour in relation to ethnic systems, and Zotin and Zotina's (1993) interpretation on thermodynamics of cellular level shed light to the cyclic process in other system forms as well. Sometimes, in systems where the cyclic processes are visible, sustainability could be mistakenly identified to be an attempt to break the cycles and maintain a recognized positive entity—or the system as a whole with some predetermined conditions to maintain—in to the future (Voinov 2008). The abundance of such relatively narrow propositions, and adhering to them, especially in the early development in the field seems to be much to do with the fact that the development of conceptual sphere has taken more of a bottom up perspective than a strictly holistic perspective. In these attempts, terms such as achieving or reaching sustainability are quite common, and fragmented visions of sustainability villages, states, countries or companies were widely considered. Another plausible reason could be that the sustainability discourse does not limit itself for academic, disciplinary frames, rather always takes diverse scopes. For instance when addressing sustainability within economic frames, it is natural to look for tangible states where indicators, incentives etc can be concisely recognizable. In such instances what often overlooked is that no end point is achievable with respect to sustainability and that progress can only be measured in retrospect due to the uncertainty of current actions on future outcomes (Mappem and Gill 1998).

The understanding and positions of sustainability has evolved over the years, and it is well recognized that sustainable development or sustainability in itself is a complex phenomena which involves number of interconnected systems, and hence balance between specific and general view is necessary in all levels. Addressing these factors, Kates, et al. (2001) identified a framework for and emerging "sustainability science" for generating useful knowledge to support transition to sustainable development.

Box 2.1. Core questions for sustainability science

1. How can the dynamic Interactions between nature and society-including lags and inertia-be better incorporated in emerging models and conceptualizations that integrate the Earth system, human development, and sustainability?
2. How are long-term trends in environment and development, including consumption, and population, reshaping nature-society interactions in ways relevant to sustainability?
3. What determines the vulnerability or resilience of nature-society system in particular kinds of places and for particular kinds of eco system and human livelihood?
4. Can scientifically meaningful "limits" or "boundaries" be defined that would provide effective warnings for conditions beyond which the nature-society systems incur a significantly increased risk of serious degradation?
5. What systems of incentive structures- including markets, rules, norms, and scientific information-can most effectively improve social capacity to guide interactions between nature and society towards more sustainable trajectories?
6. How can today's operational systems for monitoring and reporting on environmental and social conditions be integrated or extended to provide more useful guidance for efforts to navigate a transition towards sustainability?
7. How can today's relatively independent activities of research planning, observation, assessment, and decision support be better integrated in to systems for adaptive management and social learning?

Kates et al. (2001)

Later on, Swart et al (2004) with an effort to integrate scenario analysis to the sustainability analysis suggested an eighth question, "How can the future be scanned in a creative, rigorous, and policy relevant manner that reflects the normative character of sustainability and incorporate different perspectives?" Apart from these concept-based discussions of sustainability and the general discussion of complex dynamics linked to them, another key area where complex dynamics is addressed in a more specific manner is sustainability metrics. Sustainability metrics—often in the form of indicators and indexes—translate the conceptual understanding of sustainability to scientific research in a way that the conceptual understanding can be given a certain amount of measuring and evaluation capacity. Therefore, it is worthwhile to explore some of their early developments as well.

There are different levels of indicators. Any sustainability initiative needs a strong basis to evaluate and measure its progress. Still, sustainability indicators or sometimes, in general, what referred to as sustainability metrics, has remained a challenging research areas in this field. Early on, there were quite rigorous attempts to give a solid basis to sustainability. These stemmed from constructive criticisms for at the time existing methodologies that stemmed from related predecessors such as the environmental studies (Mayer 2007; Bell and Morse 2001, 1999; Bossel 1997, 1999). Bells and Morse (1999, 2001) highlighted the circular or rounded nature associated with the process of developing indicators. One of the examples they took to support their arguments is the Pressure–State–Impact–Response (PSIR) classification of sustainability indicators, which is originally developed by Jesinghuas (1999). Apart from such rare occasions, one significant factor to notice in these early developments was the gap on these numerous indicators' ability to reflect complex dynamics tied to sustainability. As Bossel (1997, 2001) observed, usually the main function of many of the indicator have been to give a measured snapshot view of certain past, present or future state, relative to a specific concerned entity. Yet the question arises, when speaking of sustainability, whether it is justifiable to consider a characteristic, structure, functions, level, or threshold indefinitely as desirable. Such fundamental questions imply that, just as much as the theoretical understanding embedded to the indicators are important, the way we engage those theoretical understanding at the application end also is critically important. Further, these observation calls forward to look for avenues where a system's complex dynamic nature can be integrated to how we perceive, evaluate, solve, place initiatives etc in relation to sustainability.

One of the key short coming of the conventional indicator approaches is that they have not deeply addressed the different levels that are associated with a human–natural systems, where systems and subsystem relationships have the capacity to show autonomous behaviours that could influence the systems as wholes. This is where these methodologies seem to appear as addressing key aspects of complex dynamics in a general sense than to explore in depth. Addressing the autonomous behaviour related to complex dynamics could be found in more modern techniques such the agent-based modelling (ABM). The ABMs resembles micro models that could reflect a bigger complex context. It has the philosophy that simple behaviour rules of a lower-level system may generate complex behaviour rules in a macro–scale system, embedded in to its modelling. However such models are confined to heavily quantitative approaches. The ideas behind their models are not often adequately integrated to the general sustainability evaluation processes that may have to deal with especially qualitative interpretations, although such conceptual-level integration may be possible. Further, not only the part's capacity to reflect the complexity's of the whole, but in the other way round, the whole's capacity to direct an evaluator to gain specifics understandings of the behaviour of the parts—as we describe later—is also significant to sustainability evaluation, especially since we must deal with interrelated contexts of different scales.

Another key area that complex dynamics linked to sustainability is addressed—especially in research and operational level—is the transdisciplinary research. Transdisciplinary research has functional links to its earlier predecessors of interdisciplinary and multidisciplinary research. Also Transdisciplinary research has played a key role in what we today call as sustainability research. Multidisciplinary research utilizes different disciplinary knowledge and practices in research, yet in terms of interactions, retains the identity of distinctive disciplinary domains. Interdisciplinary research, while still based on disciplinary vision of knowledge, seeks to coordinate the objectives and methodologies in order to achieve less fragmented views on sustainability issues, for instance the issue of climate change (Norgaard 2004). On the other hand transdisciplinary research has provided a transition phase from a highly divided disciplinary approaches to a platform where extensive interactions in the process of decision-making. It has provided the needed link between the scientific methodologies and policy decisions, which are linked with socio–natural–economic systems (Scheringer et al 2000, Wiek et al 2007, 2012). This research method acknowledges that the science is part of the process it describes and is therefore focuses on systemic view of social and natural dynamics that are shaping the world. It also recognizes the plurality of forms of knowledge, worldviews, and the ethical values connected to them within different social and cultural groups. One significant reason why transdisciplinary research is well recognized in sustainability research, especially in its practical end, seems to be the necessity to reach the same critical unsustainable problems, and the scenarios involved in those problems, from several different angles. In practice adapting transdisciplinary base enabled discussions on sustainability to be shaped by theories in fields other than traditional scientific and economic discourse (Meppem and Bourke 1999). Also it has identified the next reaction to societal demand for knowledge production and utilization in complex issues (Rist and Guebas 2006). While conceptually transdisciplinary research has a sound basis in dealing with complex dynamics (which we would discuss further in a later section), still, the question remains whether transdisciplinary research alone in most existing forms, can incorporate the complex dynamics in the same capacity as it does the flat-planed complex dynamics that does not necessary support to deal with more complex forms of dynamics. And also it may be a concern whether the researchers and the other stakeholders who are engaged in transdisciplinary research consciously address complex dynamics, so that the rich conceptual basis is retained in the practical end.

One significant strength of this type of research however is that, it functions as a platform to include diverse contexts in the decision making process. Some of the authors have identified the need of science to go one step forward this *science driven* view to a more *tradition and local* driven approach. For instance in Rist and Guebass (2006) view ethnosciences (a scientific realm on how humans are developing different forms of knowledge and beliefs) could play a significant role in linking transdisciplinarity and sustainability in the light of these views. In their narration they emphasize the importance in coupling the indigenous and ethnoscientific approaches in to contemporary frameworks for conservation and sustainable management of natural resources, and defend its pragmatic importance. Further, they explore the key conditions and dimensions of a dialogue between ontologies of ethnosciences ad transdisciplinary research to see how they could be integrated in research. However in order to gain full benefit from such a process, we need sound methodologies built in to research that utilize the conceptual significance in these diverse approaches. Scholtz and Tietje (2002) discuss the needed integration of knowledge systems and actions to address increasing complex problems proposing a method—namely embedded case study method—that enables transdisciplinary research to be effectively conducted in real world. While transdisciplinarity can generate emergent ideas based on dialogues between experts, and between experts and non-experts, such emergent processes are not always monitored. Therefore, often the results are shaped by group dynamics. While there are methods such as soft system methodologies (SSM) (Checkland, 1974, Wilson, 2001; Mingers and Rosenhead 2001) that facilitate brainstorming, these preliminary tools alone does not allow the complexities in the contexts they are dealing with to properly get translated to the subsequent formal methodologies in a systemic manner. However at the same time, it must be emphasised that these research platforms have opened a meta–discourse to integrate the interactive and dynamical nature of sustainability in to sustainability research.

Another instance complex dynamics are linked to sustainability is with relation to systems. One way of visualizing is through internal functions of a particular system, that is the functions, forces and movements any system will naturally follow in its path of evolution despite whether they support sustainability conditions or not. Different forms of such internal dynamics were found in many related fields. For instance, with relation to economic systems, the framing adapted by Bowel et al. (2003) to interpret the main forces of dynamics in a market based capitalistic economic system takes such an internal perspective, and also a dimensional approach to interpret the changes in these systems. However whether the systems are of economic, or natural, they do not exist isolated. There are always interactions with other systems, hence, forces induced from outside, are observed to affect such dynamic patterns. And it was observed that some of these external or meta-level dynamics could link to what some recognize as the principles of sustainability (Dresner, 2008), and in addition the general driving forces of sustainability. Nonetheless some of these principles are highly subjective and would often come with diverse spectrum of opinions on what they should be (Robert et al. 2002; Martens 2006; Gibson 2001, 2006). While there are well-recognized principles as intergenerational justice (Thompson 2003; Barry 1999), resource availability, ethics etc, which principle to be prioritized can be highly influenced by their implicit assumptions, where they are being applied etc. Also it is not clear whether theses meta-level principles would be equally valid for every scale of a system, for instance individual, society, village, town etc of a country. Therefore even though we can have some basis that meta-level principles could inform us about a system's sustainability, to what extent the same principles could be applied to different scales remains problematic.

Another concern is that, when we address complex dynamics related sustainability in human–natural systems, we may have to address the evolutionary patterns both from the concerned systems' natural evolution point of view and the sustainability point of view alike. The complex dynamic evolutionary patterns of systems are fairly well explored in academic literature of sustainability. Pimm (1984) for instance adapting a quantitative approach explores the measures of complexity in socio-ecological systems as species richness, connectance, interaction strength, and evenness. However, it is not clear if the same patterns (which we address descriptively later on) could be applicable to interpretations of sustainability. Because of this reason, at least in the beginning it may be helpful to separate the idea of complex dynamics of human–natural systems[6], and the complex dynamics of the sustainability interpretations in them.

In conceptual level, philosophers also have continuously tried to capture the deep conceptual implications of the overlapping domain of complexity and sustainability (Capra 1997; Morin 1998, 2008; Bateson 2001, Polanyi, 1974, 2009; Van Gulik 2001). Especially in fields such as the deep ecology such philosophical discussions continue to flourish. In addition, beyond strictly conceptual domain, a more pragmatic way of seeing complex dynamics linked sustainability is with unsustainability issues. Sustainability can be regarded as a concept that emerges out of multitude of problems facing in the face of these complexities. Taylor (2001) writes, as "This is a time of transition, betwixt and between a period that seemed more stable and secure, and a time when many people hope equilibrium will be restored. Awash in a sea of information that seems to have no meaning [...] many people have lost the sense of direction and purpose and long for security and satiability"(Taylor 2001). The stability, security, and equilibrium however could also be deceptive, for they are but momentary eddies in an endlessly complex turbulent flux. The idea of uncertainty-linked change is slightly different from what is observed as complexity across space or what the usual understanding of change bring to our mind, that is change across space and time. The uncertainty is also linked to change that occur in change, i.e., to change of 'change' and to rate of change. Uncertainty is in the heart of sustainability. Specially when system's changing patterns are not visible, and further when they are subjected to rapid changes that may involve changes in 'changes', that we also would discuss later, it become even more challenging than usual to

[6] In this separation, to some degree we assume that separation systems would follow the natural laws of complex dynamics, and the sustainability interpretations (and evaluations) specifically would reflect the agency power of human system, that may add special characteristics to human–natural systems with those interpretations and evaluation. Therefore it does not reflect a completely accurate division, however a practically supportive one for exploration.

make sustainability interpretations. A situation that involves change in 'change' may be understood as emergence in complexity. What is noteworthy is that in the face of emerging complexity, it becomes difficult and even erroneous to adhere to one critical perspective from which to assess a system.

Likewise, multiple research domains under sustainability have observed and discussed the complex dynamics stressing the challenges that they exert in sustainability evaluation (as indicated in the part one of the literature review). Just as the concept was nourished from different fields of studies, in the conceptual domain as well there is a tremendous diversity in terms of the directions from which these discussions emerged. Often the discussions cannot be traced back to the original theoretical orientations of complexity easily, and nor they entirely seem to make clear their theoretical disposition. Rather they take characteristic of the parent disciplines, in a way that a conceptual interface of complex dynamics and sustainability can be elaborated in a discipline specific manner. As a result the evaluation frameworks found in this interface often have their strong specific methodologies, and techniques embedded to them. It is extremely difficult—if not impossible, to give a summary of all the relevant conceptual developments and the significant frameworks, and it is even more difficult to compare them. While acknowledging the diversity as well as the significant contribution these studies have made, for the scope of this thesis, we would first highlight some specific areas where various ideas related to complex dynamics have informed the discourse of sustainability in a significant manner, and also would explore with which objectives and which methodologies these frameworks explore the implications of complex dynamics for sustainability. By doing so, we also wish to pave the way towards making the subsequent arguments in the thesis consistent. Therefore please keep in mind that it is not intended to claim that these are the only significant areas where complex dynamics based thinking has become explicitly visible in sustainability.

2.2 HUMAN–NATURAL SYSTEMS AND COMPLEX DYNAMIC VIEW

The systems where we address sustainability could be broadly termed as human–natural systems. There are different types of human–natural systems, or more accurately, there are different ways to view human–natural systems. According to multitudes of views, especially that describe the focusing interrelationships, they also are referred in varying names, such as socio–ecological, socio–technical, socio–economic systems, and so on. When their complex dynamic characteristics are stressed, they also have been recognized as coupled–human and natural systems (Liu at al. 2001; Ostrom 2009; Ostrom et al 2007), complex adaptive socio–ecological systems (Berkes et al 2003; Folke 2006; Ostrom, 1990, 2009), dynamic–socio–technical systems (Rotmans 2007) and dynamic–socio–economic systems (Ness et al. 2006). When the complex dynamics are highlighted, as had been the case with some of these interpretations, the term human–environment system also was especially used[7]. The key frameworks that were proposed for sustainability in these systems also naturally reflect the diversity in focus, both in terms of the underlying system relationships they address, and also in terms of the conceptual orientation to reflect complex dynamics and the patterns and mechanisms.

It is possible to see patterns in how the complex dynamic understanding had emerged out of a fragmented disciplinary basis. Gunderson and Prichard (2002) draw attention to the simplifying complexity that occur in usual responses as; "*The familiar response to these issues (the growing scale of human activities encountering the limits of nature), are often flawed, because the theories of change underlying them are inadequate. The stereotypical economist might say "get the price right" (i.e., ensure that prices internalize significant environmental externalities) without recognizing the price system requires a stable context where social and ecosystems behave nicely in mathematical sense […]. The stereotypical social scientist might say "get the institutions right" without comprehending degrees to which*

[7] The term environment had gained two separate meanings. It has been used in situations where the dependency on natural resource base is not the strict focus of the discussion. Further, especially when complex dynamics are highlighted and the viable relationships of systems to its outside needs to be highlighted, again the term environment has been specifically used. In this thesis we would use the term for both its general meaning and the complex dynamics related meaning, however would highlight as much as possible when it's used for the later case.

those institutions submerge ecological uncertainties and economic and political interests. The stereotypical ecologist may say "get the indicators right" without recognizing surprises and that nature and people inexorably continuously generate. And the stereotypical engineer might say "get the technological control right and we can eliminate those surprises" without recognizing the limits to knowledge and the control imposed by inherent uncertainties and unpredictability of the ever evolving interaction of people and nature" (Gunderson and Prichard, 2002). Likewise, seeing the separation between the traditional disciplinary way of looking at human–natural systems as separate social and natural systems, and the lack of understanding of complex dynamic nature in them—not only the nature, but the implication on them for conceptual interpretations—new concepts to interpret the human–natural system relationships have emerged.

Human–natural systems have the organizing ability that relies on feedback mechanisms which takes them apart from just complicated systems. With that basis alone they become inherently complex systems. A well-known model developed in ecology to interpret complex dynamic behaviour of human–natural systems (more specifically ecological systems in this instance), and later got strengthened towards sustainability interpretation, is the Panarchy model (Holling et al. 1998). The early developments of the model with the cyclic and ecological view (where four main stages of evolutionary cycles described) seem to have been somewhat a reactive and contrasting interpretation to, at the time prominent equilibrium thinking. Later on, the model has tested and explained mainly with relation to different types of socio–ecological systems, and also occasionally to socio–economic and socio–technical systems as well. Specially with large-scale systems, these studies have come up with further theories to interpret different phases the systems go through that allow them to transform itself (through conservation, release, reorganization and exploitation stages) and to go through interacting hierarchies that engage revolt and remembrance processes (Please refer to Gunderson and Holing, 2001). In Panarchy model, the system's complex dynamic patterns and mechanisms are dealt in both conceptual and analytical level. While it gives guidance for possible patterns and mechanisms of changes for a system at a certain specific time, as a concept it also mostly limits its scope to explanatory level, allowing room to adopt context specific techniques at diverse application ends. One significant idea that have transferred effectively with Panarchy model is the idea of creative destruction, which conceptually almost rivals with the idea of resilience[8]. Both creative-destruction and resilience lies in the interface of complex dynamics

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[8] Resilience measures the strength of mutual reinforcement between processes, incorporating both the ability of a system to persist despite disruptions and the ability to regenerate and maintain existing organization (Gunderson and Prichard, 2002). Such persistence could solidify both sustainability well as unsustainable conditions. The creative destruction proposes a means to restructure the system without letting the system to settle in harmful basins.

and sustainability. Further, related to the same study, Gunderson and Prichard (2002) indicate the characteristics that are valid for complex systems as;

(i) The organization of regional resources systems emerges from the interactions of a few variables
(ii) Complex systems have multiple stable states
(iii) Resilience derived from functional reinforcement across scales and functional overlap within scales
(iv) Vulnerability increases as sources of novelty are eliminated and as functional diversity and cross-scale functional replications are reduced.

For the same intent of interpreting complex dynamic nature of human–natural systems the idea of coupled human and natural systems have been proposed (Ostrom, 2009). Here the system relationships are not seen as explicitly ecological as in the previous case, rather related to more separately functioning human and natural system interactions. In very simple sense 'coupled' denote the interrelatedness' (Liu et al. 2007). The idea also seems to have the underlying intension of reconciling ecological and social research in terms of views, and methods and techniques of evaluation, in the wake of increased fragmentation of disciplinary knowledge and the increasing complexity in interactions between human system and planet's other natural subsystems. For instance Liu et al. (2007) writes, "*Although human and nature interactions have long been recognized, the complex patterns and processes involved in such interactions have not been well characterized or fully understood. Traditional research in the social and natural sciences informs the current interest in CHANS (Coupled Human And Natural Systems). However, social scientists have often focused on human interactions, minimizing the role of environmental context or perceiving environmental influences to be constant, whereas ecologists have traditionally focused on pristine environments in which humans are external and rarely dominant agents. Although disciplinary research continues to be important to advance disciplinary inquiries into many aspects of human and natural systems, it is not effective to study human and natural systems separately when addressing social-ecological and human-environment interactions*" (Liu et al. 2007). Ostrom (2009) propose a framework to analyze sustainability in coupled human and natural systems. The framework gives a somewhat directional basis in terms of watch points, not just to understand these systems, but also to manage these systems. The study observes significant dimensions that drive changes (in other words acting as variables). In these milestone works as well, aspects such as, 'cyclic behaviour', 're-organizing', and 'self-organizing' have been observed as the key change mechanisms in systems. Further especially in the study by Ostrom (2009), ‘diversity’ is recognized as a key factor that may promote self-organizing, and by doing so would create new sustainability conditions.

These are some prominent frameworks that could be regarded as lying in the interface of complex dynamics and sustainability. The patterns and mechanisms with which sustainability interpreted in the theoretical developments of the mentioned and other related frameworks differ, obviously so, because their underlying view towards human–natural systems, objectives, and the focuses are different. Also Panarchy and subsequent related developments can be observed as having a relatively strong specific view (that can be referred as a meta–structure) towards the patters of human–natural system changes. In the same vein the framework proposed by Ostrom (2009) basing on the argument of self-organizing as one of the dominant change mechanisms has a strong inclination towards recognizing variables that can support such changes. Further they also have a somewhat common conceptual basis that complex dynamics are external entities in the systems and would be equally visible to any observer regardless of their pre-understanding, knowledge, views etc.

If we go back to the human–natural systems, it is unarguable that both human and natural components of our systems are relevant in sustainability interpretations. However often they are not treated as being closely interrelated and to function as one system. The idea of coupled human and natural system in a way gives equal significance to both human and natural systems and their capacity to influence and change each other. We recognize similar equal importance to both human and natural systems when we use the term human–natural systems to denote them collectively. However because one of our main targets is to address the epistemological and methodological ambivalence, for the time being we try to separate complex dynamics from the systems for the analysis purpose to explore human–natural system’s complex dynamics and the complex dynamics linked to evaluation process separately.

Further as we mentioned, Turner et al. (2003) have explicitly used the term human–environment system to describe the systems that are relevent in sustainability. The idea of ‘environment’ goes beyond the usual spatial implications to include an outside territory that would closely interact with a system/system-entity that would enable it to change itself and to make the environment also change. Wiek et al. (2011) observes that in early developments in the field of sustainability, there was a certain assumption that the improved understanding would automatically lead us to ensure sustainability in these systems, and as a result, the research in sustainability have stayed more in descriptive–analytical stage than focusing on transformative types of research. However, it is noteworthy that when we start to observe human–natural systems (or human–environment systems in Turner’s terms) in deeper sense, the transformability could be already embedded at least as far as human component is concerned. This would be especially so if the evaluating entities belong to the system itself. Still, it is also true that with the frameworks and methodologies we develop to observe these complexities we do not often incorporate methods that can recognize complexities in observations nor do we acknowledge and explore enough the transformative processes that both system entities (as those experience sustainability) and the observers (as researchers and practitioners) also would go through in terms of their sustainability understanding and views. Even while we often stress on complex dynamic nature of systems, and adopt specific methods and techniques to explore them, there still may be a gap in terms of awareness of meta–structures[9] that we adapt in connecting these concepts and specific methods, and therefore the value that we give to the influence of such meta-structures on our evaluations and system's sustainability changes. In other words it seems that there still is a gap that researcher even while recognizing that they are dealing with complex dynamic systems, is unable to internalize the full spectrum of that understanding in to the methodologies, methods and techniques to address sustainability.

The discussion of transformation also leads us to sustainability pathways. Leach et al. (2008) highlight that one significant way of responding to dynamic contexts (could be extended to complex dynamic contexts) is by recognizing that there could be *multiple pathways* to sustainability. The idea of pathways is very much tied to complex dynamics and aligns with our own initial disposition that sustainability needs to be regarded as a path/process that continuously being shaped, invented, created etc (selection of term may often be based on context and also preference). Noteworthy is that, pathways also mark deviation from static and linear view. In author's words, 'the explicit normative stance, together with dynamic complexity perspective, contrast strikingly with more technical, managerial, and equilibrium approach to sustainability'. By giving a historical account for the conceptual diversity in sustainability and sustainable development (please refer to Leach et al. (2008) for a elaborative account for this), they also stress that clear expression on definition of sustainability by stakeholders is a necessity. In other words, the authors point out the fact there are *multiple contexts* of sustainability and moving along pathways of sustainability is a reflexive movement at each point of decision in the pathways. Even though the paper does not specifically make note to mechanisms involved in subsequent sustainability understanding, nor they differentiate between the complexities on the ground and the complexities associated with the understanding process, it is noteworthy that the need for reflexivity in conceptual and action domain to translate complexities in to sustainability decision-making process has been stressed. Also noteworthy is that the idea of multiple contexts is well embraced in the discussion of multiple pathways (Juarrero, 2002). While context specificities are emphasized,

[9] A detailed description of sustainability related meta–structure would be given a subsequent section.

when the ability to see multiple contexts, or in complex dynamic systems, multiple pathways are addressed, automatically the opposite direction of holistic understanding would be encouraged.

Further note

When we recognize that sustainability is very much tied to different contexts[10], we further face the challenge of incorporating context specific understanding while ensuring holistic understanding too at the same time. This applies to not only for the systems we observe to reach sustainability understanding and evaluations but also for the frameworks, methodologies, methods etc with which we observe these systems, which also appear to reflect contextual focuses. As we would see sustainability involves continuously changing dynamic systems. These changes are in different degrees. Changes would indicate system interactions, and they would include changes to changes that would lead to adaptive and transformative process, and further scale up in magnitude to lead to even system collapses[11]. In the heart of dynamics is the complex interactions taking place between multiple different systems where the systems themselves are complex systems. Therefore, to grasp the implications of the dynamic nature of the systems, we have to go one step further to understand the complexities in more detail. Further, sustainability understanding, and subsequently evaluation is very much tied to the way we observe these complexities. Observations are made on both general complex dynamic patterns and the complexities exerted by context specificities. Often rather than focusing on both while consciously differentiating them, either specific but not representative enough sustainability interpretations, or on the other end, too much simplified or too generalized regard can easily occur. This could be often be a result of poor understanding of different scales (such as systems and subsystems) and how the systems of different scales influence each other in a complex dynamic manner. These limitations are also aggregated in the methodologies, methods, and techniques that we as researchers and practitioners incorporate in sustainability evaluation (Most of the existing methodologies, methods, and techniques allow us to deeply analysis parts and specific processes, or on the other end, allow us to have generalized overview ideas that aim to reduce the complexities).

On the other hand examining the deep meaning of complexity is also challenging, as the field of complexity has been developed in branched-out manner. While these branched-out developments have informed other fields of studies as well, often in these other studies

[10] Note that the term context in sustainability carries two distinctive meanings. The first is that context reflects a special location, a situation that gives special conditions and meanings to sustainability. When we say context specific understanding (contrasting to holistic understanding) we address these specificities that require scrutinizing and zooming in to see them. Further, context also can expand its mean different faces of sustainability that gives different emphasis to not only to locations, issues, solution trajectories and so on.

[11] For critical perspectives of historical collapse in (human-natural) systems please refer to (Butzer, 2012).

‘complexity’ and related complex dynamics seems to remain as a general or worst as an illusory understanding. This appears to be true for its entry to sustainability studies as well. In its development phase, sustainability research seems to have relied on methodologies developed in diverse fields. Some of these fields, such as environmental studies, ecological studies, ecological economics, developmental studies etc., can be seen even as parent fields to sustainability. A direct outcome of such external developments and later adoption is that the methodologies, methods, techniques that reflect the complex dynamic understanding in observing systems also reflect this branched out nature. As a result these methods and techniques work more as bottom up approach to evaluate/analyze sustainability, however not because they all do not share similar standpoints from the perspective of complexity, but because they are already been translated to methods and techniques in different languages and been already distanced from the basic idea of complexities and dynamic. Subsequently, even while knowing and accepting we are dealing with complex systems, and also while using appropriate frameworks, methods, techniques etc, practitioner and researchers do not always engage themselves as active participants with, and observers of, such complexities.

While the diversity in system complexities, and extensive focus on those specificities has created difficulties in actual planning, problem solving activities, on a positive note these conflicts also have paved the path for new methodologies and techniques (e.g. transdisciplinary approach, and strategic sustainability analysis frameworks, aggregated indicators) to address sustainability in these systems. However, focus on human–natural systems complexities (and dynamics), or the merely bringing together different ideas, expert knowledge, or stakeholder views alone do not capture the real essence of complex dynamics that are relevant to sustainability, mainly because still we lack observing methodologies (here it is re-emphasised that often we acquire methods and techniques, however not methodologies) that hinders the process of recognizing complex dynamics in a rigorous manner.

We saw that, there are several significant research avenues and frameworks that have addressed complex dynamics linked to sustainability by observing the change patterns in human–natural systems. Some of them have explicitly focused on sustainability evaluation, while others stay in interpretations domain. The need to build frameworks that support in mobilizing sustainability change through driving and transformation also is increasingly recognized, however not many examples appear yet. Even with the existing ones, there is not much benefit in trying to compare them, as the aim and addressing domain of these frameworks are quite diverse. However for our own study, some inferences could be drawn from them, especially in the way they conceptualize the complex dynamic reality. In our understanding it is necessary to translate the basic ideas of complex dynamics in to not just methods and techniques, which certainly are valuable, but also in to methodologies that could combine observations, analysis, and transformations with decision making in these systems (Methodologies as Soft Systems Methodology and Trans-disciplinary methodology that would be explored later have specially addressed the later role). For this purpose the subsequent sections would explore the basic ideas of complexity, while discussing some key implications on sustainability. Following this basic overview, an in-depth discussion on those implications would be done under the section of conceptualization.

2.3 FROM COMPLEX DYNAMICS TO COMPLEX COMPLEXITY, BY EMPHASISING OBSERVING COMPLEXITY

> *"Since the time of Russell, Whitehead and Einstein, thinkers have pointed out that problems created at one level of thinking can only be solved at a higher or meta-level of thinking" (Espinosa et al, 2008[1]).*

This second section of the review would engage in an in-depth discussion on the complexity. As mentioned the understanding of complexity could be both general and specific, and have varying degree of significance given in the research approaches we follow in sustainability. In this thesis it is argued that the way one view complexities plays a major role in this regard, therefore the explanatory section intends to provide a thorough enough literature basis of complexity, upon which the subsequent theoretical development in thesis would stand. In addition, the earlier theoretical developments that support the thesis methodology, assumptions, conceptualizing process etc also will be critically reviewed to derive the key implications.

2.3.1 Revisiting Complexity

2.3.1.1 What is complexity?

The field of complexity or complexity studies also is a diverse and a complex field in itself. The idea of complexity, until recent times, has popularity as both a general concept and an explicitly scientific concept. As a scientific concept, it is with some radical developments in cybernetics that the concept is recognized as to make the entrance to science. With the information age and with extensive physical good, service, and information transactions across the globe, people are experiencing complexities in daily life. This is the often-found general interpretation of complexity. Linked to this general interpretation, at first glance, complexity is a quantitative phenomenon, with an extreme quantity of interactions and interference among a very large number of units. Further, in an even more reduced manner, we can interpret complexity as a characteristic of a system that has a huge number of interacting parts. Complexity is not only about quantities of units and their interactions that allow us to make certain amount of calculations and analysis however the implications of complexity do not stop at this level. The interacting parts may be capable of generating organizing relationships that make it heavily linked to uncertainties, interminancies, and random phenomenon (Morin, 2008, 2010). Richardson and Cilliers (2002), in an overview, define what they call three themes, or communities, in the literature: *'hard, reductionist complexity science'*, *'soft complexity science'* and '*complexity thinking'*. *Complexity science* aims to understand the principles of complex systems. *Soft complexity science* uses complexity as a metaphorical tool to understand organizations. And *complexity thinking* considers the epistemological implications of assuming 'the ubiquity of complexity' (Cilliers, 2007). More recently Byrne (2005) has distinguished between 'simplistic' complexity (similar to the first of Richardson and Cillier's categories) and 'complex' complexity (which seems related to Richardson and Cilliers third category, discussed in the context of research methodology). It is important to note that within these different interpretations of complexity there are different degrees of weight attached and they are in different conceptual zones, which need to be examined thoroughly to eliminate miss-interpretations. Based on the generally agreed explanations that are not heavily reductionist, the most comprehensive interpretation for complexity that we could give at this point is that it is a measure that describes the degree to which the system can be differentiated with its parts and can be integrated with wholes[12]. Yet, we also highlight that many of these even non-reductionist

[12] The role of parts and wholes in complexity will be discussed in detail later.

interpretations carry the importance of parts and wholes, yet they do not yet carry the crucial aspect related to observing the phenomenon.

2.3.1.2 What complexity is not?

In order to explore complexity as of complexity studies, first it is signifiable to state what complexity is not so that the proper idea of complexity that we highlight in this thesis emerges.

(i) Complexity vs Complicated

First it is important to note the difference between a complex system and a complicated system, as in general use often they are not distinguished from one another. As shown in the previous example, some systems have a very large number of components and perform sophisticated tasks, but that can be analysed accurately. Such a system is complicated. Other systems are constituted by such intricate sets of non-linear relationships and feedback loops that only certain aspects of them can be analysed at a time. A good example to make the distinction between a complicated system and a complex system is to think of a disordered bookshelf. The bookshelf could be organized by someone external, however among the books themselves they do not have the capacity to be organized by itself to bring back order to its unorderliness. In other words, there is no internal feedback mechanism that informs each of the components—that is the books—of the shelf to rearrange itself. Therefore the bookshelf ends up being just a complicated system than a complex system. But if we consider human–natural systems, which are our main interest, we recognize that they essentially differ from complicated systems. Human–natural systems are internally tied with system–subsystem interactions and externally tied with interactions with other systems in its environment. Some of these interactions reflect essential feedback mechanisms that allow the systems to reorganize within itself and adapt to the changes in its environment[13]—following an reorganizing process in a bigger scale. Therefore human–natural systems are not just complicated systems, but essentially complex systems.

(ii) Complexity vs. Simplicity

Another useful aspect to note is the difference between the complexity and the simplicity. Serra and Zanarini (1987) note that the distinction between complex and simple often becomes a function of our 'distance' from the system. This particular argument carries an

[13] The environment in this instance can be the external environment to the human–natural system, and also it can be the internal environment to the subsystems within the macro human–natural system.

added weight for the 'observation process'. According to the philosopher Henry Atlan, complexity is what that we cannot grasp (Wells 2012). When a certain idea or a phenomenon cannot be grasped fully, the tendency is almost always to simplify it. Especially the modern era has shown a tendency for extracting simple from complex (Wells 2012). It seems that the simplification tendency is visible in sustainability discourse, not necessarily for any value laden preference for simplification, rather often for the need for practicality and for the necessity to face the challenges such as the associated urgency, limitations in existing methodologies for knowledge extraction, necessity to reduce uncertainty, so on and so forth. With such necessities, there is a high tendency towards aiming for one of the views among the bird-eye view or the scrutinized view. The bird-eye view allows us to see macro patterns of interactions projecting a complex reality to a simplified map. There, the cognitive distance to many of the objects of examination are often high. Contrastingly, in scrutinized and focused examinations, such as what we do in anthropological studies, the distance to the objects of examination is less. Such scrutiny allows us to see more details than what we acquire in the bird-eye view, bringing out a complex reality in a smaller scale. However, the closeness also refrain one from seeing a macro pattern to which the smaller objects (and patterns) are bound beyond their immediate boundaries. Therefore, it is important to recognize that the notion of 'distance' have more than one implication on the observation of complexity, and the distance would define whether a system or a phenomenon is regarded as complex or simple.

2.3.1.3 Forms of complexities in complexity studies

Just as it is necessary to distinguish complexity from other closely related concepts, it is also necessary to explore the leading branches of complexity to obtain a better understanding. Two of such significant branches are the catastrophe theory and chaos theory.

(i) Complexity in the form of catastrophe

The central idea of catastrophe theory is the discontinuous change, and the fact that an abrupt change can make a sudden dislocation or discontinuation. A French mathematician Rene Thom has based his theory on mathematics, while examining a broad range of social, natural, and cultural phenomena, and recognizes that important changes are not the results of continuous and quantitative development, rather of qualitative, abrupt changes that create sudden dislocations and disruptions. He also mathematically proposes seven types of catastrophes (Taylor 2001, p 13). The area of study can be regarded as focusing on identifying the recognizable patterns in complexities around equilibrium conditions.[14]

(ii) Complexity in the form of Chaos

When in cybernetics in the beginning the concept was introduced, it is in a way to go around part of complexity, which involved chaos, and also the zone of uncertainty (Morin, 2008). Chaos theory investigates nonlinear systems. The systems that are most interesting for chaos theorists are those in which extreme sensitivity to initial condition creates effects that are disproportionate to their causes. This property of the system is widely known as the butterfly-effect. When chaotic conditions are involved, inability to identify all relevant initial conditions makes it impossible to predict system behaviour accurately. However it also holds the fact that nonlinear dynamic systems are not indeterminate rather follows definable rules (Taylor 2001; Stacey 1996).

(iii) Complexity as complexity theory

The term Complexity theory (Cilliers 1998; Byrne 1998) also is referred as dynamic systems theory (Fogel 1994; Valsiner 1998) and occasionally, as theory of emergence (Goldstein 2000; Johnson 2009; Chalmers 2006; Samet 2012). It does not refer to a specific body of literature in particular, rather to a field of study, which has its origin in scientific domain and in mathematical sciences, and later ideas have been taken up by diverse fields. Further, without adhering to strict terminologies that is shared by complexity studies, some other fields also have been generally observing complex phenomena, and in the process, have adopted the significant theoretical implications from the original field of study such as emergence, and self-organization, and have built upon them. These developments also come under complexity studies.

With the verities of such theoretical implications presented under the term 'complexity theory', the ideas that have dissipated in to sustainability studies also not easily traceable back to the original theory. While it is worthwhile to explore the significant root branches of complexity theory in detail, that is outside of the scope of this thesis. For a detailed account of the significant branches of complexity theory, we urge the reader to refer to Wells (2012). Some of the influential teachings had been the discontinuous change (which is highlighted by both complexity theory and the catastrophe theory) and dynamics of nonlinear systems

[14] This particular zone of complexity is interesting for us, mainly because one of the features that we want to emphasise in the proceeding framework is that, there could be hypothetical boundaries within which a systems would act in a sustainable way, not reaching irreversible conditions.

(which is highlighted by complexity theory as well as chaos theory). The exploration of the activities of a system 'far from equilibrium' and ' at the edge of chaos' is an essential concern in sustainability, yet not well explored. As Taylor emphasized, this idea also could be comprehended in general understanding about socio-environmental, cultural, technical etc systems. When there are too much order systems are frozen and cannot change, and when there is too little order, systems disintegrate and can no longer function[15]. In the field of sustainability however, the fact that the significant changes take place between too much and too little order remains intuitive yet scientifically unexplored.

Among these prominent fields of complexity studies, we could identify sub domains where focuses, modes and types of observations, and methods of observation differ from each other. Also it is possible to recognize that the implications of complexities would not be confined to natural phenomenon but also would extend to social, political, economic, cultural spheres. In order to recognize them, first it is necessary that we are able to identify complex systems in these spheres. To recognize complex systems it is supportive to know their characteristics. For the development of our framework we try to be informed of the characteristics of complex systems by referring to these branches, and pay an extra attention to their implications on what could be described as complex complexity. A selected characteristics of complex systems are as follows.

2.3.1.4 Significant characteristics of complex systems and their relation to dynamics

(i) Openness

The fundamental feature of open systems is that these systems can be understood only in the context of an environment. The environment contains matter, energy and even more significantly in our case, the information that define the system. When the systems are complex with subsystems and system entities, each individual entity or subsystem also become an open system. In order to describe them the information of their environment would also be necessary.

(ii) Part and whole relationship

As can be intuitively deduced the understanding of openness naturally leads to the understanding of part and whole relationship. What is additionally noteworthy is that part and whole relationship is two-fold, that is the part and whole relationships that leads to

[15] It is also held that far from equilibrium, systems change in surprising but not necessarily random ways

organizational patterns, and the part and whole relationships that are tied to observing and knowing these patterns. As would be elaborated later on with the support of several key literature, 'part' and 'whole' understanding is one significant point in observing and evaluating sustainability.

(iii) Nonlinearity

Another feature of complex systems is the nonlinearity. Nonlinearity represents the dynamic nature of the system, and is generated through feedback and feedforward mechanisms. Feedback is relatively well-comprehended term, while feedforward is more of planning, management, and communication term. It mainly refers to a massage that has the characteristic of control impact for a downlink to a subordinate, to a person, or to an organization from which we are expecting an output.

(iv) Emergent nature of change

Emergence is known as a property of a whole, not a property of parts, and therefore, cannot be deduced from properties of parts. However the idea also has been illusory in terms of exact theoretical definition. One definition of emergence is that 'emergence a process by which relatively simple rules leads to complex pattern formation' (Holland 2000). The emergence seems to arise when there are constraints, and also when there are enough interactions between systems/system entities. This particular feature has a special appeal when we intend to transform our systems from one state to another. In a strong philosophical sense emergence is argued to be central to life (Wells, 2012). In living systems, emergence properties are usually identified by hierarchies, and called as intrinsic type of dynamics. Another slightly material-based interpretation of the emergence is made by Van Gulik (2001). He differentiates three types of emergence, namely, Specific Value Emergence, Modest Emergence, and Radical Emergence. *In Specific Value Emergence,* the whole and its parts have features of the same kind, but have different specific subtypes or values of that kind. For example, a bronze statue has a given mass, as does each of the molecular parts of which it is composed, but the mass of the whole is different in value from that of any of its material parts. In *Modest Emergence*, the whole has features that are different in kind from those of its parts (or alternatively that could be has by its parts). For example, a peace of cloth might be purple in hue even though none of the molecules that make up its surface could be said to be purple. In *Radical Emergence*, the whole has features that are both different in kind from those had by its parts, and of a kind whose nature and existence is not necessitated by the existence of its parts, their mode of combination and the law-like regularities governing the features of its parts (Scott, 2013). Similarly there are other theoretical interpretations and classifications of emergence, and must be noted that, in many of these interpretations, the concept stays in illusory and debated grounds that many scholar refuse to even use the term emergence in their theoretical developments (Wells, 2012), nevertheless, its importance continues to win attention.

The highest significance of emergence in the context of sustainability comes in interpreting change in sustainability. Changes in sustainability can take the form of changes in human–natural systems, and also in the form of changes in the sustainability understanding. In philosophy, this differentiation of observer from what is being observed is well discussed by Van Gulik (2001) around the idea of reduction[16]. He raises the argument that in order to define a specific notion of reduction, one has to address the question of *releta*. Relata can be addressed in two ways, (i) relation between real-world items—objects, events, properties[17], and, (ii) a relation between representational items—theories, concepts, models[18] (Van Gulik, 2001) .[19] In the same vein we can argue that related to sustainability change, emergence can occur, as system's emergent changes—due to complex dynamic interrelationships of systems, and as observer's emergent understanding—due to complex dynamic information handling by the observer in the process of observing these systems. Further when it comes to change, emergence suggests different degrees of change that are founded in complexity. This has special appeal in sustainability, as changing sustainability to a completely new level than before will have to encompass such a dynamic process.

(v) Change as self-organization, self-regulation and adaptation [20]

In the heart of self-organization lies the idea of movement towards pre-defined order. This is a conception that seems to be shared by major contemporary theories such as the quantum theory, living system theory, systems theory, and the chaos theory. The second law of thermodynamics states that the universe as a closed system has the tendency to eliminate all distinctions. Thus the ultimate state is a chaotic simplicity that shows both sameness and randomness. In other words the Entropy, that is the measure of randomness, always increases.

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[16] Reduction related specifically for sustainability interpretations and progress could be found in Gasparatos et al. 2008.

[17] This he further refers to as *Ontological Reduction.*

[18] This he further refers to as Representational Reduction.

[19] In the paper he observes that while these two aspects are interrelated they also have distinctive implications on *relata, and often* the dialogue on reduction tend to mix these two aspects.

[20] As a distinct aspect of (or alternative vocabulary for) complexity, general notions of self-organization in evolutionary studies focus on the ways in which the emergence of order need not always be seen as a consequence of hierarchical causal relationships (Jantsch 1980; Bak 1997) – an insight applied in some branches of economics (Krugman 1996) and geography (Allen 1997). Finally (and related closely to the study of self-organization), the more specific 'branded' concept of autopoiesis has arisen in systems theory applications to molecular and evolutionary cellular biology and (Varela et al 1974) and has inspired from there newly-intensified attention to the implications of recursivity, self-referentiality and reflexivity (Salzman 2002) in general social theory (Luhmann 1995) – adopted from Scoonest et al. 2007).

Contrastingly, the findings from quantum theory have suggested that universe is an open system. Open systems are neg-entropic and exhibit a tendency towards order. As early as 1945 Schrodinger outlined the paradox of living organization. Living organizations did not obey the second law of thermodynamics. Von Neumann identified the paradox in the difference between living machines (self-organizing) and artificial machines (simply-organized). In simply organized systems it takes just a change in one constituent part for the whole to be blocked. In other words the parts are more reliable than the whole. However, in self-organizing systems the constituent parts are not very reliable, yet, the whole organism retains its forms even while all the parts are being replaced. The whole is more reliable than the part.

(vi) Stability as self–organization, self–regulation, and adaptation

Self-organization is often known as the process where some form of global order is achieved through local interactions of an initially disordered system. This order could ultimately reflect a stable state of a system. However the concept along with emergence also has been debated over the years and has acquired slightly different and specific interpretations from different fields of studies. In philosophy, Morin (2008) defines self–organization as ensemble of processes involving order, disorder and interactions in a complex dynamic system. Although a closed system has little individuality and no exchanges with the environment, some self–organizing systems have the capacity to function individually with no exchange with the environment. One characteristic of this later type of self–organizing system is that, it seems to be detaching itself from its environment and distinguishes itself by its autonomy and individuality, yet it also seems to link itself more to the environment by increasing its openness and the exchange (Morin, 2008). Some parts of this view also been shared by several other philosophers of complexity. Further in his work Morin gives the term self-eco-organization to describe this process, characterizing a self-eco-organizing system as more autonomous and less isolated where internalizing its environment play a co-organizing role. He writes "*the self-eco-organizing system has its individuality, linked to its environment, and, therefore, cannot suffice unto itself, it can't be totally logical except by introducing, into itself, the foreign environment. It can't achieve itself, completely itself, be self–sufficient* (Morin 2010, page, 19)".

The argument that is raised around internalizing the environment and co-organizing with the environment is rather important when considering the sustainability in human–natural systems. Earlier we described that human–natural systems are essentially complex dynamic systems. They have the capacity to organize within itself, and further to internalize its environment in its evolutionary adaptations. In addition to that, Morin's concept on self-eco-organization may have added significance in sustainability observations. In general any observation of a system involves not only the focus on a specific system alone, but also the consideration of its environment, especially in defining the system boundaries. Further, the interpreting sustainability of the system naturally engages its environment through system relationships that include the environment. In addition, this property could be one point where living systems become distinctive from the other systems. Living systems—including human centered anthropocentric systems such urban systems that we explore in the discourse of sustainability—seems to have an inherent capacity to internalize its environment. (Further this particular feature seem to have added elegance to the core theories of complexity, and been represented as geometrical forms and art, however to stay within the scope of the thesis, exploring deeper in to them would not be done here; please refer to note the works as Capra (1998) and Taylor (2001) for an extended exploration on these significant but still not very well explored implications of self organization [particularly of the idea seem to represented by self–eco–organization], where first work explores complexity in the perspective of ecology and living systems, the second in the perspective of network cultures). For us, the idea—even in its vaguest form—carries profound implications for sustainability evaluation. Particularly in the not very visible observation process that precedes these evaluations, we have to at least to a certain extent isolate a system from its environment, and to still it for observations. Often we do not regard of the boundary of the system as permeable enough, therefore, we do not consider the systems as having capacity to internalize its environment, nor do we recognize that our own observation process may in itself internalize these systems in the process of giving interpretations to them.

(vii) Complexification

Complexification can be referred to as another key characteristics of the complex systems. The complexification is the process by which reality develops increasing degree of complexity[21] (Wells 2012). One of the philosophical basis of the idea of complexification is that through various processes as emergence and self organization the reality continuously develop novel properties over the time, therefore the reality have a general tendency to become increasingly complex. The idea of comlexification highlight the evolution pattern of a human–natural system, hence also the change of its sustainability. Complexification is also relevant for 'observation'. One of the key features to note in the process of observing a complex system or a complex phenomenon is that, the more we observe the more complex the system/phenomenon appears. It is often believed that in order to make more accurate evaluations and decisions, with respect to observations, more concreteness and less ambiguity would be desirable. However such a principle is no longer applicable for a complex system,

[21] The term is first used and defined in this way by Rescher (1998).

as the less system relationships and interactions that we focus upon, a less accurate (in other words less complex) model of actual reality that we would obtain, which ultimately would lead to less accurate interpretations and evaluations.

Additional note

Looking at these characteristics of complexity, we can predict that most of the significant dynamics related to sustainability may occur as a result of the complexity. At least they would have a close interrelationship. Therefore it is appropriate to consider them together than alone. Further, as we would see later on, the relationships between complexities and dynamics seem to be also linked to the limitations.

2.3.1.5 Modelling and framing complex dynamics

All the above mentioned, and also numerous of other not mentioned characteristics of complex systems suggest that, the ways of modelling and framing these systems are important and should be given serious consideration as much as the results obtained using them. Why do we need to model or frame complexity? There are two significant perspectives to answer this question (Morin 2008; Cilliers 1998)

(i) First perspective is traditional science oriented. In traditional sciences models are necessary in order to control and predict the behavior of complex systems. Obviously there are advantages in this approach, the explicit scientific models have severe limitations, especially in terms of how these can be tested, evaluated, how much details need to be considered to show their validity etc.

(ii) The second perspective is philosophy oriented. Here we model systems in order to understand them better.

These categories may be expanded to include a third perspective that is increasingly recognized with relation to complexity, yet not much explored in modeling.

(iii) The third perspective could be both science and philosophy oriented, however especially tied to the change of a system. Here we model in order to not only to understand and predict, but also to change and transform the systems.

In reality, it is hard to separate these different perspectives. For instance when the system entities are the observers, by better understanding the complex nature of their system, the system change already starts to occur as their perspectives, frameworks, decisions would change along with the change in understanding. In the process of building the models and frameworks that allow deeper knowledge and direction for changes, it is worthwhile to be aware of their different roles. Therefore it is useful to explore at least some of the already developed ideas/methodologies in sustainability-related fields that have internalized these basic roles in to their models and frameworks.

2.3.1.6 Exploring complexity-based methods in some related academic fields

Earlier we mentioned that the idea of complexity have been dissipated in to other fields of studies in a fragmented manner. Sustainability science/sustainability studies always have been in a multidisciplinary, interdisciplinary, and transdisciplinary terrain. Whenever sustainability research meets those other fields of studies, the methodologies we borrow from them also reflect such fragmented, hence somewhat dissipated perspectives of complexity. Therefore it is worthwhile to review some the methodologies found in related fields of studies (Please note that the developments specific to cybernetics and natural science fields would be omitted, mainly because the implications from these alone are somewhat distant for the development of subsequent arguments, and also, some essentials of them have already been discussed in other places in thesis. Also please note that following exploration does not claim to represent a comprehensive review, rather the highlights with selected prominent works and implications. For a sound review on how complexity studies have informed other fields of studies, please refer to Wells (2012)).

Developmental studies

Addressing sustainability could not be distanced from another preceding ideology, that is the development. Sustainable Development has its foundation strongly linked to developmental discourse, mainly as a critic of the direction it has stood for, that is the ‘growth’, and ‘efficiency’. Further, sustainability as a concept, focus upon development in some contexts. Therefore, it is supportive to explore the key concepts in the ‘developmental theory’ and their connotations in addressing complex dynamics. Conceptually features such as direction, change, and transition are closely embedded in ‘development’. However the theories developed around development studies over the years have taken a unidirectional understanding. Pieterse (2010) observes the unidirectionality resonated in field's theoretical developments to be the main reason for that. According to him, for a development theory to be significant, social forces must carry it. To be carried by social forces, he further argues that, it must match their (society’s, stakeholders’ etc) worldviews and articulate their interests. In other words, the theory must serve an accepted ideological function. While pointing out that an explanation that satisfies a peasant does not satisfy a landlord, a banker or an IMF official, he further argue that the strength and weakens of development studies had been its policy–driven nature (which he refer also as problem–driven) instead of having purely theory–driven basis (Pieterse, 2010). However for the same reason, the developmental studies have attracted fundamental criticisms from social science for the way its theoretical basis got developed over the years[22]. Further the policy driven characteristic could also be the reason for why dialogue of multiple pathways did not properly get integrated in to the concept, even while development discourse by nature did include many different contexts and settings that would have naturally opened up such discussions. At the same time, the ideas of complexity have not been completely eluded in the development of developmental discourse either. Action research, which is a significant branch of developmental studies and is also closely tied to sustainability, is one such example (Phelps and Hase 2002; Stokols 2006). However, as very well discussed by Phelps and Hase (2007), few authors have drawn any explicit connection between action research and complexity theory, or complexity studies in the light that we try to examine in this study. While the use of the term complexity in general sense is more abundant, still occasionally even deeper ideas such as 'complexification' has been implicitly addressed, for instance when it is argued that " action research becomes an instance of complexifying the relationship among researchers and research situations so that the boundaries between these are blurred (Sumara and Davis, 1997)".

Transdisciplinary research

Transdisciplinary studies is a terrain where diverse understanding and expertise are left to interact and facilitate new understanding and collective decisions. In the perspective of sustainability transdisciplinary practices have added advantage of bringing different perspectives in to discussion and as to create solutions in a way that the complex dynamic nature of the problems are dealt in a complex dynamic platform itself. Even though in recent times transdisciplinarity has gained wide popularity in academia in tackling complex problems, also known as wicked problems, the concept doesn't seem to have strict consensus (Balsigar 2004, adopted from Lawrence 2010). Acknowledging this factor, Brown et al (2010) further elaborates characteristics of transdisciplinary studies reviewing its key features. Some of them are;

i. Transdisciplinarity tackles complexity is science and it challenges knowledge fragmentation where it deals with research problems and organizations that are defined from complex and heterogeneous domains. E.g. Climate change
ii. Transdisciplinary research accepts local context and uncertainty.

[22] He also recognizes that the problem and policy driven nature of developmental studies, for the same reason, has made it a follower of frameworks developed in other sciences than a trendsetter. For a thorough understanding of his critical review, which in my understanding has several implications for the theoretical developments in the field of sustainability science, please refer to the chapter, Trends in Development Theory, in Pieterse, 2000.

iii. Transdisciplinarity implies intercommunicative action (transdisciplinary knowledge is a result of inter-subjectivity, it is a research process that includes practical reasoning of individuals with constraints and complex nature of social organizational and material contexts, which occurs in the 'mediation space and time' or 'border work'.

iv. Transdisciplinary research are often action oriented, it makes linkages not only between disciplines but also between theoretical development and professional practices.

v. Transdisciplinary research often deals with real-world topics and generates knowledge that contribute to understanding the problems but also that contribute to their solutions.

Brown et al (2010)

The authors indicate that these characteristics alone however are too restrictive because, in their terms, there is no reason why theoretical development—especially analytical description and interpretation of complex environmental question—cannot be achieved by transdisciplinarity. For this purpose they propose a new way of seeing transdisciplinarity, as 'imaginative transdisciplinarity', which could also be built upon critical transdisciplinary inquiry. The authors suggest to "*draw on our all intellectual resources, valuing the contribution by all academic disciplines as well as other ways in which we construct our knowledge, and in order to meet the challenge of developing open transdisciplinary mode of inquiry capable of meeting the needs of individuals, community, the specialist traditions and influential organizations, and allows for holistic leap of the imagination*" (Brown et al. 2010). In other words Transdisciplinary research could become a significant leap towards addressing the complex dynamics in sustainability analysis in a much effective manner than merely serving as a platform of linking different stakeholders, and their knowledge, perspectives etc. This sort of dialogue allows the practitioners to engage in problem solving (though it is not explicitly mentioned transdisciplinary approach can be used in planning for sustainability as Scholz and Tietje (2002) has shown with the case-study methodology they propose), with more refined philosophical understanding, and critical stance, however still the practitioners of transdisciplinarity have to depend on existing methodologies mostly from their own disciplines. It is important to note that the 'mediation space and time' and 'border work' (originally mentioned by Després (2004) and Horlick-Jones and Sime (2004) respectively) where transdisciplinarity thrive, also lack structures that can guide the practitioners to adapt the theories in a non diluted manner. These observations suggest that transdisciplinarity needs its own way of structuring and handling complexity.

Further, it is worthwhile to mention one philosophical interpretation of transdisciplinarity. Drawing from Philosopher Edgar Morin's work Montuori (2005) summarizes transdisciplinarity as;

(i) A focus that is 'inquiry–driven' rather than disciplinary driven. Without rejecting disciplinary knowledge, it involves development of knowledge that is pertinent to the inquiry for the purpose of action in the world.

(ii) A stress on 'the construction of knowledge' through an appreciation of 'meta–paradigmatic dimensions'—in other words, the underlying assumptions that form the paradigm through which disciplines and perspectives construct knowledge (disciplinary knowledge generally does not question its paradigmatic assumptions).

(iii) An understanding of the organization of knowledge, isomorphic at the cognitive and the institutional level, the history of reduction and disjunction ("simple thought" in Morin's terms), and the importance of contextualization and connection ("complex thought" in Morin's terms)

(iv) 'The integration of the knower in the process of inquiry', which means rather than attempting to eliminate the knower, the effort becomes one of acknowledging and making transparent the 'knower's assumptions' and the process through which s/he construct knowledge.[23]

Montuori (2005)

The author further quotes Morin as " *The observer should not just practice a method that permits her to shift from one perspective to another [...] She also needs a method to access a meta point of view on the diverse points of view, including her own point of view*" (Morin 2008). This particular interpretation of transdisciplinarity, unlike the previously mentioned and similar other widely known interpretations highlights the observer's special role in the research process. The observer no longer observes an existing paradigm, nor s/he merely ride the paradigm, rather the observer is an active part of the paradigm and can be successful only if s/he employed a meta level of understanding that is to a certain extent detached from the observation process. Also note the way the reduction and disjunction is contrasted with contextualization and connection (in closer terms relationships). Especially the meaning of contextualization in this instance goes beyond the idea of paying attention to specifics—which it can occasionally resonate, but invokes the interconnectedness—the complexities in relationships, and one step further, the complexities in observations. Also it is noteworthy that this way of looking at transdisciplinarity further highlights the fact that, just as much as the complexities of the knowledge generation and decision making that involves multiple

[23] All highlighting quotation marks do not appear as they are in the original text (only some of them appear). They were incorporated here to stress on the factors that would especially be taken in to account in this study's later sections.

stakeholders, the complexities in individual observation and inquiry is necessarily tied to the purpose and the targeted action.

In this regard the methodologies with which transdisciplinarity is practiced play a significant role. One of the developers of the Soft System Methodology[24]—one of such methodologies—Brian Wilson states that a 'methodology', among other factors is better equipped when having following characteristics.

i. The methodology has to be structured, and structure should be visible and should have the capacity to guide a thinking process
ii. It has to be flexible
iii. It has to be explicit to provide a defensible audit trail

(Modified from Wilson 2010)

In addition to the Soft Systems Methodology, the embedded case-study method proposed by Scholz and Tietje (2002)—that also is intended to supplement transdisciplinary studies—is a good example where the methodology to support such mediation spaces and border work are shown explicitly.

Agents-based modelling (ABM)

Addressing the autonomous behaviour related complex dynamics are reflected in more modern techniques such the agent-based modelling (ABM). The ABMs resembles micro models that could reflect a bigger complex context. It has the philosophy that simple behaviour rules of a lower-level system may generate complex behaviour rules in a macro–scale system, embedded in to its modelling. However such models use heavily a quantitative approach. The ideas behind their models are not often adequately integrated to the general sustainability evaluation processes, which may have to deal with especially qualitative interpretation. Further, not only the part's capacity to reflect the complexity's of the whole, but in the other way round, the whole's capacity to direct an evaluator to gain specifics understandings of the behaviour of the parts—as we describe later—is also significant to sustainability evaluation.

Some philosophical perspectives

When it comes to a broad and even to some extent illusive topic as complexity, it is hard to make differentiation with what comes under science and what comes under philosophy. This is mainly because deep theoretical discussion in any of the sciences can naturally and easily lead to the domain of philosophy. Some of the significant theoretical equations in other

[24] Soft System methodology would be further discussed in a later section.

sciences have already addressed the concept of complexity in a philosophical sense than strictly scientific sense. Also the understanding of sustainability in a deep sense is linked to internal reference frames, worldviews, beliefs—that include ethical beliefs, therefore not only the philosophies that concern scientific knowledge, but also the ones that concerns people's value systems[25], everyday beliefs and common-sense also needs to be included. For the scope of this section, only few of modern philosophical arguments have been selected, as they pave the way to the points being highlighted; that is the complexity (with relation to sustainability) starts in the very process of observing sustainability in surrounding and the implications are far-reaching than what usually perceived with the general use of the term complexity. To reach the topic of philosophy of complexity, it is helpful to explore how Edgar Morin answers the question 'what is complexity?'

" *Complexity coincides with part of uncertainty that arises from the limits of our ability to comprehend, or part with a part of uncertainty inscribed in the phenomenon. But complexity also cannot be reduced to uncertainty; it is uncertainty in the heart of richly organized systems* […]*, complexity therefore is linked to a certain mixture of order and disorder, a very intimate mixture, one that is very different from static conception of order and disorder (where order reigns at the level of large population disorder reigns at the level of elementary units*) […] *and also it coincides with the uncertainty observed in the face of the lesser values and provisions.* [...] *The theoretical problem of complexity concerns the possibility of getting inside black boxes*[26]*. It is to consider organizational and logical complexities. Here, the difficulty is not only in the renewal of object, it is in the reversal of the epistemological perspectives of the subject, in other words, of the scientific observer* [...]*"* (Morin 2008, p 21) Following his arguments it is possible to recognize that, complexity (in this case the complex complexity) also coincides with part of our inability to comprehend everything completely at once, leading to different targets, starting points, and logics. These aspects to some extent are represented in the ordinary use of the term 'context'. Apart from the surface meaning, 'context' carries the idea that a system can be understood relative to multiple different logics that are connected to multiple different background understanding. Under such interpretation, the whole of the observation process loses its simplicity, and solidity. Morin further elaborates, " *Von Neumann pointed to the logical door of complexity. We will attempt to open it, but we even don't hold the key to the kingdom, and that is where our voyage remains*

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[25] That include both individual value systems as well as the collective value systems that act as meta-systems binding collective groups, societies etc.

[26] He brings out this argument, comparing to the regard of complexity in Cybernetics, which in his view recognized complexity in parenthesis without denying it. He uses the metaphor black box to describe complexity in Cybernetics. One considers the inputs and outputs to the black box, which allows one to study the results of the system's functioning, the resources needed by the system, the relationship between inputs and outputs, without ever entering in to the mystery of the black box.

unfinished. [We will glimpse at the logic, starting with some of its external characteristics, we will define few of its traits as yet unknown, but we will not be able to elaborate a new logic, not know of if it is temporarily or forever, out of our reach]. But what we are persuaded is that if our current logical-mathematical correspond to certain aspects of phenomenal reality, it does not correspond to its truly complex aspects. That means that our logic has to develop itself and go beyond itself in the direction of complexity" (Morin 2008). This paragraph in itself provides the most significant entry point that we wish to highlight with relation to observing complexity. In observing complexity it is important to direct our inquiry in a way that the logic we adopt itself represents what the complexity means (in our context and purpose). Therefore, from the very start, the foundation of the logic we adopt in observing a system, such as collecting data, selecting analysis methods, analysing, and so on, need to carry the idea of complexity as an embedded stream within the whole process. As Haggis (2007) observes complexity theory offers a set of ideas about process and formation which could be used in relation to both realist/explanatory and interpretive approaches; however what often overlooked, is that complexity offers not just another theory, but a completely different starting point for theory, and also for the conceptualization of methods.

Systems thinking

At this point, it is important to see what the field of 'systems thinking' has been offering. 'Systems thinking' is the field of study where awareness and observation of complexity probably were dealt the most. Even though the discussion made so far did not mentions specifically the branch of systems thinking, we need to remember that, many of the recent developments in almost every field in this respect, at some point seem to have encountered the ideas developed in systems thinking.

There are different branches in systems thinking, that have highlighted different structural and functional features of systems. They have each supported as pillars of, what is known today as systems methodology. Historically system's thinking has strong link to systems theory, therefore to the field of cybernetics and the strict theoretical basis of complexity. Capra (1998), saw systems thinking as a process that changed our mechanistic thinking of ecological paradigm, which he further identifies with the *metaphor of chaotic pendulum*—where the oscillations that almost repeat themselves but not quite, seemingly random and yet forming a complex, highly organized pattern. He also highlighted the basic tension that has been between part and whole in the sense of epistemologies and methodologies, where part was called *mechanistic, atomistic or reductionist*; the whole, *holistic, organism or ecological*. It is important to note the positioning of the term *holistic* here. Some argue that, in twentieth century science the holistic perspective has become known as 'systemic' way of thinking

(Capra 1998; Wilber 2000). However over the years, there seem to have generated debate around the term on the degree and kind of 'holistic' it is actually implying that the idea behind 'holism' has changed over the years. Having said that, still to this day it is being pointed out that the term has not been used in the same strict way the 'holistic' being described in complexity, rather often just synonymous of 'wholistic'.

Complexity thinking

Recent developments in systems thinking address the 'holism' as well as the 'complex complexity'. Morin argues that in the modern era, complexity arose first in philosophy and later in physics, chemistry, and biology. He differentiates between complexity in these types of systems, and the complexity in the process of observation. Similar arguments by Capra (1998) and Morin (2008) are also elloborated by Gharejadhagi (2011), however, in terminologies that are more frequent in systems thinking. He differentiates the terms Analytic thinking, Synthetic thinking and Process thinking. Analytical thinking (*mechanistic, atomistic or reductionist)* is the essence of classical science. Classical scientific method assumes that the whole is nothing but the sum of its parts, therefore, understanding the structure is necessary and sufficient to understand the whole. Synthetic thinking (*holistic, organism or ecological)* is the main instrument of the functional approach. By defining system by its outcome, synthesis puts the subject in the context of a larger system of which it is a part, and then studies the effects it produce on the environment. Dynamic thinking focuses on process. It looks to the how question for the necessary answer to define the whole. (In other words dynamic thinking has a purpose attached to it (Gharajedhagi 2011)). Note the context where he uses the term '*holistic*'. This particular factor is clearly the point when Capra (1998), Morin (2008) and many other authors highlight, when they argue that the complexities are not reflected in an adequate manner under the term holistic. Aligning with the earlier mentioned part and whole relationships, the term 'holistic understanding' can be considered to denote not just the understanding of whole—that comprise of parts, nor just the understanding of parts—in a context of whole, but the understanding that reflects both whole and parts simultaneously, and further an understanding that spans across both space and time, that means including their dynamic interrelationships that continue to inform each other. In our analysis, it is appropriate to use the term 'complexity thinking' to denote a thinking process that supports such multiple factors and directions of complexity simultaneously. However still it is important to make differentiations as done above, and give equal significance to this subgroup of complex thinking in any observing methodology that we develop. For example in the case of sustainability planning, dynamic thinking has added implications. Sustainability, especially in the case of its applied orientation—where future sustainability conditions are sought-after—has necessarily a purpose attached to it. Even without focusing on the application end, the very process of sustainability understanding involves boundaries and directions that utilize a continuous information selection process (please not that this point would be elaborated further in the section of concept building). What at this point important to note could be that, being aware of complexity in a system in strict sense involves a complex dynamic process whose individual attributes cannot be separated from each other. However, it is important to be aware of different types of cognitive processes at different steps, because what appears as a simultaneously occurring complex observing process could actually go through patterns that involve several significant steps. Further there seem to be still a lack in terms of the capacity of complexity thinking (along with dynamic thinking as described above) to fully capture not only the complexity but also the dynamic patterns that arise due to those complexities, especially with relation to the parts and wholes of the system.

Observing complexity

Likewise, in addition to complexity being a characteristic of a system, in order to identify complexity and subsequently in understanding the system for what it is, the process of observation matters. However as earlier mentioned under 'emergence', often the interpretation from the nature of what is being observed is not adequately differentiated, so the observation is not perceived as a separate process (Van Gulik 2001). Bogen (2013) illustrates this fact effectively when he writes, "*Observers use magnifying glasses, microscopes, or telescopes to see things that are too small or far away to be seen, or seen clearly enough, without them. Similarly, amplification devices are used to hear faint sounds. But if to observe something is to perceive it, not every use of instruments to augment the senses qualifies as observational*" (Bogen, 2013). Therefore it is very much important to separate the complexity in observation form the complexity in reality. This is desirable not only because at least in ontological sense, there is a difference between reality and what is being observed, but also, because as we would see in later sections, there is a degree of complexity tied to the observation that needs separate attention.

With relation to observation in where complexity is involved, Morin (2010) elaborates three *stages of complexity* by taking the simile of a tapestry.

> *i) In the first stage of complexity*, we have simple knowledge that does not explain the properties of the whole. A banal observation that has consequences is not banal; the tapestry is more than the sum of the threads that it is composed of. The whole is more than the sum of its parts.
>
> *(ii) In the second stage of complexity*, the fact that there is a tapestry means that the qualities of this or that type of thread cannot be fully expressed. The threads are inhibited or virtualized. The whole is therefore less than the sum of its parts.
>
> *(iii) The third stage of complexity* poses problems relating to our capacity to understand and our thought structure. The whole is simultaneously more and less than the sum of its parts.

Morin, 2008

As we earlier discussed, complexity in a simplistic manner could be interpreted as a characteristic of a system that has a huge number of interacting parts that are capable of having organizing relationships. It could also be interpreted as the degree to which the system can be differentiated with its parts and can be integrated with wholes. Given to the fact that number of other factors involved, they are not comprehensive enough interpretations although they suggest that one fundamental aspect to the complexity is the relevance of parts and wholes and their mutual interactions (to create the organizing ability). Further, recognizing these factors alone does not capture the role of observer as an entity who understands and interprets those factors. It is only with examples as above (of tapestry) that we could expound the mutual interaction of parts and wholes one step further to include our understanding of them. Understanding is closely linked to observation step. The observer's involvement has strong implications for a situation where a system is actually complex but we fail to observe it as complex. Polanyi and Prosch (1977) give two scenarios to explain when observation process plays an illusory role in recognizing complexities, again, with relation to parts and wholes. " *(i) At the time when flying by aeroplane was first developed, around 1914–18, traces of prehistoric settlements are discovered from the air in field over which many generations had walked without noticing them. Though the aerial photographs clearly revealed the outline of the sites, the markings on the ground, which constituted these outlines frequently, remained unrecognizable. Such sites are comprehensive entities that are precisely traceable without mental effort from a distance, while the identification of their particulars at close quarters presents great difficulties. […] (ii) In 1923 H. Mark and I established the atomic structure of white tin. Shortly after that we had a visit by Professor van Arkel from Holland who claimed to have established an entirely different structure. Eventually, it transpires that this structure had the same arrangement of atoms as ours, but that he has* *described it along lines forming an angle of 45° to those along which we had seen it. This trivial difference in viewing the atomic arraignment had rendered it mutually unrecognizable to both parties, simply because we lacked a sufficient understanding of the relationships involved in the atomic arrangement* […]. We can see then two complementary efforts aiming at the elucidation of a comprehensive entity. One proceeds from *recognition* of a whole towards an *identification* of its particulars; the others, from *recognition* of a group of *presumed* particulars towards the *grasping* of their relation in the whole"[27] (Polanyi and Prosch, 1975, pg 123-124). These two examples illustrate where complexity can elucidate critical facts of what is being observed, simply because *the focus is on either parts—where it should have been on wholes, or on wholes—where it should have been on parts*. Similar examples are found with relation to sustainability evaluation as well, where bird-eye view can help to recognize global patterns more clearly, while elucidating significant contextual factors that determines those patterns, and vise versa, where scrutinizing and detailed analysis can give us very distinctive information of the systems, yet make it difficult to extrapolate the results to a bigger context failing to expose the patterns that connect them. These examples indicate that in order to observe a system giving attention to its complexities, we need a certain amount of effort directed in each direction. Further the Polanyi goes deeper in to the observation process. "*I have called these two efforts complementary since they contribute jointly to the same final achievement, yet it is also true that each counteracts the other to some extent at every consecutive step. Every time we concentrate our attention on the particulars of a comprehensive entity, our sense of its coherent existence is temporarily weakened; and every time we move in the opposite direction towards a fuller awareness of the whole, the particulars tend to become submerged in the whole. The concerted advantage of the two processes arises from the fact that normally every dismemberment of a whole adds more to its understanding than is lost through the concurrent weakening of its comprehensive features, and again each new integration of the particulars adds more to our understanding of them than damages our understanding by somewhat effacing their identity. Thus an alteration of analysis and integration leads progressively to an ever deeper understanding of a comprehensive entity*" (Polanyi 1974, pg 125). Likewise, there is a necessary link between *observation* and the *understanding*. While the term observation (or observing) can occasionally include the understanding step, that is not necessarily so, especially when the observing entity has complexities in it. Between observation and understanding, there seem to be at least one significant entity, the process of knowing. Polanyi (1974) builds upon the part and whole relationship to analogous in several process of knowing; namely (i) the

[27] Italics do not appear in the original text. They are made to highlight the observer's involvement in the observation process.

understanding of physiognomies, (ii) the performance of skills, (iii) the proper use of sensory organs (iv) the mastery of tools and probes. As a way of interlinking them through common terminologies, he emphasizes some essential features in the relation of particulars (parts) to comprehensive entities (wholes). For instance particulars (parts) could be noticed in two different ways. First is that, we could be aware of them uncomprehendingly—i.e., in them selves, or the second, we could be aware of them understandingly—i.e., in their participation in a comprehensive entity. He further elaborates that in the first one, we focus our attention on isolated part, and in the second, our attention is directed beyond them to the entity to which they contribute (Polanyi 1974). Further, he specifically uses the terms 'focal awareness' and 'subsidiary awareness' to differentiate the two types of awareness achieved in observing the same particulars. He emphasizes that the terms such as 'seeing' and 'looking at' cannot be generally used instead of subsidiary and focal noticing[28]. While the description of focal and subsidiary awareness goes deeper in his narration, we could gather that there is a ontological distance between looking at (which also can be referred as observing) and being aware (which also can be referred as understanding) of the characteristics of a system. We will come to the point of directing our attention to a focus and to an entity beyond focus in a comprehensive manner in a later section. At this point we want to bring-forth the relationship of understanding to their observation where parts and wholes are involved. Slightly differing to the way the author use the term 'understanding' one would also identify what obtained by focusing on a part as being aware both understandingly and comprehendingly. The only difference is that that such strictly part-focused understanding does not represents the whole of reality of what is being observed, and the observer is unaware of it. Therefore when we use the term of understanding of a system (a complex system), we have to take a position that we mean the understanding that represent both part and the whole, in other words the understanding that is closer to comprehensiveness.

As an additional point, it is important to see the relationship of observing complexity and observing complex dynamics. It is apparent that the part and wholes are essential attributes to describe the complexity, yet their implications in observing the systems that are complex can be seen as growing out of the domain of complexity to complex dynamics. The steps from initial observation to understanding (and subsequently evaluations if it applies) have a minute amount of time lags involved. This fact is not often explicitly discussed, mainly because the understanding of dynamics are often integrated and treated as self-apparent to discussions of complexity, and also because these entities are discussed as attributes or measures of complex systems, not as factors that are significant for the observation process of a system.

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[28] Please refer to Polanyi (1974) for detailed description of focal and subsidiary awareness.

2.4 OTHER USEFUL CONCEPTUAL IMPLICATIONS

2.4.1 Change as a concept

(i) change vs persistence

Change and persistence are two concepts that cannot be explained without the other. This also means whenever one tries to examine change, they must examine persistence and its related characteristics such as stability and cyclic behaviour (that keeps a system without making significant transformations). Exploring persistence enable us to see that there are different types of persistence. Further persistence could involve some amount of change, but may prevent transformative and perhaps exponential changes that would prevent stagnations, even with internal visible changes. This enables us to see that there are different degrees to change. However often these two concepts of change and persistence are dealt separately, especially when they are considered in theories. Further when one is concerned with one of those aspects the other is taken as natural, therefore as granted.

(ii) first order change vs second order change

Change comes in different degrees. The velocity and the acceleration both are forms of change however are not the same. Watzlawick et al (1974) separates the first-order change and second-order change. He gives an example with a machine. Changes in a machine could represent component changes. As a result of the changes in component level there could also be behaviour/function changes of the machine. The component change is a first order change. The change in machine function is a second order change. A change from first order to second order involves not just a group change but also a logical change, and also it may involve a change of a change. The same differentiation we could recognize in many instances relation to sustainability change, as we would see in the subsequent sections.

2.4.2 Time and Space

Time plays a center role in sustainability. The very idea of intergenerational justice that defines one key principle of sustainability resonates the importance of time. Just as system interactions and relationships across time, the interactions and relationships across space also are equal relevant in sustainability. However, before starting to refer to relationships across time and space, as if they are self evident, it is appropriate to explore the theories around time separately as there have been substantial views, concepts, philosophies developed to explore their nature individually. Out of them we select a few that closely connect with sustainability.

A considerable amount of work with relation to philosophy of time is connected to the Fatalistic view of time (Markosian 2014). The thesis related to fatalism is that whatever happen in the future is unavoidable and beyond human apprehension and control. Apart from it, the other philosophical views of time include, the 'Open Future' and the 'Growing Universe' interpretation of Time. These are extremely conceptual, and detailed descriptions of them stay beyond the scope of the thesis, however with them an interesting question appear with respect to the topology of time, that is, which shape that we should seek to describe the flow or the movement of time? For instance when we visualize time, should it be visualized as a relation among things and events? Or should it be visualized as a single line or an arrow? If so would such a line have explicit attributes to it, or should it be considered as a dimension, similar to the dimensions in space that do not exist in reality, yet help to interpret the reality? Even further what is the connection of time and our interpretation of it? Or should the time be visualized in an entirely different shape such as a closed loop or a spiral that encompass a flowing nature? Can it be treated as a stream that can flow in any direction? These are only a few of the fundamental questions relevant to interpret time, and in past there have been many theories formed around them. Out of these theories there are two separate interpretations in philosophy that differentiate the absoluteness and the relativity of the time. They are the Platonism- and the Reductionism-based Time interpretations. These two opposite views have significant implications on the way we interpret surrounding with relation to time. Especially when those interpretations also involve complex phenomenon. Mctaggart in 1998 has argued that there is no such thing as time in reality, that the appearance of a temporal order to the world is merely an appearance (Markosian 2014; Gell 1992) [29]. (This view along with another view that highlights the 'presentism' is also seemed to have shared by several of Eastern

[29] He develops his arguments around what he called A-series and B-series of time. A-series order time in terms of properties. B series order time in terms of relations (between the properties mentioned in A series). He shows that these theories create contradictory propositions and logically conclude Time, along with both A-series and B-series is unreal. Please refer to Markosian, 2014 for details.

philosophies). One implication (highlighted as B-theory) is that time also can be visualized much like the dimensions of space. Those who skew towards opposite direction (that is towards A-theory) however hold that there is a crucial ontological difference between the dimension of space and the dimension of time (Markosian 2014).

While the nature of the time continues to stay debated, there are strong implications of time in processes such as observation, perceiving, understanding a complex phenomenon. Related to these processes further conceptual views of time such as ecological, structural, geographical views (Gell 1996) were developed. The geographical view of time (also referred as geography of time) highlights that that the orientation of time (e.g. past, present, future) is varying from society to society, region to region and country to country. The ecological view of time highlights the interconnected nature of it to events. Especially in past, the time scale has been defined by occurrences in a community and these occurrences give the perceptual measures, therefore the meaning to the concept of time. These varying concepts indicate that beyond what is apparent the interpretation of time has an anthropological aspect to it and its interpretations can vary from person to person, from place to place, across space and also across time itself. Such concepts further denote that even if there are recognized differences in terms of how people perceive time, there also might be underlying commonalities in terms of how a system such as a village or a country would perceive time. Further they highlight the often-overlooked plurality around time—i.e., a person, a group, or a system could employ more than one theory for their interpretation of surrounding changes. The complexity surrounding these varying concepts of time is amplified in the discourse of sustainability, further contributing to the normativity associated in its principles. Further sustainability in its principles encompassing considerations for several generations, the complexity in perceiving time runs across not only individuals and places, but also across time in itself. This fact further highlights that visualizing the connectivity of past present and future has added significance in sustainability interpretations. The implications of time-connectivity in the form of memories, past, present, and future orientation etc vary across individuals and societies. Further the changes to their interpretations along time itself are essential factors to think, especially when we try to interpret the past and present conditions, and try to perceive the future and how the future generations would interpret their past. Any assessment framework, which deals with such interpretations, has to be sensitive to such variations.

2.4.3 Top–down and Bottom–up approach to sustainability

Top–down and bottom–up approach have specific meaning in specific contexts. In general they may even indicate two directions with which societies can move forward. Such basis seems to reflect in historical sociology thinking as well[30]. In the development of sustainability discourse, with debate and dialogue about concept, methodologies, methods and techniques, the discussion of the top–down and the bottom–up has always been in the heart. It is visible in research approaches, policy initiatives, regulations, as well as in new creations, innovation, artifacts and so on. Cairns (2003) writes "*Humankind is now moving from the age of reductionist science to an age of synthesis or integrative science. This transition does not mean that reductionist science is no longer appropriate, but rather that as levels of complexity in any system increase, new properties emerge that were not apparent at lower levels. Consequently, one means of reducing uncertainty in this age of synthesis is how congruent a particular hypothesis or body of evidence is with other related bodies of evidence within the particular system being studied*" (Cairns 2003). Both top–down and bottom–up sustainability strategies will require synthesis and also a means of coping with scientific uncertainty. Apart from that, top–down and bottom–up approach could also reflect worldviews linked to sustainability. Further, they reflect the idea of parts informing the whole and the whole informing the parts, and the their directionality or development. One thing to note of top-down and bottom-up approaches is they have a strong sense of directionality attached to the concepts. Also with the directionality, the capacity of a smaller unit to influence, and react to a larger external units functions (such as through internalization, adaptation (Common and Pearce, 1973; Hjorth and Bagheri, 2006) etc) and vise versa also gets highlighted.

2.4.4 Role of conceptual framework in sustainability

A *conceptual framework* is described as a set of broad ideas and principles taken from relevant fields of inquiry and used to structure a subsequent presentation (Reichel and Ramey 1987). A conceptual framework could also be regarded as a metastructure (Beckers 2011) or a system of thoughts (Jenks 2002). When clearly articulated a conceptual framework has potential usefulness as a tool to scaffold research, and therefore, to assist a researcher to make meaning of subsequent findings. In one way, such a framework can function as a starting point for reflection about the research and its context, assisting a researcher to develop

[30] For an account of historical development of sociology thinking please refer to (Hollis 1994).

awareness and understanding of the situation under scrutiny and to communicate it effectively. The framework itself can be argued to form part of the agenda for negotiation to be scrutinized and tested, reviewed and reformed as a result of investigation (Guba and Lincoln 1989; Smyth 2004; Jabareen 2009). Apart from that, there are other roles of a conceptual framework. They can be considered as a type of intermediate that attempt to connect to all aspects of inquiry (e.g., problem definition, purpose, literature review, methodology, data collection and analysis) and also to contribute for the trustworthiness of the study (Goetz and LeCompte 1984). Further conceptual frameworks can act like maps that give coherence to empirical inquiry. Because conceptual frameworks are potentially so close to empirical inquiry, they take different forms depending upon the research question or the problem.

The role of conceptualization in Cognitive mapping of multiple stakeholders

Sustainability problems are connected with diverse human–natural systems, therefore tackling these problems often needs variety of stakeholders coming together to make decisions and policy initiatives. Usually the diverse perspectives of stakeholders are addressed in the decision making process, which traditionally in the past was limited to experts and policy makers. However, with each sustainability-related issue the decision process involves much earlier stages as even problem identification itself. The question of *'what is the problem as well as the shape of the problem'* is receiving wide attention lately, mainly because the consensus among stakeholders for next steps is difficult in many of the sustainability related problems.

Increasingly we have come to recognize that significance of transdisciplinarity approach to address unsustainability issues. Yet, the fact remains that, the diverse perspectives of multiple stakeholders also becomes a barrier from the outset of the decision making process. One character of sustainability is that the concept stands the same importance for all types of stakeholders regardless of their expertise. The basic value judgments, which reflect the ideas such as wellbeing, do not rely on expert knowledge alone, therefore need diverse understanding and perspectives at different stages of analysis. However multiple perspectives need not be the barrier rather the strength in making decisions in a transdisciplinary platform. The emerging decisions as a result of complex interactions of multiple perspectives in multiple spatial and temporal scales can result in innovative solutions that would not have been there, if not the ideas are subjected to those complexities. One significant barrier to realize the full potential seems to be the lack of frameworks that guide these complex decision making processes, both within individuals, and within groups. In order to deal with this issue we have to have tools, that to a certain extent structure the cognitive process of the stakeholders to better suite an effective decision making process. Therefore a framework for sustainability has added advantage if it carries generality and simplicity which can allow different mindsets to be able to relate to.

The role of conceptualization in scientific analysis and policy-making

In addition, for the mentioned reasons, beyond the usually recognized importance in research building, such a method can also support a general sustainability related policy process. One significant difference with policy process in a transdisciplinary type interactive decision process is that while the policy process has to rely on expert knowledge it also needs to include non-expert knowledge types. However, due to the gaps in translatability to the decision and policy making steps, some of these knowledge types can be either neglected or poorly represented, even though the stakeholders may even reach common understanding ground for their significance for the context's sustainability. One possible way to address this challenge is by framing the understanding coming from different knowledge types in to a common systemic frame, so that each knowledge type gets the necessary recognition. However, it is also important to recognize that mere systemic view will not eliminate the difficulty faced in giving different types of knowledge a similar quantifiable value. In other words, in order to recognize their prominence, steps such as merely recognizing them all as different entities that effect different parts of a system at different times alone will not be very supportive. One improvement could be giving weight to each different knowledge type, so that their collective significance as aggregate entities in a subsequent step can be effectively brought in to the decision process. In order to make such a process viable, a conceptual framework that has the capacity to incorporate both qualitative and quantifiable aggregates could be considered as to give a preliminary foundation.

Further, a framework that support such an approach may bridge the gap between the three entities of the expert scientific knowledge, the local and non-expert knowledge, and the policy formulation and decision process.

The role of conceptualizing in sustainability evaluation/ assessing

With relation to evaluation/assessment conceptualization could play a distinctive role. Broadly they can be viewed under two streams.

a. Understanding sustainability and complexities, dynamics related to sustainability

- Supporting the visualization of sustainability (specially in relation the question of what is sustainable and what is unsustainable or in other terms what would be the boundaries of sustainability).

- Supporting the understanding and awareness of significant principles of sustainability, aid in forming thinking patterns which enable such principles[31]
- Supporting in visualizing multiple systems involved, and holistic and complex nature of sustainability problems.
- Provide a platform to make long term focused observations, evaluations, and other decisions.

b. *Identifying mechanisms related to complexities and dynamics, and the mechanisms related to sustainability change*

- Supporting visualize interactions between different systems and their influence on sustainability.
- Supporting further inquiry and understanding of those interactions and complex dynamic patterns that can alter sustainability states[32]

<u>*The role of conceptualizing in sustainability observation*</u>

In order to reach evaluation, the actors who are involved in the process of evaluation, must pass through less visible steps of 'observation' and 'understanding'. As we indicated earlier 'understanding' is very much a subjective entity. Further it is closely linked to the initial step of observation. Compared to the understanding, the observation can be regarded as a step that has more intervening capacity, and also, that has choice embedded to in a more visible way. When it comes to interpreting sustainability, the observations can take either complex dynamics in to account or, they can disregard the complex dynamics and still make interpretations (that would lead to more refined evaluation of sustainability/unsustainability). In the same manner, the evaluation methodologies, methods and techniques can be conceptualized in a way that they explicitly make us be aware of our role as observers in the process of evaluation, or they can guide us through the evaluation process as completely detached entities. In this situation we may treat the situation with a limited comprehension. Both methods may have merits in different occasions; yet, looking at the highly complex and normative characteristic of sustainability, and its unavoidable basis on human interpretations, in the long run the first approach may hold higher merits.

[31] We would discuss sustainability principles that are explicitly recognized in academic literature of sustainability in the section three of the conceptual framework.
[32] An elaborated discussion on sustainability states is included in conceptual framework section I ad II .

2.4.5 Methodologies, methods, and techniques

As mentioned the key outcome of this thesis is a methodology. While maintaining the internal cohesiveness of the methodology with literature to identifying key principles of sustainability, the theoretical justifications aim to link these principles with complexity-based discussion. Therefore, in this sections some prominent methodological paths, which already in use in sustainability research, are explored in detail. In this regard, the methodologies that are utilized in observation and evaluation of sustainability are specifically considered.

Sustainability research involves simultaneous regard of multiple principles, multiple systems, and multiple normative and contextual factors. In academic point of view, these considerations needs to be equipped with methodologies that pay attention to the concept's philosophical, scientific as well as operational significances. Therefore when adopting a methodology, their underlying epistemological standpoints need to be thoroughly explored beforehand. The thesis is very much interested in complexities generated in the process of observation of human–natural systems. Therefore, not only being aware of multiple research methodologies and their theoretical basis, but also it is necessary to have understanding of, complexities linked to such observation process, limitations faced in adopting the existing methodologies as they are, possible other methodologies, and so on. Therefore, it is helpful to examine what is a methodology (beyond the obvious), and further what it is not.

The methodology often gets confused with the method and the technique. The former is less prescriptive than either of the latter. Wilson (2001) writes, "Methods and techniques to problem solving may best be described by the 'cookbook' analogy. Their characteristic is that they provide precise definitions of what to do, and, if followed, will produce a defined outcome. Methodology, on the other hand, will not guaranty a solution. The nearest equivalent praise is *'a structured approach'*. However it is an approach which require judgment; in terms of both application and structure itself. *A particular methodology is a set of guidelines that stimulate the intellectual process of analysis*. " He further elaborates that, "[...] in order to appreciate this last sentence, it is necessary to return (address) to the distinction between *'real world'*, i.e. the source of the problem or the problem to which the methodology to be applied and the *process of thinking* about the real world. […] It is in the latter domain that methodology resides. Techniques, methods, and methodologies are all ways of thinking about problems and hence represent structured ways of undertaking the intellectual process involved in analysis. It is only the degree of prescription that differentiates them. [...] In other words methodology is a description of how to think about the process of analysis prior to doing it. Hence the intellectual process of choosing concepts and deciding how they might be structured in a methodology is really concerned with thinking about how to think, an unusual process. It has the advantage however, that the resultant methodology is tailored to fit the particular situation, and the analysts know why they are doing what they are doing relate to what they will be doing next [...] given the great variety of (organizational[33]) problems, considerable flexibility must exist in the concepts and structures available to the analyst. Unless a particular methodology is assembled as a conscious part of the analysis it is unlikely that the changes and/or solutions identified will represent an effective output of the analysis. Additionally, a specific methodology needs to be explicit in order to provide a defensible audit trail from recommendations back to initial assumptions and judgments" (Wilson 2001).

Out of these observations, we can summarize several of key characteristics of a methodology as follows;

(i) A methodology has to be structured, and structure should be visible and should have the capacity to guide a thinking process

(ii) A methodology needs to be flexible

(iii) A methodology has to be explicit to provide a defensible audit trail

Being aware of them would be useful in the outset of developing a methodology. Paying attention to these aspects, we can ensure the replicability of the methods and techniques that the methodologies embody by an end user.

Comparison with Soft System Methodology (SSM)

At this point it is also worth to mention of the soft system methodology, which is developed by Checkland (1981) and Wilson (1990), mainly because the epistemological foundation it supports may have significant commonality to the methodology that is proposed in this thesis. However the end user of our one are slightly differing. The logical structure followed, therefore, also differs.

SSM methodology has some significant basis that is useful in sustainability analysis. This methodology was originally developed to incorporate multiple viewpoints of stakeholders in organizations. It aims to give a structured approach that can be adopted in multitude of organizations that are diverse in their practice. One of the key assumptions upon which SSM is based is; whatever the nature of the organization, it is possible to assume that the individual within it are pursuing purposeful activity, i.e., the purposefulness is one of the common goals of all of the organizations (Wilson 2001). The idea of purposefulness has significant

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[33] Note that even though the original text aims to describe a methodology that fits to organizational problem solving, as indicated earlier with the inherent complex dynamic nature of sustainability problems, the arguments raised here are equally applicable in the context of sustainability as well.

implications on sustainability evaluation. Whether the evaluations are intended for problem solving or planning, they all have the purpose of achieving some sort of sustainable conditions in the systems at the end. Checkland use the term *'holon'* to indicate systems that represent purposeful activities together with relationships between them (Checkland 1981; Wilson 2001). The idea of purposefulness also faces a challenge in conventional sustainability evaluation. Even though at the pragmatic end, sustainability can be argued as carrying a purpose or at least value orientations that imply a direction to it, in sustainability assessments, supporting such directionality could cease to be the main goal. Further, while SSM can be used to reach agreements between individual, especially by exposing the internal mental frames and by creating a platform for dialogue, the method in itself may not be enough to surface the complexities involved in the evaluation process at all levels in a systematic manner. This would be the case especially in a situation where the complexities are generated not by the stakeholders' different interests alone, rather the complexities tied to the human–natural systems being observed, to the complexities tied to the principles that informs even an unbiased observer, and also to the process of observation—which is closely linked to the observer's knowledge, mental-frames and multitude of other factors. Therefore, the implications from the soft system methodology are extremely useful for our own methodology, however would not be enough as themselves.

2.4.6 Theories and frameworks and their implication on sustainability evaluation

Pieterse (2000) denotes 'Theory is a critique, revision, and summing up of past knowledge, in the form of general propositions, the fusion of diverse views and partial knowledge in general frameworks of explanation'. In the case of developmental theory, which in the context the author speaks of theory, it refers to large explanatory frameworks, while this involved leading theories, and also had the characteristic that many rival and subsidiary theories do not quite make it the limelight (Pieterse 2000). Theory also is a distillation of reflections on practice in to conceptual language so as to connect with past knowledge. The relationship between theory and practice is uneven: theory tends to lag behind practice, behind innovations on the ground, and on the other hand, practice tends to lag behind theory with lack of scrutiny and reflection. Further, addressing the developmental theory, he brings out an interesting argument, that a theory to be significant, social forces must carry it. To be carried by social forces it must match their worldview and articulate their interest; it must serve an ideological function. He also goes on mentioning the trouble with the idea, that the explanation that satisfies a peasant is not the same as one that satisfies a landlord, a baker or IMF officer (Pieterse 2000, 2010). This may have been one of the reasons for his observation of leading few theories in the field, are the ones that got support from the action end. This particular observation is relevant for sustainability, as the field of sustainability also necessarily involve multiple different stakeholders and multiple different interests. One significant factor that could be recognized by exploring discourse of sustainable development vs. developmental discourse is that the former carries a necessity to see the complexity more than the later. While development has become an ideology, sustainable development or sustainability surfaces challenges in ideologies. In developmental ideology and also growth ideology, the complexities are already reduced by already selecting a purposeful direction. In sustainability often multitude of ideologies are met, clashed and transformed. By drawing attention to conflicting aspects such as the intergenerational and intergenerational fairness, one of the roles of sustainability awareness and inquiries is to draw attention to complexities on the ground, i.e., the conceptual, and ideological complexities. Therefore in sustainability it seems that rather than solid theories, the theoretical implications embedded in frameworks that engage the users of those frameworks become more valuable.

<u>Theories for observing complex dynamics</u>

As indicated earlier, sustainability is a concept for complex dynamic contexts. As very well elaborated by Morin (2008) with a simile of a tapestry, the observation of complexity involves three significant attributes. We have already addressed them in detail. Further, David Silverman, author of 'Doing Qualitative Research' observing his own experience as a researcher and practitioner remarks that policy makers and sociologists believe that social research driven by theoretical concerns can contribute to policy and practice. It becomes apparent that not only the part and whole relationships are significant in terms of observing complexities, the idea of part and whole relationship needs to be extended across different dimensions and scales, in this particular instance to encompass the problem and the targeting end solution/policy. The problems and envisioning multiple solutions act as parts the trajectories that combine these problems, solutions, and actions that connect them become wholes in achieving sustainability. Therefore when the evaluations are done in different stages of these trajectories, we should be able to recognize these complex relationships. In addition, the understanding gained by observing those parts and whole should go beyond the parts and whole to let new understanding emerge by dynamic interaction of information. *Therefore we can further deduce that understanding observing complexities involve at least three significant steps.*

(i) Decomposing the Complexity to parts

(ii) Analyzing the system according to decomposed parts

(iii) *Reflex and iterate the analysis process to reach new sustainability understanding that represents a complex dynamic whole*

This method of observation, through differentiation, analysis, synthesis may have roots in philosophical inquiry. In scientific academic literature the differentiation between analysis and synthesis method were originally made in the age of high scholastics (Bhatnagar and Kanal 1992). Scholz and Tietje (2002) refer to these earlier works and writes, "*Zeberrella's differentiation encompasses the whole field of science. On one hand, there are the synthetic contemplative sciences such as philosophy, in which knowledge acquisition and inquiry are stimulated through intrinsic motivation and holistic consideration. On the other hand, we find the analytic sciences, particularly mathematics and natural sciences. According to prevailing interpretation, mathematics starts with axioms and derives new knowledge by method of proof. In the natural sciences, analysis reveals hidden rules, such as natural laws that that underlie the natural cause-and-effect relationships and their phenomenology. Analytical methods are both inductive and deductive. The key to analytic methods lies in the principles of analytical decomposition, which makes it possible to explain a new invention through what is already known. Rene Descartes went further as considering analytical method to be the only true method for both philosophy and science. Synthesis on the other hand, as a method a method of contemplative philosophy is now part of the humanities and is often associated with pre-scientific categories of knowledge and direct experience [...]. Synthesis is considered as an philosophical approach to understand the essence of the whole*." (Adopted and modified from Scholz and Tietje (2002)). Their own proposing holistic case study approach integrate both these methods. While in the process of approaching the case studies, their method had been helpful, in addition to that, the conceptual framework, as would be indicated in subsequent sections, adapts a similar integrated approach, in this case, emphasized as, enabling the complexities of the context of observation to be properly translated in to sustainability understanding and evaluation.

2.4.7 Theory-based methodology in doing case studies

This thesis ultimately proposes a framework that can be utilised in preliminary sustainability observation and evaluation. When we say sustainability observation, it often involves an actual human–natural system. In other words, the framework that is proposed can be utilized as a methodology to do a case study in sustainability evaluation. The underlying argument is that the proposing theory/framework have the capacity to direct the observation process in the case analysis stage. Therefore it is necessary to explore the role of a theory in exploring a case, or in a deeper vein, doing a case study. For that exploring some of the well-known arguments laid by Yin (2003) upon case studies is helpful. He indicates that reliance on theoretical concepts to guide the design and data collection for case studies remains one of the most important strategies for completing successful case studies. “Such theoretical concepts can be useful in conducting exploratory, descriptive, or explanatory case studies. [..] The goal is to develop a preliminary concept at the outset of a case study. One purpose of such concept is, as in other empirical studies is to place the case in appropriate literature, so that the lessons of the study will advance the understanding of a given topic." (Yin 2003) Further, he recognizes six different types of case studies, placing them in a 2×3 matrix. First case-study research can include *single-case study* or *multiple-case studies;* second, whether single or multiple, the case study can be exploratory, descriptive, or explanatory (causal). A single case study focuses on a single case only. While multiple case studies include two or more cases within the same study, they are selected in a way that they replicate each other-either predicting similar results or contrasting results (literal replication) for predictable reasons (theoretical replication). An *exploratory case study* (whether based on single or multiple cases) is aimed at defining the questions and hypothesis of a subsequent study or at determining the feasibility of the desired research procedures. A *descriptive case study* presents a complete description of a phenomenon within its context. An *explanatory case study* presents data bearing on cause-effect relationships explaining how events happened (Yin 2003). In this regard the case study selected for this thesis comes under exploratory case study, where the theoretical argument based framework is explored for its practical application. Please refer to Yin (2003, 2012) and Baxter and Jack (2008) for a further description of explanatory and exploratory case studies.

2.4.8 Case-based theory generation

Eisenhardt and Graebner (1989) writes "Building theory from case studies is a research strategy that involves using one or more cases to create theoretical constructs, propositions and/or midrange theory from case-based, empirical evidence. Case studies are rich, empirical descriptions of particular instances of a phenomenon that are typically based on a variety of data sources. The central notion is to use cases as the basis from which to develop *theory inductively*. In this instance the theory is considered as emergent in the sense that it is situated in and developed by recognizing patterns of relationships among constructs within and across cases and their underlying logical arguments. The major reason for the popularity and relevance of theory building from case studies is that it is one of the best (if not the best) of the bridges from rich qualitative evidence to mainstream deductive research. Its emphasis on developing constructs, measures, and testable theoretical propositions makes inductive case research consistent with the emphasis on testable theory within mainstream deductive research […] Further with them it is possible to observe that the inductive and deductive logics are mirrors of one another, with inductive theory building from cases producing new theory from data and deductive theory testing completing the cycle by using data to test theory. Also they emphasize that when using the direction of case to theory as a research strategy, researchers also must take the added step of justifying why the research question is better addressed by theory-building rather than theory-testing research. In addition to clarify why the research question is significant, and why existing theories fail to offers a feasible answer, they argue that it is also critical to convince readers that the research question is crucial for organizations and/or theory, and demonstrate that the existing research either does not address the research question at all, or does so in a way that is inadequate or likely to be untrue. For theory-driven research questions that extend existing theory [...], a researcher has to frame the research within the context of this theory and then show how inductive theory building is necessary" (Eisenhardt and Graebner 1989). One significant occasion where theory-driven case method being utilized is the grounded-theory research approach. The objective of building theory from cases is the theory itself. But unlike in hypothesis-testing research, there is no specific template for writing emergent theory in theory-building research. The procedure is not as straightforward. Also since different readers have their own preferences, the ways of formulating the theory can easily be questioned. A more subtle challenge arises from confusion about the meaning of "grounded theory building." Langley (1999) noted, for some scholars, grounded theory building simply means creating theory by observing patterns within systematically collected empirical data. This view often includes some notion of recursively iterating between (and thus constantly comparing) theory and data during analysis, and theoretically sampling cases (as described earlier). In this view, the quality of the theory and the strength of its empirical grounding are more central to research quality than the specifics of the theory-building process. That means it is important to further differentiate between the exploratory case study, cause and effect illustrative case study and the grounded theory.

Grounded theory approach

The emphasis of general grounded theory is that it is good for new theory development. In keeping with the principle that theory evolves during the research process itself and is a product of continuous interplay between data collection and analysis of data. Unlike many other methods, the grounded theorist does not wait until all the data are collected before analysis begins; rather, the search for meaning through interrogation of data commences only in the stage of data collection.

Among exploratory case study, cause and effect illustrative case study and the grounded theory, in the first two instances, theory supports the case while in the latter the case supports theory. However it is also noteworthy that, just as hinted in the description of exploratory case study by Yin (2003), a case can easily start to play roles in both ways. If one is not clearly aware of the theoretical process and the main purpose of the case, the process can become miss-directed.

In contrast, in phenomenon-driven research questions, where context and data are slightly special in character a researcher has to frame the research in terms of the importance of the phenomenon and the lack of plausible existing theory. Here the research question is broadly scoped to give the researcher more flexibility. The justification rests on the phenomenon’s importance, and the lack of viable theory and empirical evidence (Eisenhardt and Graebner 1989). Contrasting to case driven theory, phenomenon-driven theories seem to give the researcher more freedom to move between different contexts.

In the early stage of methodology building, this research also considered the grounded theory approach for a number of reasons. The exploratory nature of the thesis is a prominent one out of them. As Scholz and Tietje (2002) indicated there are different types of research approaches depending on how far the problem and solution can be defined prior to field research.

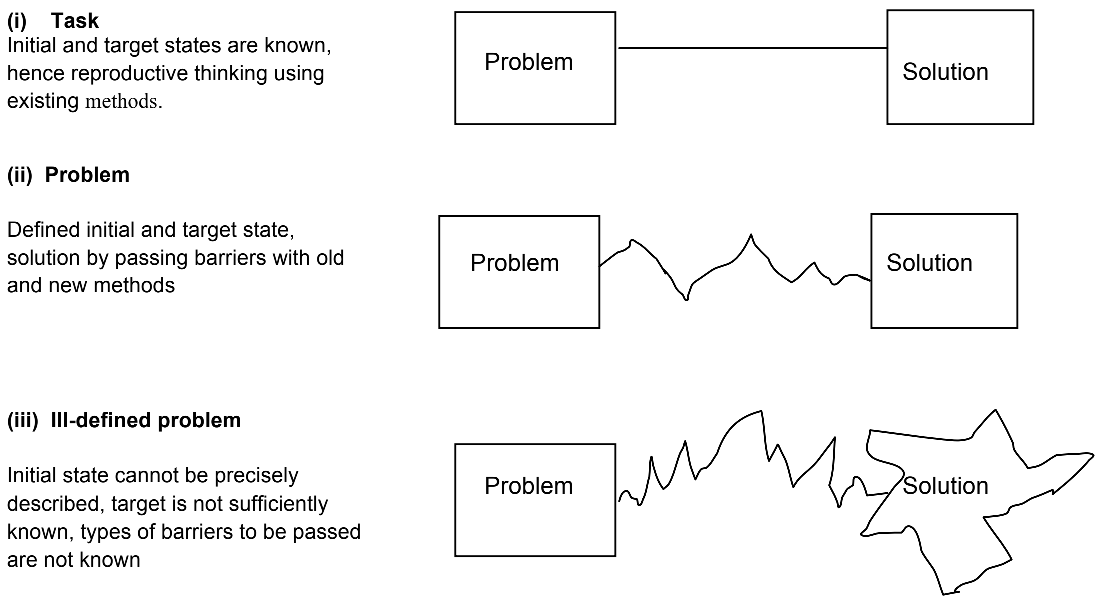

Fig 1. Interpretation of problem and solution space: adapted from Scholz and Tietje (2002), originally appear in Satanarachchi and Mino (2009)[a]

In their narration, while the original interpretations of problem and solution space were focusing on action research, the epistemologies that were highlighted spreads beyond action research alone. In the case of sustainability research, the evaluation or a decision about sustainability shows diversity at a specific time and also change across time. In addition the systems' intrinsic conditions where such evaluations and decisions are made also show similar diversity and change. This idea leads us to argue that sustainability needs to be regarded as a process than an end point. The process thinking suggests that the end is always ill-defined, or avoiding the impression of error, can be regarded as a continuously changing characteristic of a system. In this situation in order to start observing the systems without having a very clear theoretical framework about what sustainability, how to indicate / measure it etc, it appears as justifiable to let the theoretical understanding emerge from a specific system itself, so that the context specificities of the system is appropriately captured. As discussed the grounded theory approach is one well-known example where the idea of theory being stemmed up from context specificities is deeply embedded in it. However, just as many researchers faced when adopting the grounded theory approach, the generality of a framework built entirely upon thick descriptions of one case is always limited. Even if comparative analysis between multiple cases would be adapted later on, it is difficult to place a proper scientific ground for a theory entirely built from a specific case. Even more significantly, in the case of sustainability interpretations, theoretical understanding stemming from the direction of context alone exerts an additional limitation that is linked to the boundaries–one of the key concepts discussed in this thesis. When we isolate a specific context, systems, and subsystems to be observed in that context, we automatically draw an imaginary information based boundary. However sustainability, necessarily being an evolving concept, and being influenced by observations made across multitude of boundaries, tends to make the theoretical developments from the ground a complex process than in the usual case. In other words sustainability necessarily requires us to treat the systems (in our case human–natural systems) as a complex one and also to a certain extent a fuzzy–bounded one.

According to Healey (1998) the environmental discourse, which still can be regarded as the parent or the key underlying discourse of sustainability, has four main narratives namely; (i) Environment as a 'stock of assets' (ii) Environmental systems and carrying capacity (iii) Environment as our world (iv) Environment as a cultural conception. These and similar other narratives have shaped the way sustainability is discussed in different contexts creating pluralistic views around it. Also over the years sustainability discourse seems to have faced the need to distinguish itself from these other disciplines by organizing its own conceptual features. In such a situations usually grand narrations could be considered. Meppem and Bourke (1999) writes, " *The aim of promoting a reflexive grand narrative for sustainability is to promote the consideration of the environmental debate as a contested space based on* *conflicting stories. A grand narrative refers to a dominant worldview or a belief system, which permeates all social interaction justifying, reinforcing, and moulding change. Each sustainability narrative is taken to represent a broad sectional interest group. This discursive approach aims to place each narrative within a broader historical context in a bid to reveal their underlying belief systems and value sets. These stories describe different worldviews of common concept*" (Meppem and Bourke 1999). Such debate about the role of theory in sustainability studies, and what it should do and should not have been debated over the years and still continues. Further, it seems that there is no consensus of how the theoretical inquiries can supplement the pragmatic end of sustainability. In our understanding, even though grand narrations or theories may not fit a process of observing or analysing complex phenomena as that are found in sustainability, still, a complete void of theoretical base could also lead to negative conditions such as leading to the extreme relativity. Such a situation would harm the process of dialogue between stakeholders. Even for individual understanding, without one or few significant common guideline/methodology that run within the whole of the inquiry process that one would adapt, the conclusions derived could easily become add hock and inconsistent. At the same time, as indicated previously, such a methodology must not be totalizing and aim to explain everything as such characteristics would contradict the basic principles of sustainability, predominantly the plurality of views. Therefore going back to the very definition of methodology and exploring some of its prominent implications in sustainability evaluation can be useful.

2.4.9 Method vs. Meta–method

When discussing methodologies it is important to note the differentiation between methods, meta–methods, and meta–synthesis as all these three are followed in similar situations, and confusions could arise if not properly differentiated. In this thesis, the outcome of the study in itself is presented as a methodology. Yet it is necessary to be aware of the method/methods that run through the thesis to reach the methodology. Meta–method is the study of the epistemological soundness of the existing research, as well as the ways the methodological applications may have influenced the findings that are generated. Meta–method includes (a) examination of "methodological presuppositions necessary for carrying out" the research (b) evaluation of the research methods in terms of weaknesses and limitations, and (c) codification of new procedural norms for research in the area. Meta–synthesis on the other hand is considered as a relatively new technique for examining qualitative research (Jensen and Allen 1996; adopted from Walsh and Downe 2005). Qualitative meta–synthesis refers to the amalgamation of a group of qualitative studies. The aim is to develop an exploratory theory or model, which could explain the findings of a group of similar qualitative studies, whereas, meta–analysis of quantitative studies aims to increase certainty in cause and effect conclusions in a particular area.

2.4.10 Techniques in visualizing complexities

Observing the complexities and reaching understanding often are tied to both objective knowing and the subjective experience. The subjective potion is the one that is challenging when we try to come up with a methodology that supports the observation process. The examples that we discussed earlier to explain complexity give description of the outcome of one such technique—in this case employed by each observing individual (e.g. tapestry and the bird–eye view). However there is minimum information, especially in scientific and scholarly literature on the ways to actively engage visualizing methods to observe complexity. One visualizing technique could be the layers. In the mapping process we often utilize overlays to demonstrate different signifiers in a map or a picture, often obtained through a bird-eye view. The separation of a complex unit to layers engages placing entities in separate distances.

Another visualizing technique could be the use of dimensions. A dimensional view-based method, in one way, could function as a technique to map a certain space by highlighting prominent boundary factors. In another way, they also could function as a technique to aggregate indicators. In this situation, dimensions can give a directional value basis to the mapping process. Using dimensions to represent complexities around sustainability in terms of both structure and functions of the systems have history that goes to early developments related to environmental impact assessment (EIA), although EIAs (Wathern 2013) are not widely recognized as a sustainability assessment tool. Further, well known conceptual interpretations of sustainability (such as three pillar or sometimes referred as three dimensional approach to sustainability) has taken dimensional approach. Terms as pillars, axis, and boundaries are used alternatively with dimensions. Specially in era of transition from 'environmental issues' to 'sustainability issues', what are necessary in recognizing in sustainability has been discussed under key non-independent and interrelated dimensions in general sense, and some have explicitly named them as dimensions instead of criteria. On the other hand, there have been the scientific inquiry for measuring sustainability, where more emphasis given for criteria of sustainability. Once again, depending on the specific problem, the criteria with high weight have been changing from one study to next, hence the indicators that have come up also shows such differences. It is important to note the differentiation between category and dimension. The dimensions are not independent, but rather have close relationship with one another, while still showing some form of difference that allow to absorb such feedback and interactions better than an approach that gives too much emphasis on categories that aggregate different criteria would allow. Both category and dimensional approach have been adapted in sustainability indicators to illustrate the special variations (Simon and Bells 2001). However very rare attempts were made to incorporate the changes that take place in those dimensions over the time, and combine those changes in to a more complex dynamic indicator approach to evaluate sustainability of a system. One instance where indicator view and complexity view were aggregated is the AMOEBA approach that adopts methods of semi quantification and illustration of complexities around sustainability (Wefering 2000). Further, even though not explicitly used the term dimension in their methods, a similar way of structuring the existing or perceived problem can be found in Environmental Impact Assessment (EIA) Methods. Specially Matrix approach that some of the EIAs use, and particularly Strategic Impact Assessment (SIA) proposed by the EU to a certain degree adopt both dimensions and attributes in their methods. EIA and SIA have functioned as overarching methodologies that rely on variety of methods and techniques in different stages, such as, indicators, matrix methods and soft system methodologies and many other qualitative and quantitative research tools. The dimensions also have been employed to aggregate indicators in several of sustainability assessment tools. Usually it is observed that these processes of recognizing indicators have taken a bottom up approach, that is first coming up with a group of indicators that can be clustered together to eventually form cohesive macro indicators, (which sometimes would be refereed as dimensions). Though it is a bottom up approach, it is noteworthy that the bottom or the foundation is often to incorporate different principles of sustainability. However, due to increasing complexities observed in sustainability, recognizing the indicators have been a tedious task, and also it appears that, due to the static nature of data, techniques, method integration etc in these early methodologies, they have failed to capture the complex reality on the ground. Lazarsfeld (1958)[34]; cited in Boulanger (2008) acknowledge this aspect clearly when he highlights that the dimensions bridges the conceptual understand with more concrete measurements.

[34] Lazarsfeld P. (1958). Evidence and inference in social research, Daedalus, 87 (4)., 99–109.
2. Boulanger (2008), 1-1 Sustainable Development Indicators: a scientific challenge, a democratic issue, available online pn; http://sapiens.revues.org/166

2.5 END-DISCUSSION AFTER LITERATURE REVIEW

The above exploratory and explanatory literature review attempts to capture the existing concept based dialogue in the interface of complex dynamics and sustainability. We have examined several key areas where the changing nature of systems in sustainability analysis, assessment processes, or in simplest sense in sustainability assessments are highlighted. It is possible to see that these are not significantly different approaches, especially in terms of their conceptual basis in addressing complex dynamics linked to sustainability. The similarity lies in the understanding that general idea of complexity and dynamic nature of the systems is significant in sustainability assessment. Sustainability assessment as indicated is strongly rooted in the idea of complexity. The difference lies in their end objectives or methodologies they adopt, and also occasionally in type of data they use in those methodologies. These differences enable some points to be highlighted and further examined. Also just as in the studies it was recognized that these different approaches themselves have generated and strengthened the understanding that, there could be multiple pathways for a system, which can both describe and create sustainability/unsustainability scenarios. [I use the terms describe and create, with intension. It is possible to note that among the explained methods, and frameworks, some of them focus on interpretation of sustainability, focusing on principles, models of explanations, while others, beyond explanation, focus on a target change in the system. The understanding of sustainability is already pre-determined for a present or future state in these instances, and they incorporate dynamic understanding to propose methods and directions. In this situation beyond observation the agency, intension, creation also become prominent attributes. In my understanding both these branches are equally significant]

Finally, it is important to explicitly explain the tem *interface* (*interface of complex dynamic and sustainability*). As we earlier discussed, the complexity and dynamics have close interrelationship, therefore we refer to them here as complex dynamics. Also we discussed that limitations may have a role to play in this interrelationship. From the outset we mentioned that sustainability of a system is very much linked to complex dynamics. After an in-depth exploration of complex dynamics with relation to human–natural systems and to the observation process, it is apparent that the two concepts certainly overlap. Further, it seems that complex dynamics may have the capacity to generate sustainability/unsustainability conditions in the systems. In addition these complex dynamics seem to influence our interpretations of sustainability of our systems, through the observation and understanding process. This means not only in reality but also in a virtual sense sustainability/unsustainability conditions could be borne and changed by the complex dynamics. And such relationships as we saw necessarily involve non-linear feedbacks. Because of these possibilities, we use the term interface of complex dynamics and sustainability to interpret the conceptual territory that we explore in our study.

2.6 RESEARCH NEED AND OBJECTIVE

(A SUMERRY)

Out of the limitations and challenges that we discussed in sustainability evaluation in the pervious section, followings points can be highlighted,

First, whether it is for planning or problem solving in human–natural systems there is a strong need to take in to account the idea of change and continuation. Such change in different forms and degrees. We also observe that, in a deeper level sustainability of a human–natural system could not be properly comprehended, without relating it with complex dynamic nature of these systems. In this regard we need to have not just a general understanding of the complexity and the changing nature of systems, but a more comprehensive understanding of the complexities and dynamic patterns of change in those systems.

Second, in the face of complexity, sustainability evaluation in these systems faces the challenge of incorporating the two ends of the holistic and the context specific understandings that we have of these systems. Often specific but not representative enough interpretations of sustainability, or on the other end, too much simplified or too generalized interpretations can easily occur. These limitations are also visible in methodologies and techniques that we as researchers and practitioners incorporate in sustainability evaluation. Most of the frameworks, methods, techniques that we use would allow us to gain generalized overview ideas that aim to reduce the complexities. Or else, in contrast they would allow us to conduct deep analysis of parts, specific processes that highlight individual aspects of complexities. Such frameworks address complex relationships in systems that they are specifically concerned with. Each approach goes deeper in a certain specific direction. This feature can be regarded as contributing for the strength of sustainability. However extensive focus on complexities hence diversities of system specificities has created difficulties in actual planning, problem solving activities, However due to the fact that the highlighting points are differing, in conceptual, as well as application level they also face the risk of alienating from one another, which makes a preliminary assessment/decision making process adapting these different scattered but significant frameworks in the very outset of sustainability assessment to be problematic, and further to lead towards an extremely 'relativity' situation. While those conflicts have also paved the path for new methodologies and techniques (E.g. transdisciplinary approach, and strategic sustainability analysis processes, aggregated indicators) to address sustainability in these systems, these approaches still stay as scattered and optional techniques in scattered steps in sustainability evaluation. Focusing on human–natural systems' complexities (and dynamics) alone, or merely bringing together different ideas, expert knowledge or stakeholder views—as most of these techniques would support—would not capture the real essence of complexities that are relevant to sustainability. One significant reason is that, we do not have an assessment process that would enable us to reflect on our own understandings and the interpretations we make about sustainability

And third, which became apparent in the process of first two points, is that sustainability evaluation at the end would very much depend on the 'observation', which is one step before the understanding. We saw that there is a close interlink between the observation and evaluation, yet this is not easily visible. Complexities in 'observation' is often disregarded, even though we often address the result of observation of complexities through stakeholder agreement, brainstorming, theoretical justifications/debates, and so on. In order to capture the complexities in observation, we still lack observing methodologies (here it is re-emphasised that often we acquire methods and techniques, however not methodologies) that could surface multiple sustainability interpretations. Therefore an evaluation process that pay attention to complex dynamics, beyond a general sense, but in a much more conceptually rigorous manner, still remains a challenge.

When it comes to these points, we have recognized that there is a gap between conceptually recognizing the importance of complex dynamics and translating that recognition in to methodologies, methods, and techniques. One reason we identified is because the existing frameworks, methods, techniques are scattered in their emphasising points. Another reason is that, many of these evaluation methods and techniques do not seem to treat sustainability as a process that actively engages the evaluator. Further to simplify such an evaluation process, we recognize that it is very much necessary that it to be built upon techniques that are compatible with one another. In this regard, systems thinking and systemic way of observing sustainability could be supportive. Frameworks that adopt systems view-based methods would make it easy to visualize complex dynamics, therefore could structure the observation and evaluation process. However because of the very nature of complex dynamics, it is also noteworthy that such frameworks should not be a totalizing or truth promising ones, but supportive entities that can guide the steps in sustainability-evaluation. This also demands the framework to be a flexible one, which has a balanced amount of generality and specificity.

In this thesis, we want to explore if we could develop a framework that adhere us to pay attention to complex dynamic nature of human–natural systems, and the process of observing sustainability in them, that would in tern would enable us to make more accurate evaluations by exposing especially the dynamics related to sustainability[35]. If those were possible the methodology supported by the framework would have clear influence on defining a system's future sustainability/unsustainability path.

Considering these factors the thesis aims to propose a conceptual framework that can be utilized to observe and evaluate sustainability in a human–natural system. In the process it also aims to explore the idea of sustainability dynamics, and to explore means with which complex dynamic understanding of sustainability could be effectively integrated to evaluations.

The overall framework is developed in three main steps. They are summarized as follows.

<u>I. Initial conceptualization of suitability boundary, sustainability path and sustainability sphere</u>

Here we aim to explore with which metaphors we should address the sustainability of human-natural systems. To translate the understanding in to a sustainability evaluation technique, as a novel approach we aim to proposed to visualize sustainability as a path that connect multiple sustainability states over the time. The boundary of the path that signifies sustainability/unsustainability conditions would be visualized as sustainability sphere (*Keywords- sustainability state, transition between sustainability states, sustainability path, sustainability sphere)*.

<u>II. Foundational framework to observe and evaluate sustainability in a complex dynamic context (In a temporal stable state)</u>

The foundational framework is intended to illustrate general patterns and mechanisms of complex dynamics involved the process of observing sustainability of human–natural systems in a relatively stable temporal state, and to internalize them to an observation method that enable us to make sustainability interpretations and evaluations. For this we hold that looking at not just parts but comprehensive wholes is one of the key requirements to properly observe complexity. We aim to utilize two significant streams of literature, (i) literature describing basic theoretical arguments of complexity, complex dynamic systems, observing complexity in human–natural systems (ii) literature describing general principles of sustainability.

(Keywords- sustainability state, context, focus system, background layers, sustainability boundary, multiple sustainability boundaries)

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[35] As discussed at several place, when it comes to human–natural systems, and to sustainability in general as a concept, dynamics and complexity could not be separated easily. However the changing patterns also could look independent and also may attract our attention individually due to the fact that their individual impact are more visible. However, beyond the general interpretation of dynamics as changes identifying their patterns, mechanisms and aspects that generate and influence them, we could further understand the nature of sustainability changes, therefore may be able to influence our systems in a positive manner. The interlink of complexity and dynamics may provide a basis for understanding such patterns and mechanisms further.

III. Macro framework to observe and evaluate sustainability in a complex dynamic context

In this section we aim to strengthen the foundational framework for its specific sustainability/unsustainability defining capacity. For that we aim to propose a set of dimensions that are based on sustainability principles and context specificities, to gain specific sustainability/unsustainability knowledge of the system. Further we aim to strengthen the framework's capacity to look in to not only the complexities across space but also the complex dynamic patterns across time and organizing relationships that would enable a system to persist, change, and transform. *(Keywords- dimensions, dynamic sustainability boundaries, sustainability sphere, driving force, feedback)*

Finally, in order to further illustrate the framework and to show its implications for sustainability evaluation and planning activities, we aim to support the framework with two case studies. The first case study is dealing with a global level unsustainability issue. We aim to explore the events that led to recognize the issue and solutions for it. The second case is dealing with a local level socio-ecological system that faces several of unsustainability issues. We aim to explore the system's sustainability/unsustainability changes over the years. In both instances we aim to interpret multiple sustainability contexts, boundaries, and changes to those boundaries. In addition to demonstrating the applicability of the framework, with case studies, we also intend to recognize what triggers sustainability/unsustainability change in those particular human–natural systems by exploring their intrinsic complex dynamic characteristics and changing patterns, to see if they would have special implications for their future sustainability.

3. CONCEPTUAL FRAMEWORK

A FRAMEWORK TO OBSERVE AND EVALUATE COMPLEX DYNAMICS LINKED SUSTAINABILITY IN HUMAN–NATURAL SYSTEMS (SECTION I, II, III)

"The systems approach provides a multidimensional framework in which information from different disciplines and domains can be integrated without being forced in to a one-dimensional mapping. It entails considering various agents interacting in the world as systems, involving invoke of general principles concerning systems to make inferences about likely and actual interactions between the systems under consideration, and to analyze observed patterns of interactions. (Clayton and Radcliff, 1996)"

Giving attention to complex dynamics involved in the process of observation (and subsequent interpretation) is essential for sustainability evaluation. Much of the debate and criticism over holism and reductionism upon which the foundational arguments of the epistemological standpoints of sustainability is built upon address such observation related complexities. However often these debates fail to address some of the prominent and non-negligible implications of complexity and as a result, the sustainability evaluation frameworks seem to have still failed to capture the complex dynamic nature of the concept in itself. Addressing these, this section aims to develop the conceptual basis of a framework to evaluate sustainability, by giving attention to patterns and mechanisms of sustainability change to equip it with the ability to guide a user to recognize these patterns and mechanisms.

3.1 FRAMEWORK OVERVIEW

The framework is developed to address multiple sustainability contexts and evaluation basis that are relevant to gain a holistic understanding of sustainability of a human–natural system. For this we explore the complex dynamic nature of those systems and the complex dynamics linked to the process of observation and evaluation of sustainability in them. In other words the interface of complex dynamics and the sustainability have been the focus in the process of developing this framework.

Since human–natural systems are subjected to complex dynamic changes which include both spatial, and temporal dynamics, as a preliminary hypothesis it is suggested that the sustainability/unsustainability of these systems need to be regarded as a dynamic process, and appropriate to visualize beyond a certain desirable state to be reached, which often is the case with most of the sustainability practices. Such static form of regard around the discourse, as we saw, is reflected in the approaches adapted in indicator developments, policy recommendations and implication, as well as forming visions for new infrastructure, cities, societies etc.

Addressing these aspects in this chapter we propose a framework for sustainability observation and evaluation, which is divided in to three main sections. In these sections, framework's development processes, as well as its main features are explained in detail.

<u>Section I: Initial conceptualization of suitability path and sustainability sphere</u>

Overview: Initial conceptualization is based on literature review on, discourse of sustainability, human–natural systems, challenges in preliminary sustainability assessment, existing frameworks, and their focus on complex dynamics and contextual significance.

As a first premise we argue that more than a state with which the system ought to be recognized, the sustainability of human–natural systems needs to be regarded as a continuous process that evolves along with the systems. To translate this understanding in to a sustainability evaluation technique, as a novel approach, sustainability is proposed to be visualized as a path that connect multiple sustainability states over the time. The boundary of the path that signifies sustainability/unsustainability conditions is visualized as sustainability sphere.

Keywords: sustainability state, transition between sustainability states, sustainability path, sustainability sphere

<u>Section II: Foundational framework to observe sustainability in a complex dynamic context</u>

The foundational framework is intended to illustrate general patterns and mechanisms of complex dynamics involved in observing a human–natural system's sustainability state.

Two significant streams of literature, (i) literature describing basic theoretical arguments of complexity, complex dynamic systems, observing complexity in human–natural systems (ii) literature describing general principles of sustainability, were utilized. Human–natural systems are considered as complex dynamic, open systems that have system–subsystem relationships as part and whole relationships. It is argued that, with relation to a particular system in one temporal state there are multiple sustainability boundaries. Recognizing them involves recognizing (a) multiple facets of sustainability (b) complex dynamic nature of systems (c) complex dynamic nature of cognitive process in observing sustainability. Further we suggest that interchanging the 'focus’ and the 'background' that form environment could indicate multiple sustainability boundaries. This involves a reflexive and iterative observing and understanding process

Keywords: sustainability state, context, focus–system, background layers, sustainability boundary, multiple sustainability boundaries

<u>Section III: Macro framework to observe and evaluate sustainability in a complex dynamic context</u>

The dynamic nature of the boundaries of sustainability is the focus of the macro-framework. A set of general dimensions that supports in describing the interface of complex dynamics and sustainability of human–natural systems was proposed. The dimensions, namely, (i) sustainability–linked knowledge (ii) sustainability–linked worldviews (iii) resource limitation/availability (iv) well-being views (v) policies, rules, regulation, and governing practices (vi) new creations, innovations, and artefacts, are considered as relatively independent dimensions in terms of their role in forming and influencing the change in sustainability boundaries, still with mutual interaction collectively influence the sustainability path by supporting change within or transforming sustainability states. The mechanisms involved in emergence of sustainability understanding and forming sustainability related organizing patterns in systems, through positive-negative feedback processes and adaptations to new temporal states that allow systems to move between states, were discussed. It is recognized that patterns and mechanisms explained in the process of observing sustainability boundaries in a sustainability state also are important in observing transition between sustainability states related to these dimensions. Highlighting these and other patterns and mechanisms the final conceptual framework is proposed.

Keywords: dimensions, dynamic sustainability boundaries, sustainability sphere, driving force, feedback

3.2 METHODOLOGY

Section one of the framework is developed with the literature basis of complexity studies, with emphasis on observing complex systems. The direction towards complexity was selected identifying some basic loopholes in the conventional approaches in sustainability assessment in the face of complex dynamics. The literature review for this section included a review on existing methodologies for sustainability assessment, followed by a review on strict meaning of complexity, and complex systems. An intensive literature search was used with search methods by key words, reference, and cross-reference. In order to avoid extreme 'berry picking' (Bates, 1989) approach to literature review, several key themes were selected, which allowed the exclusion of noise to a certain extent and to give a verifiable capacity in building arguments. Several different databases, prominent journals, and prominent publishers were used to acquire papers and material with good quality. The most challenging part was to select an inclusive enough set of dimensions that can be used to represent the sustainability change of the systems, and to maintain the generality of them, while retaining their applicability in specific situations. The ability to scrutinize them further to select specific contextual dimensions was considered in for the selection. For this step, leading discussions in sustainability were followed (Further discussion on specific sources would be given under the section where the dimensions are discussed individually).

The methods followed in each sub section of the thesis differ from one another. They could be summarized as follows.

<u>Section I: Initial conceptualization of sustainability path and sustainability sphere</u>

(i) Literature review on discourse of sustainability, human–natural systems, challenges in preliminary sustainability assessment, existing frameworks and their focus on complex dynamics and contextual significance (illustrated in the exploratory and explanatory section).
(ii) Theoretical arguments for the basis of the proposed frame of understanding.

<u>Section II: Foundational framework to observe and evaluate sustainability in a complex dynamic context</u>

Two significant streams of literature were utilized, namely;

(i) Literature describing basic theoretical arguments of complexity, complex dynamic systems, observing complexity in human–natural systems.
(ii) Literature describing general principles of sustainability.

Section III. Macro framework to observe and evaluate sustainability in a complex dynamic context

The theoretical arguments in this section are mainly built upon the foundation placed by first two sections. The first part of literature review was mainly on the methodology itself, which included;

(i) Conceptual debate on ways to visualize sustainability/unsustainability
(ii) Significance of contextuality
(iii) Principles and indicators to represent patterns and mechanisms of changes.

The second part of review was to recognize dimensions, mainly as general principles of sustainability that can be used as aggregated variables to represent sustainability or unsustainability. Then a discussion is made with regard to patterns and mechanisms involved in emergence of sustainability understanding and forming sustainability related organizing patterns in systems, through positive-negative feedback processes, adaptations, and transformations to new temporal states that allow systems to change its sustainability states. Highlighting those common patterns and mechanisms the final conceptual framework is proposed.

Conceptual framework-Section 1:

3.3 INITIAL CONCEPTUALIZATION OF SUSTAINABILITY PATH AND SUSTAINABILITY SPHERE

Overview

As a first premise we argue that more than a state with which the system ought to be recognized, the sustainability of human–natural systems need to be regarded as a continuous process that evolves along with systems. To translate the understanding in to a sustainability evaluation technique, as a novel approach, we propose to visualize sustainability as a process (metaphorically indicated as a path) that connect multiple sustainability states over the time. The boundary of the path that signifies sustainability/unsustainability conditions for the system is visualized as sustainability sphere.

This section conceptualizes the sustainability state, the sustainability path, and the sustainability boundaries (visualized as a sphere) by laying down the underlying theoretical arguments. Also we discuss the benefit in visualizing sustainability in this way.

3.3.1 Complex dynamics in human–natural system evolution

3.3.1.1 Visualizing system interactions across space, time, and organization

In order to visualize sustainability as a path or a process, we highlight thee types of complex dynamics, namely, intrinsic dynamics, horizontal process dynamics, and long-term process dynamics. These are essentially dynamic patterns that are considered as significant in observation process.

(a) Intrinsic Dynamics

In general, the term intrinsic has been associated with internal movements and changes in different contexts. As described earlier, any of the systems that we could think in our surrounding, or even within ourselves, are essentially linked with other systems in a lower or higher level. For instance human body functions depend on number of other internal systems, such as the system of blood circulation, nerves etc, which again are arrays and patterns created by cells, whose functions further depend upon integrity of several other smaller entities. In other words, the functionality of the body will depend on the functionality of those of its subsystems. The higher entities' functions are influenced by the lower entities. The opposite relationship can also occur. These relationships expand beyond biological systems to other social systems, planetary systems, and even beyond. Similarly it is possible to see such relationships in systems that concern sustainability. The three systems of human, social, and global systems are sometimes visualized as one system enclosing the other, focusing on their interdependencies, physical territory etc. Such enclosing systems are referred as viable systems. A viable system is a system of complex entity capable of maintaining an independent existence—not an existence totally separate from an environment, but one where structural changes take place without loss of identity and without severance from a niche (Espinosa et al 2007). The dynamics that links with the viability of a specific system can be regarded as a main building block of **intrinsic dynamics.**

(b) Horizontal process Dynamics[36]

Just as system subsystem interlinks, the same system could essentially have numerous links with other similar ones in its outer environment that do not necessarily have viable relationship to it. The path which any of them will take relative to its surrounding or relative to its own dynamical axis, within higher dimensions of time and space, can be argued as determined by several stable states joining one another in the scale of time. These sates that would appear as being stable relative to longer time scale will have complex short-term interactions within themselves. These interactions will be linked with behavioural changes induced by short-term feedbacks, incentives etc. The noteworthy factor of these patterns of interactions is that they and their significance to sustainability can be observed only when one distance him/herself from both the system and its environment and then take a snapshot view of what is being observed. In other words the span of time when the interactions are observed is comparatively very small from the perception of time of sustainability of the considered system. In addition, this type of dynamics can be better visualized once the time lags between feedbacks are not fully considered (Satanarachchi and Mino 2009[a]).

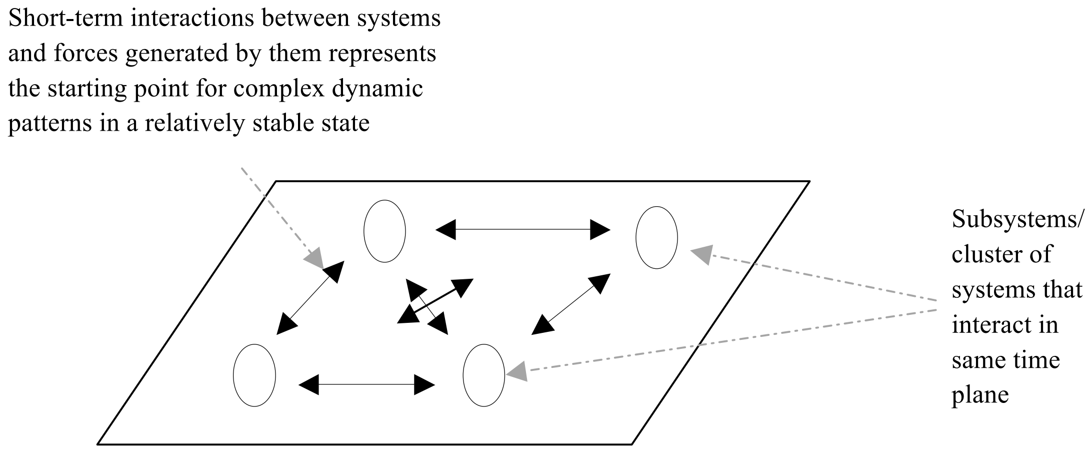

Fig 2. Visualizing horizontal process dynamics (Originally appear in Satanarachchi and Mino 2009[a])

Note: the plane represents a random system's particular state relative to time, and circles represent subsystems, or entities within the system. The interactions and triggers generated by interactions are identified as horizontal process dynamics

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[36] The terminology of horizontal and vertical has been earlier used by Ostrom (2002) and later Berkes et al. (1994, 2003) argue adaptive-co-management that links institutions both horizontally (across space) and vertically (across hierarchy).

The complex dynamics in spatial state is relatively easier to visualize. However complex dynamic interactions do not necessarily help to create sustainable conditions, as their effect may well support unsustainable conditions, or the conditions that can deviate a system's path away from the sustainability sphere in the long run. With the complexity of globalization many short-term interactions as information flows, market transactions can be observed spread across a flat plane. This flat plane could be the World Wide Web, stock exchange, or even a discussion taking place in a class room where a group of students trying to learn sustainability. Or it could be basic livelihood taking place over days, months or even years in a rural village.

In sustainability observation and evaluation, the horizontal process dynamics become significant for several reasons. As mentioned, the ability to observe these relationships in a horizontal manner depends on the ability to detach oneself from the system and to have a bird–eye view. In sustainability evaluation, often it is straightforward to focus on one system, subsystem, or a system entity and interpret its sustainability, without recognizing the effects of the relationship it has with its surrounding systems, subsystems, and entities. These interactions also are significant to understand the system behaviour, especially behaviours that are linked to its complex dynamic evolutional patterns. When visualizing horizontal interactions, the axis of time needs to be fixed while axis or plane of space alone would be scrutinized.

(c) Long-term process dynamics

Long-term dynamics on other hand are the movements or interactions that may attribute for evolution, progress, and adaptation over the time, of a particular system or a cluster of interlinked systems. These in fact are the ones that bring a system from one stable state to another along its path over the time. What makes the vertical process dynamics significantly different from horizontal process dynamics is their strong link with the time axis. The perception of time should be a strong consideration, to perceive evolution of any human, social, or natural system, whether they are considered distinctively separate from each other or regarded as intervened. These dynamics could be influenced by memory, learning, or knowledge progression. Or else some time they could be related to what we call as envisioning future, making targets etc where the feedback, signal, learning is received from a future state to a past or present state. In other words dynamics across time may consist of what is carried forward or even backward from each horizontal interactions and triggers they generate.

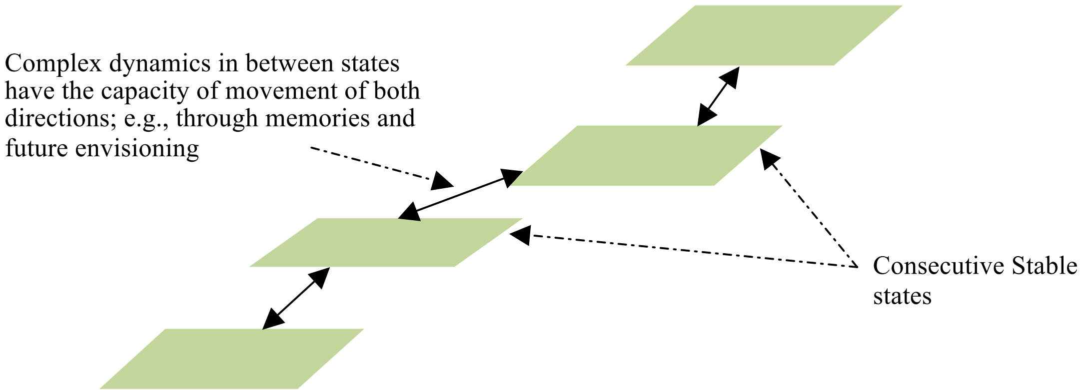

Fig 3. Visualizing long-term dynamics (Originally appear in Satanarachchi and Mino 2009[a])

Note: Each plane represents a random system's particular state relative to time, and what link two such states are observed as long-term process dynamics or the dynamics that change a system's state over time.

The long-term dependent complex dynamic processes of a system, or cluster of systems are the movements or interactions that may attribute for system's evolution, progress and adaptation over the time.

Additional note

These three types of dynamics are identified and differentiated based on their role in the process of observation. In otherworld these are patterns of changes that can be observed. Even though the patterns are related to the complex dynamics of the systems themselves, such complex dynamics are often interlinked. The above differentiation is based in seeing patterns in those interlinked complex dynamic changes. Also it is important to note that, in selecting above mentioned three categories, we have paid attention mainly to the visible patterns of complex dynamic changes, not strictly to the mechanisms involved, such as self-organizing. For the same reason instead of highlighting the complexity potion, we have highlighted the dynamic features.

3.3.2 Sustainability as a path

The dynamic understanding in sustainability as described here is strongly linked to the preposition that we briefly introduced earlier, that is sustainability of a system could be perceived as a path, instead of only a past or future state to achieve or a present state to maintained. Just as change and evolution is important for any existing socio-cultural or ecological system, there need to be well-adjusted balance between change and stability. This fact may lead to the preposition that any system we encounter would have its distinct path in time. This path may closely be related to its evolution. When perceiving a system's sustainable path its internal movements will take place due to both natural and man-made/influenced causes. In other words systems would have both natural and human induced factors that determine their evolutionary path. Sustainability in them is linked with either maintaining a certain existing characteristic or navigating the systems behaviours and functions till a certain characteristic or set of characteristics reach a desired level as being interpreted by the human system. Such desired level would change over the time. What would connect these desired levels or states over the time would form a path relative to those set of characteristics of the system. This process often takes a complex dynamic outlook involving complex dynamic interactions between its subsystems and with its environment. In addition to that, it is also noteworthy that, a path-based interpretation has a strong element of observation attached to it. It also embeds views of the observer that reflects his/her space and time perceptions.

3.3.3 Sustainability boundaries

A path-based view of sustainability naturally leads to another concept, i.e., the boundaries of sustainability. In a very simple sense, the term boundary is used to demark something from what it is not. In the understanding of sustainability, a sustainability boundary would mark what is sustainable and what is not sustainable. Therefore sustainability boundary means the enclosing conceptual line/surface that marks sustainability/unsustainability conditions for a particular human–natural system. Understanding of the surroundings with relation to boundaries is not a new attempt. As a concept, sustainability often addresses location-specific *facets of sustainability.* Examples of facets are development, growth, technological efficiency, environmental and cultural conservation, and ensuring socio-natural resilience. They represent prominent sustainability issues and their solution trajectories or sometimes positive or negative characteristics of human–natural systems that lead towards sustainable/unsustainable conditions. In addition, they indicate a set of paths towards the future. These paths form their own unique boundaries to characterize the sustainability of the human–natural systems they represent, and they therefore appear as different faces of sustainability.

On the other hand, the discourse of sustainable development and sustainability has been enriched with conceptual interpretations that are based more on the *explicit boundaries*. Traditionally, the very *idea of the sustainability boundary has been directly related to limitations*. Early dialogues focusing on the dependency of human functions on the natural resource base has addressed explicitly the *physical limitations* on Earth. They have brought out terminologies as *limits to growth,* which signifies an upper cap on the stresses on the global physical base (Meadows et al. 1972). The term *our common future* implied a future limited space in which the whole of humanity operates with these physical limitations. Additionally, the concept of the *ecological footprint* (Wackernagel and Rees 2009) has given a strong metaphorical representation and a quantitative basis to many of such physical limitations. Recently, as observed, stemming from ever increasing global catastrophes, *planetary boundaries* have highlighted the significance of being aware of physical thresholds, and also of the complex dynamics that can trigger rapid movements towards these thresholds (Rockstrom 2011). They propose a new approach to global sustainability in which we define planetary boundaries within which that humanity can operate safely. Planetary boundaries define, as it were, the boundaries of the "planetary playing field" for humanity to avoid major human-induced environmental change on a global scale. Here it is identified that there will be multiple planetary boundaries and transgressing one or more of them may be deleterious or even catastrophic due to the risk of crossing thresholds that will trigger non-linear, abrupt environmental change within continental to planetary-scale systems. They identify nine planetary boundaries and, drawing upon current scientific understanding proposing methods of quantifications for seven of them, namely;

(i) Climate change (CO_2 concentration in the atmosphere <350 ppm and/or a maximum change of +1 W m^{-2} in radiative forcing)
(ii) Ocean acidification (mean surface seawater saturation state with respect to aragonite ≥ 80% of pre-industrial levels)
(iii) Stratospheric ozone (<5% reduction in O_3 concentration from pre-industrial level of 290 Dobson Units)
(iv) Biogeochemical nitrogen (N) cycle (limit industrial and agricultural fixation of N_2 to 35 Tg N yr^{-1}) and phosphorus (P) cycle (annual P inflow to oceans not to exceed 10 times the natural background weathering of P)

(v) Global freshwater use (<4000 km^3 yr^{-1} of consumptive use of runoff resources)

(vi) Land system change (<15% of the ice-free land surface under cropland); and the rate at which biological diversity is lost (annual rate of <10 extinctions per million species).

(vii) Chemical pollution

(viii) Atmospheric aerosol loading.

They further estimate that humanity has already transgressed three planetary boundaries: for climate change, rate of biodiversity loss, and changes to the global nitrogen cycle. These planetary boundaries are considered as interdependent, because transgressing one may shift the position of other boundaries and cause them to be transgressed. The social impacts of transgressing boundaries will be a function of the social–ecological resilience of the affected societies they introduce the first estimations for rough form of boundaries surrounded by large uncertainties and knowledge gaps (Rockstrom 2011). Conceptually planetary boundary implies a safe space for human actions particular with innovations and developments. The mentioned are physical limitation the planet is facing. In addition it suggest a human-actions related limitation, that is, other than obvious physical limitations, the concept reflect upon the relationship of human have on their surrounding. This view of boundary, still somewhat lacks the attention to some of significant complexities that affect these boundaries. For instance the complexity exerted by our lack of understanding of how the available resources, the new ways of utilizing those resources, and also the way of observing the current problem situations with relation to past and future conditions may need further attention. However, it is important to note that planetary boundaries as interpreted above, implicitly suggests *a safe boundary for human actions* very well indicating the highlighted connectivity of human systems in a wider ecological setting.

Further, the discussions of boundaries are closely linked to sustainability's conceptual roots. Bells and Morse (1999) identify two six roots of modern view of sustainability, namely;

(i) Biosphere Root

(ii) Resource/ environment root

(iii) Ecological carrying capacity root

(iv) Critique of technology root

(v) No-growth slow growth root

(vi) Eco-development root

Out of them to discuss further on the indicators, they identify the ecological carrying capacity and the technology as key bases of sustainability.[37] Carrying capacity highlights the importance of being conscious of the relationship human have to their nature, in terms of dependence, exploitation, regeneration etc.

The notion of boundaries formed by ecological limitations carries broader implications. In them, to identify physical boundaries are more common and easier. However, the limitations do not remain in physical forms alone but rather extend to biological forms, and especially to human-related forms that again include not only the readily visible boundaries of technologies and institutions but also those of knowledge, views (Hartmann 1991)[38], capacities (Sen 2009), wisdom (Sternberg 1990), aesthetic sensitivity and so on. Obviously, they lie in multiple trajectories. Unlike physical limitations, which mark clear thresholds (especially in the case of viewing the world as one planetary system), the other limitations tend to be those that can be overcome, or at least, those that can reach a stage where they are no longer regarded as limitations (e.g., new knowledge, different levels of understanding, and capacity (Sen 2009)). Additionally, some are easily recognizable and communicable while others, like wisdom and views, tend to be subtler and may not be easily recognized as limitations. Even further, our very understanding of concepts such as aesthetic sensitivity (Bateson 2000; Kagan, 2010, 2011) and their roles in the perception of system interlinks is quite limited.

Even though it is difficult to clearly differentiate these groups of boundaries, we could roughly categorize them as *soft* and *hard boundaries of sustainability*. In terms of qualities such as ready visibility, tangibility, and quantifiability, there is a spectrum from soft to hard. For both types, one important common implication is that all the boundaries strongly influence the very ideas of our well-being, justice, the ways that we perceive the integrity of surroundings and, as a result, our reactions to stability and change in all living systems.[39]

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[37] Carrying capacity is the notion that an ecological system (eco system) can only sustain a certain density of individuals because each individual utilize resources in that system. Too many individuals result in overshooting of carrying capacity resulting in overuse of resources and ultimately collapse of the population (Bells and Morse, 2003). The idea of Maximum sustainability Yield (MSY) is a related concept, which implies a sustainable utilization of resources. It is understood that when MSY is exceeded, perhaps because of population increase or simply because of greed, then the system may collapse with negative consequences for those depend upon the resources.

The significance of carrying capacity in sustainability is well apparent it being a central concept in ecology, where the earliest discussions in sustainability has been formulated (Meadows et al. 1974) related to the above identified roots is that it is in fact in the hear of the other five roots, which brings out the importance of carrying capacity or in closer sense the resource availability or limitation of a certain context to be considered as one of the key elements of sustainability.

[38] Within the term view, beliefs and mindsets are also included.

[39] The general understanding of 'sustainable development', which became popular with Bruntland's report (1987), aims at a development of human societies that would achieve "the reconciliation of social justice, ecological integrity and the wellbeing of all living systems on the planet Earth" (Moor 2005, p.78). Further there are studies on specific directions such as ecological integrity (Pimentel, 2001)

Our awareness of them heightens our understanding to a next level where limitations often in the form of recognizing new unsustainability issues would continuously change how we perceive sustainability in these systems.[40] Explaining how each and every one of the boundaries and many other interrelated factors are linked with *boundaries of sustainability* warrants a deeper and extended discussion. Still, by mentioning them briefly here, we intend to bring forth the fact that, beyond physical and already well understood forms of ecological limitations, the concept of sustainability boundaries draws multiple other implications from other boundaries relating to human systems (such as boundaries linked to individuals, societies, organizations and networks), and the sustainability boundaries are not always readily visible. These boundaries themselves can be regarded as different types of systems, as they are heavily interconnected with various types of relationships (e.g., physical, biological, behavioural, and cognitive relationships) forming complex dynamic systems (How this happens will be explained in subsequent sections.) They sometimes merge and are sometimes highlighted, subsequently influencing the boundaries within which we view sustainability. Likewise, to grasp the full implications of sustainability boundaries related to a particular setting, we need to understand what sustainability means in relation to different human–natural systems, and we need to look closely at the ways we understand our surroundings and the boundaries within which we see *the systems we live by*.

Further, beyond the simple idea of threshold and the fact that there are different types of boundaries, it is important to note that sustainability boundaries of human–natural systems are also linked to the way systems are observed to behave over the time. One example where such boundaries are discussed is in the cyclical complex-adaptive changes described in the model of 'Panarchy'. In this case the thresholds are described relative to structure and function of the systems (Berkes et al 2003). This particular interpretation of boundary takes the complex dynamic changes a system goes through in to direct consideration. Other than that sustainability boundary also reflects a complex dynamic decision/view process related to sustainability.

Interpretation of sustainability in general is heavily subject bound. Depending on the form of relationship the human system had with the natural system, the influence human add on nature in the process of having their way have differed from place to place in history.

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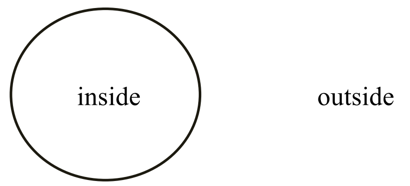
[40] It is also noteworthy that the distinction between physical limitations and others is not a straightforward task as the different physical, biological, mental, ecological, social, human and natural systems have overlapping boundaries. Wells (2012), for instance, makes such distinction between social systems and ecological systems mentioning that 'social systems are anchored in ecological constraints and create additional social constraints—norms, regulations, and laws. Social constraints are not as deterministic as physical constraints, but rather are flexible and prone to being transformed—ideas, agency, habits, strategies, and choices.'

Human tendency to prioritize survival has not changed, attempt to control and predict has not changed, may be different degrees in place to place and person to person, but not in complete contradiction in terms of behaviour can be observed from past to present (Satanarachchi and Mino 2009[a]). What is significant is that with ever increasing speed of information, knowledge being shared across the world, one of the fundamental aspects that become crucial to our discussion on sustainability, that is the worldview of each individual, also is changing. Before the process may have occurred slower, and have dependency on the context in geographical sense, however ever increasingly, the context is getting separated from the strict geographical or geographic-bound societal features, rather context becomes a platform that can have elements of multiple geographical (resources availability based on location), social (the interacting society), temporal influences (past, present, or future oriented practices, decisions), and value spheres (religious, normative positions). So that a multi–dimensional context will influence the choice and judgment of the system entities. Accepting this phenomenon makes any prediction focusing at one point of space and time in the process not just extremely difficult but even impossible in strict sense. At the same time such a process give a relatively structured understanding of the complex situation one is confronted with. That means not only the variations in context generate differing sustainability interpretations, but also there is a heavy contextual influence on the human systems' subjective interpretations.

In addition sustainability interpretations are made often in an uncertain grounds. The observers make choices with the limited information and knowledge they have at the present, to frame and solve problems that have implications not only for them and their own future, but also for the future of generations to come. The only possible solution to deal with this continuous uncertainly is the acceptance that one can't be fully right or wrong at any present moment, and make not only the physical, institutional frameworks to have the capacity to be flexible as possible. In order to do that, the cognitive frameworks with which the observations and solutions are made also need to exert the same characteristic. Therefore the boundaries of sustainability from the very outset of the observation need to be viewed as being evolving continuously. When such evolution is taken in to account sustainability boundaries no longer appear as static, but evolve along the time as a continuous sphere.

Likewise, sustainability boundaries are context and subject bound, and further, are evolving, often in a fuzzy terrain. How do such sustainability boundaries influence the way we address sustainability in practice? Ken Wilber in his book No boundaries writes, "The peculiar thing about a boundary is that, however complex and rarefied it might be, it actually marks off nothing but an inside vs. an outside. For example, we can draw the very simplest form of a boundary line as a circle, and see that it discloses an inside vs. an outside:”



He further goes on saying; “notice that the opposites of inside vs. outside didn't exist until we drew the boundary of the circle. It is the boundary line itself, in other words, which creates a pair of opposites. In short, to draw boundaries is to manufacture opposites. Thus we can start to see that the reason we live in a world of opposites is precisely because the life as we know it is a process of drawing boundaries.” This fundamental idea of boundary has been borne by many of the philosophical traditions. Based on it, it is possible to illustrate one of the key cognitive bottlenecks the practitioners or problem solvers are facing. Sustainability, in understanding and in practice through problem solving and evaluation, involves drawing sustainability/unsustainability boundaries through our interpretation. This process extends further to specific problem-based interpretation of sustainability, which creates necessity to isolation problems by making a boundary around them. In this process we tend to see a separation between what is happening inside the problem domain and what is happening outside of it. However in many instances solving one issue in one location has resulted in either merely shifting the same problem to another location—as of in not in my back yard concept—or generating a seemingly non-related issue in a separate location. One reason is that, many of the unsustainability problems are quite complex in nature that it is usually hard to trace the cause and effect relationships in them within a limited boundary. Also for the same reason sometimes effects are magnified out of proportion, exceeding the limits of the initial boundaries. The usual approach to isolate the problem and attempt to solve it within confined boundaries does not take the complexities and the related fuzziness of the boundaries. Further with relation to issue-based understanding of sustainability we face the challenge of defying each individual understanding about the issues and s/her surrounding, which frame to a great extent how the individuals relate and interpret the issues. The result is a diverse spectrum of interpretations from the outset. There are several ways proposed to deal with the problem of bounding the problems. David Bohm (1998) argues that key such technique could be the ‘*dialogue*’. In his view dialogue allow multiple such separate processes of interpretations[41] come in to

[41] In the original text the ‘process’ is specifically a cognitive process, it is possible to see the close relationship it has with a problem interpretation/definition process.

contact. With regards to an issue, when multiple points of views interact, they bring the understanding of beholders of those separate views to a different level than before, resulting in a new level that hopefully support a wider form of differentiation (Bohm, 1998). A similar idea can be found in the underlying concept of spiral dynamics where multiple levels of understanding are assumed to exist in different individuals (Beck 1996; Wilber, 2000). The demarking points of these levels of understanding can themselves be visualized as boundaries. However spiral dynamics does not specify how to navigate between levels of understanding. The soft system methodology and the transdisciplinary approach, as we saw, can be identified as two of the key related methodologies that have utilized the concept of dialogue in sustainability related decision-making. Also, it is noteworthy that implications of crossing the boundaries go beyond creating dialogue between different stakeholders' viewpoints to cross boundaries. It also involves creating dialogues even at individual interpretation level. For instance, with the mental work of the same individual, there can be internal dialogue between different possible interpretations of sustainability. Such a process would alter the boundaries of sustainability both across time and space even within the individual.

Finally it is noteworthy that, even though these arguments are highly conceptual, and in themselves represent one or similar hypothesis with relation to nature of boundaries that are concerned with sustainability, they all highlight the role of human interpretation in their definition. Interpretations are based on observations. The idea that the observer is a significant entity of the process of observing the surrounding and the issues in it, gives a certain less fixedness towards the boundary. Once the boundary is diluted, the usual analysis and appraisals done regarding systems become increasingly complex, and prone to debate and disagreements. This is where some form of commonality for observation is necessary. As we saw, the systemic view is one strong platform where such a common ground can be achieved. The boundary concept is quite significant when we look at the reality in terms of systems and adopt systems approach to solve problems. One of the key features of systems approach is that we regard a system in a way that it allows us to conceptually isolate the system from its environment and interpret its sustainability/unsustainability. However, once we leave the bird–eye view, and enter to the zone of real world problem appraisal, it becomes obvious that problems are quite complex, and the situation or the context where these problems are based are complex too, that makes systems to have complex boundaries.[42]

[42] Apart from what is discussed here, for an example of ways of visualizing boundaries in a specific context, please refer to the paper in Annex.

3.3.4 Sustainability Sphere

Based on such grounds, the boundaries can be visualized in several different ways. One simplified way is to visualize it as a sphere. The very basic idea in sustainability sphere is that, there could be hypothetical space within which systems operate in safe manner, therefore, as long as the system's path stays within this hypothetical boundary the system could not face irreversible and collapsing situations. In other words within sphere system can be regarded as sustainable. The benefit of this idea is that, it allows us to visualize the sustainable/unsustainable conditions with relation to boundary factors. Also it allows us to see the human–natural systems' complexities in a more specific manner. Questions as, what kind of relationships would keep a system within sustainability sphere, and what would drive it away from such safe operating space, may be regarded in a more visible, and quantifiable manner[43].

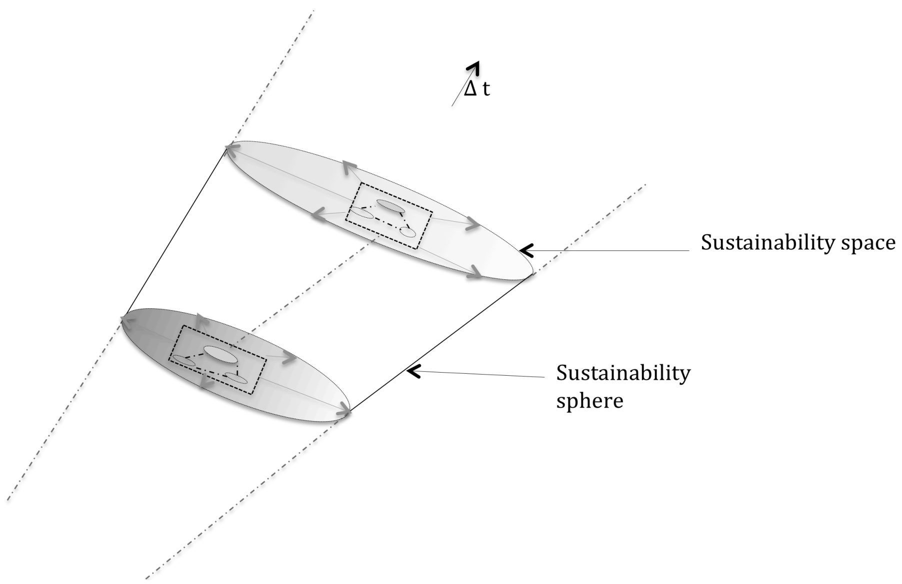


Fig 4. Illustration of the idea of sustainability sphere that connect multiple sustainability boundaries across time

Note: Also additionally other details as arrows and subsystems indicate that subsystem relationships intrinsically influence sustainability boundary change, hence, the hypothetically change in the sphere shape

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43 Earlier the sustainability sphere and sustainability path was conceptualized relative to a market based capitalistic economic system (Satanarachchi and Mino 2009 b; please find attached to Annex). In this early conceptual development high priority was given to internal dynamics of the system. However a set of sustainability principles relevant to this particular scenario were taken as base line, in order to identify points or extremes. Also much of the prior conceptualization in observing sustainability as a path that continuously being shaped with internal and external forces were discussed in the previous part of this study (Satanarachchi and Mino 2009 a).

3.3.5 Visualizing the affect of system interactions on system sustainability

What is described so far is an encompassing frame with which sustainability can be visualized along with the system specific changing patterns involved. However this is a simplified visual overview of the changing patterns. In order to go deeper in to topic and to enable to translate these basic ideas in to a formal methodology of observing complex dynamic changes linked to sustainability, it is necessary to explore the patterns and mechanisms in detail. The key patterns of system-specific complex dynamics described with relation to spatial and temporal system interactions give a baseline or watch points on sustainability of the particular system, both in its spatial and temporal domains. However, the path/process view of sustainability in itself cannot inform the observer with useful information to draw specific understandings and evaluation of sustainability. For this it is important to explore these patterns and mechanisms in a more comprehensive manner. Further, interpreting sustainability with relation to system interactions involves the activity of observation. An observer could focus on a single system, a certain function, characteristic etc of the systems alone. Also s/he could observe the change in the relationship it has with other systems around. In a changing system how sustainability is interpreted depends on how the observer would see the above-mentioned different patterns of dynamics. In addition, it also depends on how the observer would recognize system boundaries (that mark its inside and the environment) and system relationships. All these factors are affected by system changes. In order to briefly visualize the patterns of dynamics the system interactions, we could think of an unsustainability issue. An issue could be considered as confined to a particular system boundary (such as a community, a lowered scale of earth system) or it could be observed not confined to one particular system, but with relation to structures and functions that connect different systems (e.g. need for easy mobility, limitations of resource that effect viability of societies). For example, we can imagine a system where system entities face a problem of a need of faster and better mobility. They foresee a form of solving this via already available resources, knowledge, and so on (e.g. already known resources of oil and steel at hand, and the human resources, in terms of knowledge, labour, existing theories, experiential knowledge etc). When the existing resources and knowledge are inadequate, system entities would look for improvements to resources, allocating methods, new resources etc. These resources are allocated via existing institution forms. Where such supportive institutions are absent, new institutions will form around the new resource allocating needs. In this process new artifacts also would be added to the existing supportive infrastructure. Also probably by the time the initial problem of mobility is solved other needs would have arisen. Similar patterns could be observed not only around the problem of resource allocation, but in other sustainability related problems. At the very outset, when mobilizing resources to address the problem, the process starts to interact with sustainability sphere, in other words the boundaries of sustainability of the macro human–natural system. Let's assume that the system decided a specific source of energy to play a key role in the process of resource extraction and mobility from one place to another. By selecting a source of energy, which may be at the time abundant yet depleting in log-term, one system (in our case the human system within the macro human–natural system) makes a choice for the future of the whole system. Once this choice is made and artifacts are made and mobilized around the issue, often these initial infrastructures do not remain serving only the original purpose for which they were made. Nor they remain in original conditions, rather often would be continuously improved and allocated to serve other needs. And they themselves may create other problems to the system. If in case the system actors within the small focused system—where the initial problem originally occurred and was solved—are distant in awareness of the other systems around them, the likely situation is that they do not recognize the destabilizing influence on these other systems around it and to a wider context[44]. Such lack of awareness in human systems can occur due to multitude of reasons. One reason is that the system does not see its relativity to rest of the systems that the awareness simply does not arise. Or the system recognize the problems that may occur, yet do not have enough knowledge to validate or defend the importance of taking another choice. Or else the system is already adequately aware, and have the knowledge to support the choice, yet the process development have taken place in a way that it is extremely difficult if not impossible to shift the direction. One good example for this last situation is the dependency on car for mobility in many places on earth. In some locations, the car and the combined infrastructure, often built according to one initial blueprint, could be regarded as a massive automated machine with high inertia, set in to motion and the motion happens in an ever increasing speed that, once the motion is set it is extremely difficult to change it's coarse of direction. Similar examples of interconnected systems behaviours can be found around what today we interpret as sustainability problems. Earlier we illustrated that system changes can be visualized as a path, and therefore sustainability in these systems also can be seen as a path. When scrutinizing the path to see how the path is being formed, we also mentioned that sustainability could be interpreted as going through different states. To observe different states with relation to a system's evolution is rather easier. However to combine the

[44] Please note that still the term context is used as a general reference, even though there are complexities as one context will be naturally part of other broader contexts, as local, regional, global etc. Further, in a later section of the thesis, the term 'context' would be used with a specific meaning.

system's evolution path with its sustainability we need to look deeper in to these system evolution patterns. As a first step we expand the path and boundary based interpretation we made, by scrutinizing and interpreting the system relationships. The following sections illustrate a form of visualizing that can be done, in order to interpret these relationships. This visualization mainly takes in to account these factors;

(i) The systems that we observe for sustainability are connected to other systems with numerous system relationships.

(ii) When we want to observe sustainability in them we have to focus of some of the specific subsystems within those cohesive units.

(iii) When we observe system relationships we have to focus specifically on some of those relationships.

Based on them we can start to visualize the systems' sustainability boundary in the form of coupled–system boundaries. Such a coupled boundary in a temporal stable state is illustrated in Fig 5. Also it is noteworthy that as illustrated earlier, there are different kinds of relationships, and they can be observed in different ways. To visualize them we adopt the same approach as before, i.e., to separate spatial, and temporal interactions.

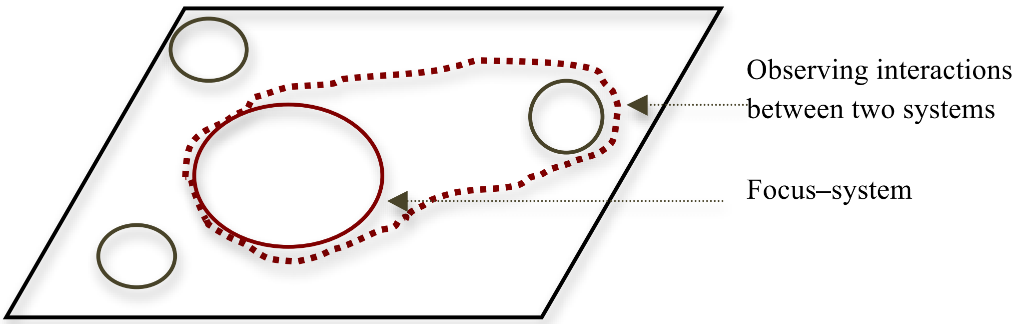

Fig 5. Using the approach of couples-system boundary for observation

Depending on the relationship that become relevant in describing an issue or the changes that happen in system over the time, the description about the system itself will be changing. Further, the significant system relationships to interpret sustainability may change as well, for instance the economy of a country may change from dependency of natural resources to more service oriented one, changing the significant subsystems to be considered in order to interpret the country's sustainability. It would also mean that sustainability of the system would change from one state to another. Then there need to be a slightly different approach to see the relationship of interactions, however the basic underlying structure that the initially focused system is regarded with its relationship with rest of the systems need not be changed (here economy is taken as one focused subsystem of a bigger system (country)). The benefit of this approach is, rather than focusing on a specific system with its own specific parameters, looking at it in relation to other systems, can give a wider perspective on dynamic patterns. Further, mapping the changes in sets of layers which describes such relationship can help to visualize some of the structural and functional changes that are not readily visible if a focused system's spatial and temporal changes are evaluated alone—without considering the relationships it has to its environment. At each stage the relationships are identified that brings a relatively complete picture in to attention, at the same time it may allow certain relationships to become more visible, while fading the others than to completely eliminate them from attention. And the provisioning for changes in not only the forms of relationships in a different layer, but also the significant points that become relevant in the sustainability discussion explicitly, would enable the examiner to see the patterns of changes within a flexible cognitive framework.

3.4.5.1 Sustainability related change process in the same temporal 'stable' state

Likewise, upon looking at natural evolutionary patterns of systems, when a system change its structure and functions, conceptually we could say that the system is changing its state, in other words going from one relatively stable state to another. These changes occur as a result of system interactions—out of which some are organizing relationships that show complex dynamic evolution patterns. Therefore in a method that visualizes the changes, it is important to identify some mechanisms with which these changes would take place. One such mechanism is the co-evolution between systems. When regarding sustainability as an ongoing process, the co-evolution becomes one of the key change processes to examine. It gives the basic insight that if systems are evolving and co-evolving and sustainability of these systems in turn depend on such processes, the evaluation for sustainability of these systems needs to be done with frameworks which could capture this process adequate enough. Further, the idea of co-evolution has general meaning as well as very specific scientific meanings. To stay in general but accurate enough domain, the co-evolution can be interpreted as a process that reflect the change of two systems or system entities by mutually influencing the change of each other. [45] Human–natural systems are organized from the interactions of a set of ecological, social, and economical systems across a range of scale. Between these systems numerous interactions take place which effects each of their individual evolution process. Usually, when a change occurs in terms of function and

[45] Note that for the ease of interpretation, in this section, only the system-based changes are considered. Therefore, when we say co-evolution, basically what meant is the co-evolution of systems such as natural and social systems of a macro human-natural system and the process's influence in sustainability. However to interpreting sustainability considering system co-evolution patterns have deeper implications. These factors would be discussed in a later section in the thesis.

structure within the system (that encompass a group of subsystems), the system goes in to different temporal states. Within one layer that goes through a dynamic stability a rapid and visible structural of functional change may not occur, eliminating a need for a new orientation for the boundary. Therefore, co-evolution can be observed as two separate types;

(i) Co-evolution that keeps the cumulative system within a relatively stable state

(ii) Co-evolution that bring the cumulative system from one state to another

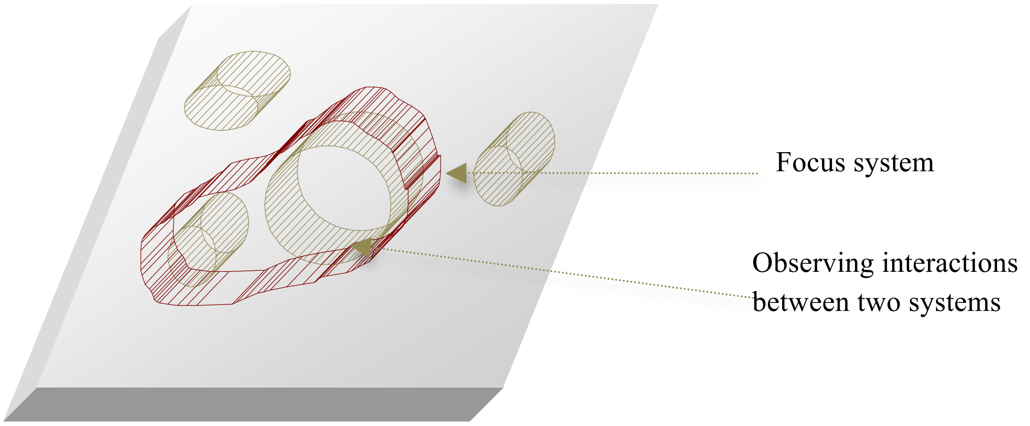

Fig 6. An illustration of internal co-evolution process in a relatively stable temporal state

One of the key characteristics of the co-evolution within a relatively stable layer is that, the systems have not yet faced a significant rapid disturbance (both in terms of spatially and temporally significant distances). Therefore conceptually it may be possible to visualize this process, but often empirically face difficulty in comparing different processes.

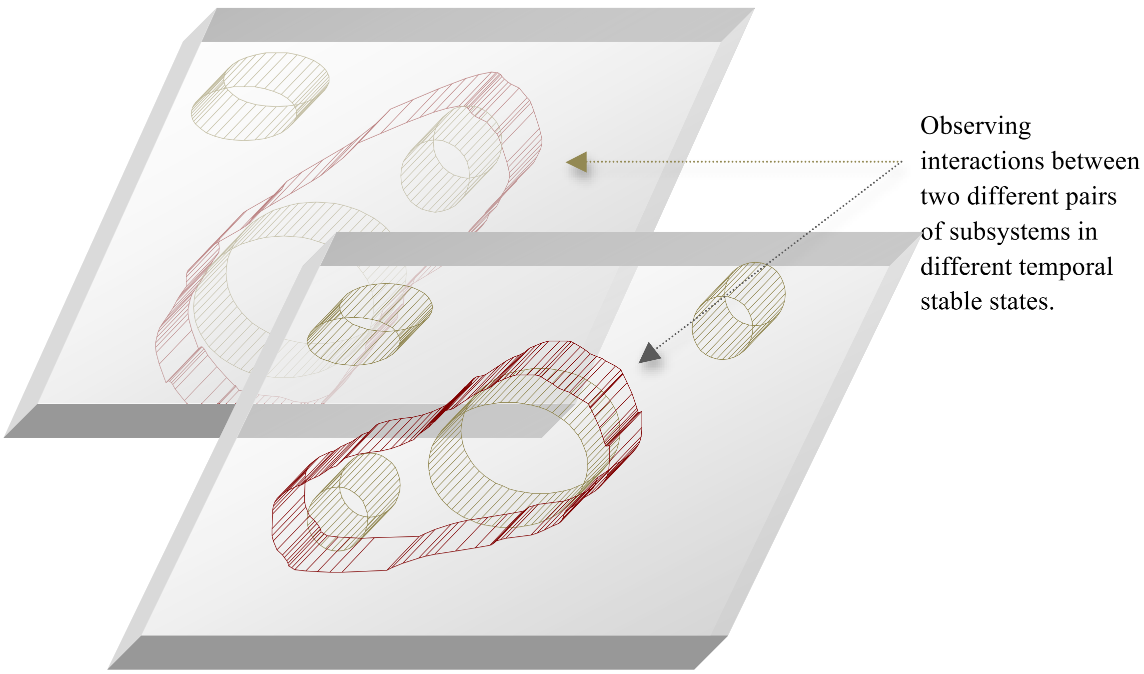

Fig 7. An illustration to show that key system units engaged in shaping sustainability conditions in the macro human–natural system may change.

Note : This would clearly mark a structurally and functionally different stable state

So both space and time wise, the systems evolve through already existing, recognizable patterns. Such patterns would make predications and measurements relatively easier. Another important thing to note in this type of a process is that, it involves evolutionary process of at least two individual systems who would not show (i) similar mechanism (ii) similar elementary units nor (iii) similar pace or patterns of changes. Still, the benefit of such an approach to setting boundary for further inquiry is that it gives inclusive enough, yet not exceedingly complex basis for evaluation of different systems. On the other hand the ontological and epistemic basis of sustainability can be addressed within separate concise domains, where useful mechanisms as co-evolution can be dealt separately[46].

3.3.5.2 Sustainability related change process in between temporal 'stable' states

Usually in addition to co-evolution patterns within relatively stable conditions, there are similar patterns connected to the periodic structural and functional changes that the systems go through. Over the time these changes can be both rapid and slower change. How the system entities as well as the context[47] as a whole would experience these changes can determine whether the system is perceived to be sustainable or not during the transition between these states. Therefore it is important to identify the mechanisms that can take place in between these states and their implications on system's sustainability. The important thing to consider during that process again is the system of focus.

Unlike in the previous case when systems are interacting in space with one another, here the key observant mechanisms lie in between temporal boundaries, were systems move through relatively stable states. Closer to boundaries there may exist extremely unstable conditions where system's structure and functions starts to collapse. According to understanding of complex systems, theoretically at this stage the system could either experience chaotic conditions that would disintegrate the system, or would show emergent properties that could bring the system to a next stable level. In one hand at this point how efficiently the system will move to a new desirable state matters, on the other hand how resilient and

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[46] Gruber (1995) defines ontology as the explicit specification of conceptualization. The term is borrowed from philosophy, where Ontology is a systematic account of Existence (Gruber, 1993). The construction of a well-designed ontology requires an explicit understanding of target world that can be shared among others (Kumazawa et al. 2009). Epistemology is the discipline of verification and logical confirmation of the explanatory structure of scientific theories, and its primary objective is to guarantee the undoubted safety of scientific methods and knowledge (Lenk, 1998, adopted from Osorio et al. 2009).

[47] The term context is used to represent a context of sustainability. 'Sustainability context' is explained in detail in a latter section. As of a brief description, a sustainability context would represent one or several interpretations of sustainability.

adaptive the system moves in the transition process becomes significant in terms of how comfortable, satisfactory, and desirable (specially for social systems) the system entities experience the transition, and would avoid system collapse situations.

Aspects such as, comfort, satisfaction, and desirability is also linked with the active engagement of setting the next stage. For instance, when a community moves from one form of resource dependency to another form, the dynamic equilibrium around the new resource becomes the target that the system is striving for, so as long as the set milestones are met the community may derive certain amount of satisfaction during the transition process. At the same time, the amount of continuous disturbance that the system entities can withstand affects their comfort during the process. However these factors alone could not signal the system entireties whether they are moving within or away from sustainability boundaries (whether context in observation is moving within the sustainability boundaries). The simple example would be that if the new resources is also a rapidly depleting essential component of the ecosystem, then there may be technologies, institutions getting woven around them quite efficiently, and the change takes place in a smooth enough manner that the system entities get the capacity to adapt both to the process of change, and to the new situation, however the new equilibrium will be accelerating the depletion of the resources making the unsustainable situation to lead to collapse of the system, and further to spill the effect to the wider ecosystem. Therefore while it is extremely necessary to observe the change process in terms of the cumulative unit's resilience, efficiency etc., in terms of reaching the new desired state, during the process itself it is necessary to evaluate the system's direction of change.

Conceptual framework-Section II

3.4 A FOUNDATIONAL FRAMEWORK TO OBSERVE AND EVALUATE COMPLEX DYNAMICS LINKED SUSTAINABILITY IN HUMAN–NATURAL SYSTEMS

Overview

Sustainability boundaries are connected to readily visible facets of sustainability, as well as not-so-readily visible implications that form the way we understand sustainability in human–nature systems around us. They are significantly tied to complex dynamic features observed in these systems, and in addition is tied to the complex dynamics involved in observing them. As the first step of elaborating this understanding, this section introduces a foundational framework that supports the visualization of sustainability boundaries. Adopting a systemic view, we first elaborate on the concept of boundaries of sustainability, and then discusses a layer view-based method that supports in observing those boundaries. Describing some significant factors involved in the observation process, we elaborate how the layer view-based method could place a foundation for sustainability evaluation in human–natural systems.

Keywords: layer view-based method, human–nature systems, complex dynamics, sustainability boundaries, context, focus–system, background

Note: Please note that some of the concepts appear in this section have been already discussed in detail in earlier sections. In order to make the development of the framework consistent they would be briefly described, for more illustrative interpretation, please refer to the earlier descriptions as well.

3.4.1 Introduction

Base on the discussion so far, it was apparent that one way of observing sustainability in the face of complex dynamics is to break the observation temporarily to observations in a relatively fixed time frame and to observations that are more focused on the variability associated—especially in temporal and organizational axis. First we will explore ways observe sustainability in a relatively stable and fixed temporal state. Then we would discuss how conceptually sustainability boundaries could be observed in this temporal stable state.

3.4.2 Observing sustainability in a complex dynamic context: A foundational framework

Boundaries o f sustainability[48]

As described in an earlier section, in very simple sense, the term boundary is used to demark something from what it is not. In the understanding of sustainability, a sustainability boundary would mark what is sustainable and what is not sustainable.

Understanding of the surroundings with relation to sustainability boundaries is not a new attempt. As a concept, sustainability often addresses location-specific *facets of sustainability.* Examples of facets are development, growth, technological efficiency, environmental and cultural conservation, and ensuring socio-natural resilience. They represent prominent sustainability issues and their solution, and sometimes positive or negative characteristics of human–natural systems that lead towards sustainable/unsustainable conditions. In addition, we also identify that they indicate a set of paths towards the future. These paths form their own unique boundaries to characterize the sustainability of the human–natural systems they represent, and they therefore appear as different faces of sustainability.

More than these general interpretations, the discourse of sustainable development and sustainability has been enriched with discussion of more on the *explicit boundaries*. Traditionally, the *idea of the sustainability boundary has been directly related to limitations*. The very first dialogues focusing on the dependency of human functions on the natural resource base has addressed explicitly the *physical limitations* on Earth. They have

[48] The boundaries of sustainability were discussed separately in an earlier section, however, in order to make the description of conceptual framework consistent, some of these already discussed basic concepts are discussed again in this section as well.

brought out terminologies as *limits to growth,* which signifies an upper cap on the stresses on the global physical base (Meadows et al. 1972). The term *our common future* implied a future limited space in which the whole of humanity operates with these physical limitations. Additionally, the concept of the *ecological footprint* (Wackernagel and Rees 2009) has given a strong metaphorical representation and a quantitative basis to many of such physical limitations. Recently, stemming from ever increasing global catastrophes, *planetary boundaries* have highlighted the significance of being aware of physical thresholds, and also of the complex dynamics that can trigger rapid movements towards these thresholds (Röckstrom 2011). The concept also implicitly suggests *a safe boundary for human actions* well indicating the highlighted connectivity of human systems in a wider ecological setting. The notion of boundaries formed by ecological limitations carries broader implications. In them again to identify physical boundaries are more common and easier. However, the limitations do not remain in physical forms alone but rather extend to biological forms and especially to human-related forms that include not only the readily visible boundaries of technologies and institutions but also those of knowledge, views[49], capacities, wisdom, and aesthetic sensitivity. Obviously, these limitations lie in multiple trajectories. Unlike physical limitations, which mark clear thresholds (especially in the case of viewing the world as one planetary system), the other limitations tend to be those that can be overcome, or at least, those that can reach a stage where they are no longer regarded as limitations (e.g., new knowledge, different levels of understanding, and capacity (Sen 2009)). Additionally, some are easily recognizable and communicable while others, like wisdom and views, tend to be subtler and may not be easily recognized as limitations. Even further, our very understanding of concepts such as aesthetic sensitivity (Bateson 1979, 2002; Kagan 2011) and their roles in the perception of system interlinks is quite limited. Even though it is difficult to clearly differentiate these different types of boundaries, we could roughly categorize them as *soft* and *hard boundaries of sustainability*. In terms of qualities such as ready visibility, tangibility, and quantifiability, we highlighted that there is a spectrum from soft to hard. .[50] Explaining how each and every one of them function in sustainability evaluation warrants a deeper and extended discussion. Still, by mentioning them briefly here, we intend to bring forth the fact that, beyond physical and already well understood forms of ecological limitations, the concept of sustainability boundaries draws

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[49] Within the term view, beliefs and mindsets are also included.

[50] It is also noteworthy that the distinction between physical limitations and others is not a straightforward task as the different physical, biological, mental, ecological, social, human and natural systems have overlapping boundaries. Wells (2012), makes such distinction between social systems and ecological systems mentioning that 'social systems are anchored in ecological constraints and create additional social constraints—norms, regulations, and laws. Social constraints are not as deterministic as physical constraints, but rather are flexible and prone to being transformed—ideas, agency, habits, strategies, and choices.'

multiple other implications from many different boundaries relating to human systems (such as individuals, societies, organizations and networks) and that the sustainability boundaries are not always readily visible. These boundaries themselves can be regarded as different types of systems, as they are heavily interconnected with various types of relationships (e.g., physical, biological, behavioural, and cognitive relationships) forming complex dynamic systems of observation (How this happens will be explained in subsequent sections). They sometimes merge and are sometimes highlighted, subsequently influencing the boundaries within which we view sustainability. Therefore, to grasp the full implications of sustainability boundaries related to a particular setting, we need to understand what sustainability means in relation to different human–natural systems, and we need to look closely at the ways we understand our surroundings and the boundaries within which we see *the systems we live by*.

3.4.3 Meaning of sustainability boundaries with relation to complex dynamic human–natural systems

In sustainability evaluation human–natural systems are a key entity. There are many interpretations of a 'system'. In a very simple sense, a system is a group of entities that are connected with a common behaviour pattern(s) (Meadows 2008, 1999). Looking at the nature of the planet earth and the human dependency on natural resources, the systems relevant for sustainability evaluation can be identified as human–natural systems. Human–natural systems are referred to by many terminologies, mainly depending on the nature of the relationships that they describe. The socio-ecological system is an ecological system intrinsically linked with and affected by one or more social systems (Berkes et al. 2003). In addition, systems such as socio-economic and socio-technical systems have immediate or distant links to a natural resource base, and therefore even these seemingly human-specific systems can be visualized easily with the natural components that they are bound to. These systems are connected in space and time through system–subsystem relationships that include complex dynamic organizing relationships.

In addition to being characterized by their relationships, many of the human–natural systems that we are interested in have special characteristics of being complex dynamic systems. They are not only bound by common behaviour patterns but also connected through space and time, and more significantly through various organizing relationships. As a result, they have complex dynamic behavioural patterns. This factor has been observed in the very early stage of sustainability discourse. One of the key documents in sustainability science, *Sustainability Science: The Emerging Research Program*, emphasizes the importance of harnessing the dynamic interactions emphasising on the needed attention to observe how social changes shape the environment and how environmental change shapes society (Clark and Dickson 2003). Early on, Constanza and Patten (1995) suggested that much of the sustainability discussion was at the time misdirected because it failed to account for the range of interrelated temporal and spatial scales over which the concept must apply. Furthermore, it has been stated that a sustainable system is one that survives or persists, which led to two questions By Howe (1997) (1) What systems or subsystems or characteristics persist? (2) For how long must a system persist to be considered sustainable? arguing that any subsystem is not indefinitely sustainable because this would eliminate evolutional adaptations (Howe 1997). Over the years, not only the general idea of continuation, movement, and evolution but also the aligning complexity based dynamic understanding and outlook have been emphasised in sustainability evaluation (Ostrom, 2009; Ostrom et al 2007; Liu 2007; Turner 2003). These observations indicate that, in addition to system–subsystem relationships, it is necessary to give in-depth attention to other forms of complex dynamic relationships in sustainability interpretations.

Complex dynamics have wide spectrum of meaning and describing complex dynamic systems fully is a challenging task. Here we provide an introduction to such systems while emphasizing aspects that we incorporate in following sections. The term *complex dynamics* carries diverse contextual meanings. The concept has been advanced by insights gained in different fields, as natural science, ecology, social science, and philosophy. The term 'complex system' originates from the complexity theory of Leibniz and Bertalanffy (Meadows 1972) and was later developed and adapted in several fields of studies. The idea of complexity in recent times has had widespread popularity outside of science, carrying a warning to our understanding, a caution against clarification, simplification, and overall rapid reduction (Morin 2010). Earlier we had a deeper discussion on complexity and the complex systems. Here as well it is helpful to refer to some of the key points that describes the complexity, and more importantly what differentiate the use of the term 'complexity' in this instance from other related concepts, allowing the meaning of complexity to surface in the process. First it is useful to distinguish between the notions 'complex' and 'complicated'. If a system—despite the fact that it may comprise a huge number of components—can be completely described in terms of its individual constituents, then it is merely *complicated.* In a *complex* system on the other hand, the interactions of constituents of the system, and the interactions between the system and its environment, are of such a nature that the system as a whole cannot be fully understood simply by analyzing its components. Additionally, complex systems are inherently dynamic in nature. They are also open systems—they interact with their environment, in terms of not only energy and matter but also information. These systems adapt to changes in the environment, and therefore their internal structure is influenced in some way by external conditions, making the very distinction between 'inside' and 'outside' of the system problematic. Moreover, the system relationships are not fixed, but shift and change, often as a result of feedback-based self-regulation and self-organization where such processes can result in novel *emergent properties* of the system (Morin 2010; Cilliers 1998; Miller and Page 2007).

Sustainability as a concept demands that sustenance should be ensured across different systems across space and time taking in to account their long-term changes. Therefore understanding the nature of complexity, complex systems, and complex dynamic patterns and mechanisms provide a sound basis to observe these systems. The complexities and dynamics related to sustainability boundaries are properly captured when the systems are viewed with the spatial and temporal and other forms of complex system relationships. In addition, what is often overlooked is the fact that the process of observing complex systems also warrants enough attention. This is so, as the observation process to a considerable extent determines how the systems are being observed. Rephrasing what we indicated earlier, Mebratu (1998) indicated that epistemological flow runs across different versions of sustainability, where the relationship between the part and the whole is not properly captured (Mebratu 1998). A well-elaborated simile that describes the observation of complexity and complex relationships in systems is found in Morin (2008). With relation to observation, three *stages of complexity* can be elaborated by taking the simile of a tapestry.

"(i) In the first stage of complexity, we have simple knowledge that does not explain the properties of the whole. A banal observation that has consequences is not banal; the tapestry is more than the sum of the threads that it is composed of. The whole is more than the sum of its parts.

(ii) In the second stage of complexity, the fact that there is a tapestry means that the qualities of this or that type of thread cannot be fully expressed. The threads are inhibited or virtualized. The whole is therefore less than the sum of its parts.

(iii) The third stage of complexity poses problems relating to our capacity to understand and our thought structure. The whole is simultaneously more and less than the sum of its parts.

In this tapestry as in an organization, the threads are not placed randomly; they are organized to make a canvas; i.e., they have synthetic unity where each part works together with the whole. The tapestry itself is a perceptible and knowable phenomenon that cannot be explained by any simple law".

(Morin 2008, p. 60)

In our understanding the simile has prominent implications in observing human–natural systems. Earlier we described that human–natural systems have numerous intrinsic system-subsystem relationships. Also we recognized that any particular human–natural system of interest also is necessarily tied to other external systems. In a sustainability evaluation process, our particular system of interest could be seen as (a) one cohesive unit (a complex whole), (b) separate parts with sensitivity to individual entities that form the whole system (subsystems) and (c) a complex dynamic system unit bound by *patterns of interactions*.

What we earlier described as sustainability boundaries is very much a cognitive entity that takes the form of a decision of what is sustainable and what is not. To reach that decision we rely on other types of boundaries as the system boundaries. In an evaluation process the boundaries are brought to a next level by explicitly recognizing quantitative or qualitative values especially for the hard boundaries. In addition we emphasised that there are soft boundaries that are not easily visible and recognizable. Reaching sustainability boundaries of a system with its parts and whole understanding can be considered as to engage such soft boundary understanding, as the process of viewing and understanding sustainability related to multiple systems involves a cognitive process of organizing mental information/knowledge. In other words, it strongly infers that the discussion of sustainability boundaries in human–natural systems needs to include the very process of observation and visualization; i.e., reflexive viewing sustainability related to complex dynamics in human–natural systems. In the reflexive viewing of systems, the special implication is the emergence. Earlier we explored what is meant by the emergence, and the emergent properties in a complex system. In addition to the description we gave at that point, the properties of emergence with relation to observation were captured effectively by Miller and Page (2007) when he states that, "The usual notion put forth underlying emergence is that individuals' localized behaviour aggregates into global behaviour that is, in some sense, disconnected from its origins. […] In this interpretation the notion of emergence also has a deep intuitive appeal, similar to observing a pixlated picture up-close and at a distance. While each individual pixel can be easily understood in terms of its shape, color, hue and other properties, it is typically impossible to figure out the entire image by simply scanning across the pixels at close range. At a certain distance the overall image begins to resolve, and pixels become indistinguishable" (Miller and Page 2007; Complex Adaptive Systems, p. 45). This idea suggests that the distance is an important factor in the process of recognizing patterns. In addition, we suggest that the emergence involves not only a shift in distance but simultaneous regard of two distances. What we in everyday terms refer to as the ‘focus’ in fact involves at least two different distances, focus with the short distance and background—with which focus emerge—with a longer distance.

Based on this understanding, we want to emphasise that there are two main factors to consider in evaluating sustainability in complex dynamic human–natural systems. First it is important to note that systems interact with each other without the engagement of human thought. Second it is important to note that the complex dynamics are also linked to our own conscious observation and understanding of sustainability in these system. This is where people interact with their surroundings to explicitly observe sustainability in systems that they already are a part of. Such understanding involves the observation of complexity of system interactions, and also it involves the complexities in perceiving and viewing of these systems. First, the basic understanding behind sustainability and how it is viewed with respect to a particular human–natural system affects the subsequent decision-making steps, that include steps to adapt (living within limitations) and create (going beyond limitations). Second, the manner and the extent to which these complexities are observed depend on the observer’s observation process that involves internal information/knowledge recognition and processing. For instance the way we observe the earth system for its complex issues as global warming are diverse, not only because the earth system is a complex dynamic system, and because the issue also shows highly complex behaviour, but also because as observers of the issue and the system, we focus from different angles, on different system parts, on different facets of the issue, and also on different levels or regions that represents parts and wholes. Therefore, when it comes to recognizing and solving problems, planning for the future, and having dialogue with different stakeholders concerning decisions that involve sustainability of these systems, the second aspect, though often overlooked, has a great importance. Any assessment of sustainability that does not adequately consider our own conscious observation and understanding of sustainability may fail to capture the full implications of sustainability in human–natural systems. Likewise, observing sustainability in human–natural systems first involves awareness of sustainability and systems alike across time and space and across different systems or organizing relationships. Second, the observation involves shifting the focus between different system boundaries. Third, it involves an ‘emergence’ in understanding. In other words, when we view human–natural systems as complex dynamic systems, the process of understanding the interrelationships that connect multiple systems or parts of the systems can be viewed as involving an iterative process that creates a *system of awareness* related to sustainability[51]. This system of awareness could be argued as being able to connect sustainability and the human–natural systems. To illustrate the process, let us select two of the interconnected branches that influence how we often recognize and interpret sustainability/unsustainability in systems; a) Interpreting sustainability with relation to systems and their change over the time, b) Interpreting sustainability with relation to prominent unsustainability issues. While being closely interconnected, these branches also have separate significance in sustainability evaluation.

(a) Observing sustainability with relation to systems (systems' complex dynamics-linked sustainability/unsustainability conditions)

As mentioned earlier, human–natural systems at all scales comprise of systems, subsystems, and interacting system entities, and thus in a very simplistic sense could be considered to be complex and evolving systems. They take the form of social systems, natural systems, socio–ecological systems, socio–technical systems, socio–economic systems and so on. When the complex dynamic qualities of these systems are recognized, the systems as collective entities are explicitly referred to as complex dynamic systems. Further depending on the special features of complex dynamics being observed, they are occasionally referred to as complex–adaptive systems (Berks et al. 1998, 2001, 2003; Gunderson and Holing 2004), coupled human–natural systems (Liu et al. 2007; Ostrom 2009), self–organizing (living) systems, and so on (Kauffman 2009; Capra et al. 2001; Morin 2010). In living systems, both adaptive and regenerative capacities are observed to interpret sustainability in them. Holing (1973) introduced the concept of resilience as a way to understand non-linear dynamics in complex socio–ecological systems, such as the processes by which the eco-systems maintain themselves in the face of perturbation and change. The resilience of socio-ecological systems is described by i) the amount of change the system can undergo in the face of perturbation and change, ii) the degree to which the system is capable of self–organization and iii) the ability of the system to build its capacity for learning and adaptation. Furthermore, the framework proposed by Ostrom (2009) for socio–ecological systems recognizes adaption as a key driving force of sustainability change. Additionally, just as natural systems alone are recognized for their complexity, the human-cognition process is also recognized for its complexity, and different mechanisms are used to describe the process (Maturana and Varela 1987; Capra 2002; Morin 2010). When individual cognition and behaviours unite collectively in the form of soft and cohesive entities, such as

[51] In addition to the given explanation, how the awareness process reflects a system can be strengthened with more theoretical arguments. For example, David Bohm argues that thoughts can be visualized as an open system (Bohm 1994, p.24). Refer to Bohm (1994) for an extended explanation.

culture, such socio–cultural systems also exert complex dynamic features and have implications on the sustainability of the macro human–natural systems that they are a part of. Likewise the interpretation of sustainability, while differing according to system configurations, is strongly linked to the complex dynamic features in these systems.

Furthermore, the interpretation of sustainability would vary not only according to the particular system configuration, but also according to the desired attributes that are linked to sustainability. For instance, sustainability is recognized with diverse attributes of systems such as system integrity, resilience, robustness, balance, room for transformation etc. With relation to each of these different attributes and the spatial and temporal scales being emphasised, the way systems are viewed would be different. Further, to observe these attributes, either the system relationships in a relatively stable past, present, or future state, or else across evolutionary cyclic processes would be observed (paying attention to different temporal states such as stable, regenerative, and collapsing states as illustrated in the Panarchy model presented by Gundersan and Holling (1998)). If systems are viewed in the form of living systems, sustainability might mean protecting the state of the self-organizing process that underlies the whole system. Generally human–natural systems have the capacity to change themselves through self-organizing. These are processes that take time and involve its subsystems and system entities, and the processes do not have linear relationships with the changes that occur in the macro-system (diversity, for example, is considered a positive attribute in living organisms, but does not always have a directly traceable cause-and-effect relationship with the 'emergence' of positive characteristics in the system (Capra 1997)). These are just a few examples of how there can be different aspects to consider when observing sustainability in complex dynamic systems. Such different aspects would affect how sustainability would be interpreted, and also whether each state would be accepted as sustainable/unsustainable at a given time. Such an observation process can become complex as by expanding and reducing the scope of the system being observed, systems may be found occupying multiple stages of multiple cycles. This would be even more so when the surrounding of the systems also takes in to account. Therefore, interpreting sustainability boundaries (i.e., in a simple sense, the question of what is sustainable/unsustainable) in the face of complexities exerted by system relationships becomes a complex task that involves normative choices that reflect competing and contradicting attributes or patterns in the system. For instance, one systems' collapsing state may be necessary for another (higher, lower or seemingly unrelated) system's growth state. Based on, which level of system relationships being considered, decisions of sustainability would vary. Visualizing these factors is not straightforward and demands shifting between multiple system boundaries. For this process, not only the above-mentioned aspects but also other subtle aspects as *internal mindsets/worldviews of the systems* would have a profound effect in terms how the sustainability of these systems is interpreted. For instance, even with consideration of nonlinearity, the embedded outlooks that the system entities carry such as viewing the world as a clock, a machine, or a living organism (a complex-dynamic system that has the capacities of self-organization and emergence) affect how the mechanisms that subsequently direct the system changes and the resulting sustainable/unsustainable conditions are derived. Likewise, the characteristics of the systems and system relationships influence the way that one understands/views sustainability in human–nature systems.

(b) Observing sustainability with relation to prominent unsustainability issues

Contrasting to systems-based view of sustainability, a powerful and more common way of recognizing sustainability or unsustainability is via unsustainability issues. This is especially so before the patterns connecting those issues become visible. The limitations related to human–natural systems are referred to as unsustainability issues of that particular system. Within the planetary system, issues such as CO_2-induced global warming, depletion of forest cover and biodiversity, and global poverty, have gained much attention and generated public awareness of sustainability. These issues also have tied diverse internal smaller-scale human–natural systems as specific countries, formal networks of countries, and specific economic/geopolitical regions and so on. Additionally, the very understanding of sustainability, which stems from the classical definition of sustainable development (WCED 1987; Meadows 1971) addresses the implicit issue of human survival on planet Earth in a deep sense, highlighting the significance of the issues faced by human system. Similarly there are other unsustainability issues that run across global, regional, and local scales. The visibility and the significance of the unsustainability issues have been powerful to the point that traditionally sustainability discourse has focused on recognizing these problems and searching for solutions to them. Even the field of 'sustainability science', which stemmed from the need for explicit research on sustainability, has often been recognized as a problem-driven discourse (Kates et al. 2007).

Issues are very much a part of human–natural systems; therefore, is difficult to clearly differentiate issues from systems. Still, the reason we observe issues forming an interlinked but also separate branch in sustainability evaluation is that some characteristics of these issues themselves have their own *dynamic boundary*-forming capacity. Why do we say so? One issue's implications range across many systems, generating complex relationships with system–subsystem units they are embedded in. An issue generated at one place can easily have repercussions affecting a geographically distant place; hence, in reality, different seemingly scattered human–natural systems are involved. Additionally, these issues involve different scales of urgency, different cause–effect time spans, and different feedback durations, and they connect systems in different ways in the temporal dimension. To prevent thresholds from being reached far ahead in a future system state, the preservation of the system integrity may demand an immediate response regardless of the system's current state. Additionally, these connection patterns may not always follow the usual rules of how the underlying human–natural systems are connected. With such process involved, it is possible that unsustainability issues have the capacity to form the boundaries of sustainability. Such boundary formation would lead to 'recognizing, understanding, and solving of issues'[52], and further would organize the systems around those boundaries affecting the connection patterns of human–natural systems. Many of the developments that occurred around the world can be viewed as having stemmed from people's intrinsic need to go beyond the limitations that they encounter. They have faced issues in diverse forms such as diseases, epidemics, food shortages, lack of resources, severe climate conditions, invasions, and social upheavals (Diamond 1997, 2005). By recognizing the limitations, and then acquiring further knowledge, formulating solution trajectories and mobilizing individuals and organizations, people have created interconnected processes that have shaped sustainability/unsustainability paths throughout history. Not only the awareness of limitations but also the paths that stem from such awareness have involved concern of past, present, and future wellbeing, new forms of knowledge, perspective, and conscious and unconscious organizations that connects further apart individuals, networks, places, and generations. Likewise, unsustainability issues could not only affect human interests, awareness, and understanding but also, in the process of changing understanding and subsequently changing actions, connect seemingly non-related human–natural systems. In this way, limitation-related issues can be regarded as forming and mobilizing complex dynamic systems in their own right.

With relation to both of these branches, we want to highlight that there is a significant aspect that influences sustainability understanding, hence sustainability-evaluations. It is the understanding process of an individual, particularly the one who is engaged in evaluating sustainability. As individuals and groups who already belong to various systems and subsystems, our understanding of planetary/global-scale issues is conditioned by numerous factors[53]. In addition, the system relationships shape the way we perceive their boundaries. The boundaries of a village include not just the physical and spatial boundaries

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[52] The problem space and solution space (Wiek and Binder 2005, Binder and Schöll 2009) describe these interconnected steps for sustainability issues in detail.
[53] This aspect is already discussed under the section (a).

relating to the physical territory of the village, which are rather easy to recognize, but also boundaries that are more subtle and formed by individuals, communities (human relationships), and relationships (e.g., human–natural relationships in the form of people's dependence on the natural resource base and the preservation of nature), which mark the identity of the village. Often the physical resource base that supports the cities lies outside their immediate physical territories. No village, town, country or region can live isolated depending only on its own physical resources. Further, highly connected activities have increased the merging of systems. It is thus clear that as far as human systems are concerned, spatially, boundaries can expand far beyond the visible physical territorial boundaries. The idea of a few generations of villagers who are linked through historical experiences, lessons and wisdom passed through framing the current mindset, views, cultures, and other inherent contextual features affects the way a village operates; hence, the boundaries of any such unit always spread across time. Some of these attributes having strong temporal significance are more visible and can be traced easily to past events; some, however, cannot even though they are significant in terms of reinforcing contextual features. Overall, many attributes can be characterized as memory and future apprehension related feedbacks[54] that the system acquires over the time, basically within the system itself. A similar set that has a strong temporal effect is the memories and feedback coming from the outside of the system. No village, country or town exists isolated, and one place can observe and adapt what is learnt in another place or culture without going through the same learning process. In this way memories and feedback tie multiple systems together across time. Likewise, the interactions involve not only the spatial and temporal boundaries but also the *organizing boundaries.* Organizing boundaries are related to hierarchical and intrinsic information connections of systems. In addition, some of these interactions are closely linked to how individuals and societies perceive their interdependencies, therefore, could also be seen as forming cognitive organizing boundaries. The memories and future apprehension related feedback relationships work across systems having partial and whole relationships. The changes in understanding and behaviour of individuals within a city, over the years, could affect the way the city's human networks would be organized and how the infrastructure and artefacts of the city would be developed. Even though it may take a long time to observe exact changes in visual patterns in physical space, it is clear that human cognition related to memories, learning, envisioning the future etc affect these patterns, and ultimately form human–natural systems whose boundaries are observed and experienced

[54] When speaking of temporality related to memories and feedback, it is important to note that some are short term and some are long term. Here the term memories of a system can represent long-term process of receiving feedback.

across many dimensions. Here the process of understanding one's environment can be argued as forming a system that both separates and connects the individual and his/her environment. In the same manner, other forms of human systems, such as networks, organizations, tribes, villages, towns, and countries, are connected with their environment (i.e., they are connected to higher and lower organization networks and natural resource bases). In this way even in a seemingly static instance, not only do the boundaries of a specific human–natural system relate to many subsystems and system entities and therefore span across several dimensions; they are also tied to an individual's subjective experience generated by relating to diverse systems. Understanding and interpreting[55] sustainability in these complex systems that include the observers themselves is a complicated process. Often the complexities involved in this process can be overlooked and specificities or general overviews alone would be derived instead of obtaining a holistic understanding and interpretations. It means that the observation process plays a key role in sustainability evaluation.

3. 4. 4 Method of observing sustainability boundaries

These observations of sustainability-related complex dynamics lead to a broader pragmatic question: can we adequately interpret, or in a later stage mobilize, sustainability with such complex patterns of boundaries[56]? Interpretation involves both understanding the complex dynamic patterns related to sustainability and the mechanisms that involved in identifying those patterns. For both steps, adequate visualization and stepwise observations are crucial factors. In order to observe these complex and evolving sustainability boundaries we incorporate two complementary observation methods. The first method is the layer view-based method. With it we intend to enable the observer to recognize the complex dynamics of the systems, and also that of the process of observation. Also the layer view-based method focus on the observation made in a relatively fixed time frame.

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[55] *Understanding* is different from both *information* and *knowledge*. Information deals with 'what' questions, knowledge with 'how' questions, and understanding with 'why' questions (Gharajedaghi 2011)

[56] Here we use the term 'complex' in general sense than including formal implications for instance that is of 'complex systems/complexity theory'

3.4.4.1 Layer view-based method

First we propose a preliminary framework that supports the visualization of different sustainability contexts and based on them different sustainability boundaries in a human–natural system. In sustainability evaluation we often focus on one system of a wider human–natural system, such as economy, society or nature, and interpret its sustainability. However, to make sound interpretations, it is also necessary to not only focus on that particular system alone, but also to refer to its environment. One group of entity that forms the environment to a particular focused system is the relationships it has with its surrounding subsystems. Another group of entities that form the environment is the explicit unsustainability issues observed related to the focused system. Depending on immediacy, proximity, and significance, these environments within which a focused system is contextualized varies, and as a result the observed sustainability/unsustainability conditions also would change.

By the layer view-based method we aim to strengthen sustainability observation process by highlighting such variations. To observe complex dynamic sustainability contexts of a human–natural system, first we propose to differentiate the system to 'focus–system’ and 'background'. The background would contain the environmental factors (described above) such as the information of the surrounding of the human–natural system and information of its own subsystems and the issues that those systems are facing (Fig 8).

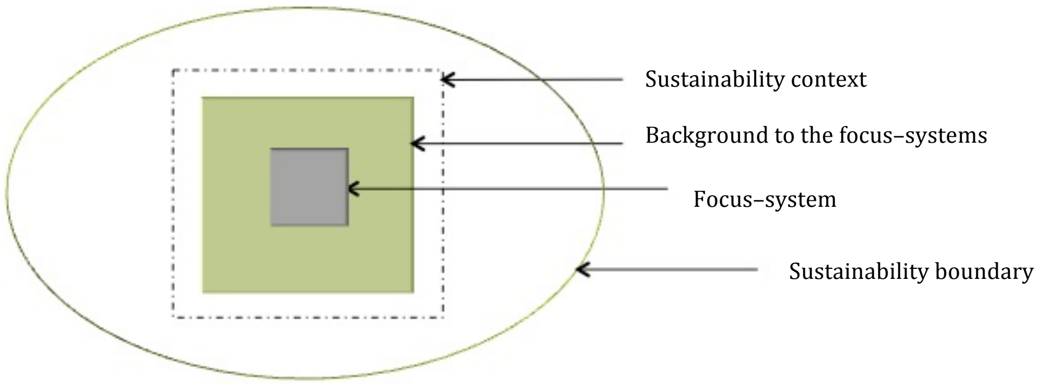

Fig 8. Illustration of sustainability boundary-described with relation to the context, focus–system, and the background

An observation process that focus on one system, by allowing information of others to form a background to make interpretations for it, engages separate cognitive distances[57]. In other

[57] Here the term 'cognitive-distance' is not used in a strict sense, however, it does not contradict with how it is being used in the field of psychology. In psychology, the term cognitive distance refers to people's beliefs about

words, the 'background' functions as a set of layers to obtain understanding of the focus–system. Also referring to the 'focus–system' and its 'background', two forms of understanding can be gained, namely primary understanding, that represents focused understanding, and, subsidiary understanding, that, when connected with primary understanding, can lead to holistic understanding[58]. The 'background' can be seen as storing information to support the primary understanding through subsidiary understanding. By interchanging 'focus–system' and 'background', and also, interchanging different 'background' of a particular 'focus–system', a holistic sustainability understanding can be gained for the human–natural system.

A significant factor emphasized here is that the focus–system and 'background' are differentiated by *cognitive distance*, and they can be interchanged. The system and background unit collectively provide different contexts to interpret sustainability of the macro human–natural system. Further the specific understanding derived as sustainability or unsustainability with relation to the system and background unit would place the first step to reach conceptual sustainability boundaries.

At this point, it is worthwhile to refer back to philosophical interpretations of emergence. For years, the question of 'what is emergence' has intrigued philosophers, evolutionists, complexity scientists, and a wide range of scholars. One early definition of emergence was developed in 1938 by sociologist Herbert Mead; "*When things get together, there then arises something that was not there before, and that character is something that cannot be stated in terms of the elements which go to make up the combination. It remains to be seen in what sense we can now characterize that which has so emerged*". Quoted in Mihata, (1997). As indicated earlier as well, the highest significance of emergence in the context of sustainability comes with changes in sustainability. Changes in sustainability can take the form of changes in human–natural systems, and also in the form of changes in the sustainability understanding. If we look closely as indicated earlier, sustainability doesn't have any meaning devoid of a decision tied with observation of what was, is, and will be the sustainability for a system. It is not an intrinsic property of a system, rather can be

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distances between places in large-scale spaces, places that are far apart and obscured as not to be visible from each other, while in contrast, perceptual distance refers to people's beliefs about distances between places that are visible from each other (Montello 1991). For the distance involved for focus and background layers, both the information explicitly perceived and that not explicitly perceived are involved, therefore in this instance, the term 'cognitive-distance' is regarded as more appropriate.

[58] More specifically, primary understanding can be gained by interpreting sustainability with relation to focus–system. Subsidiary understanding represents sustainability understanding that is gained by referring to its relationship with background (Polanyi 1974, 1977). Further, by the term 'holistic' we aim to represent the understanding that encompasses the understanding of both parts and whole.

regarded as a *context* of the systems. [59] It is important to note that, here the '*context*' introduce a different meaning than how the term was used this far. Also it is different from a system. A sustainability context carries the understanding of systems, relevant sustainability/unsustainability conditions of those systems, and the principles that inform such conditions. It is difficult to physically visualize such an entity. Despite this limitation, as a first step we propose to visualize sustainability context as illustrated in the figure (Fig 9).

The main target of identifying a sustainability context is to visualize sustainability boundary for a certain sustainability state (which can also be referred as a temporal state, a decision state). The boundary denotes what is sustainable and what is unsustainable. The sustainability boundary in a way represents sustainability indicators, or a form of predominantly qualitative (occasionally quantitative) measure of sustainability, however by using the term boundary the complexities with which such indicators or measures were reached also are aimed to surface and capture. In order to further explore sustainability contexts we propose to separate sub-contexts. To recognize these sub-contexts, the first step is propose as to separate background layers that provide different environments to the focus–system. The reason of selecting such layers is mainly to bring in the complex system based understanding in to the framework. In complex systems, we emphasised that one of the key features is the part and whole relationship. Also we emphasised that observing part and whole relationship in itself is a complex dynamic process that needs some shift in understanding, i.e., it is not only about part, and nor is only about whole. Focusing on part can inform the whole of the system, in this case the sustainability of a wider system, and also focusing on the wider context, in turn can influence the understanding of the part, or in this case the sustainability of focus–system.

Observing multiple Sustainability Boundaries

We return to the interplay of the mentioned two possible directions of framing the focused system and the background in a particular context. When a focus–system directly concerned with a particular issue becomes the immediate concern, the immediate background that informs sustainability/unsustainability of focus–system is the issue layer. The spatial and temporal distances recognized by the observer would then decide which systems to

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[59] Anderies at al., (2004) in their work in discussing how sustainability and two key concepts of dynamics of human–natural systems, namely, resilience and robustness, ask a timely question, how will actions by multiple individuals and firms based on 'sustainability concerns' effect properties of the global system in which they occur? in other words, does individual sustainability adds up to global sustainability? Looking at the diversity of contexts within which sustainability is addressed they also suggest the term 'sustainability decision making context' to be adapted to reach a common ground. The context holds the implications of observation, understanding, and interpretations of sustainability.

prioritize for being closely related to the issue. Also, a focus–system's relationship to those subsystems will contain the unsustainability issues and information required to perceive the sustainability/unsustainability of the systems. These information would involve systems that are outside of the focus–system. Therefore, the background in a way summarizes and brings the information that are relevant to describe the focus–systems sustainability closer to the focus–system. There could be several of such backgrounds that could be placed as layers (Fig 9).

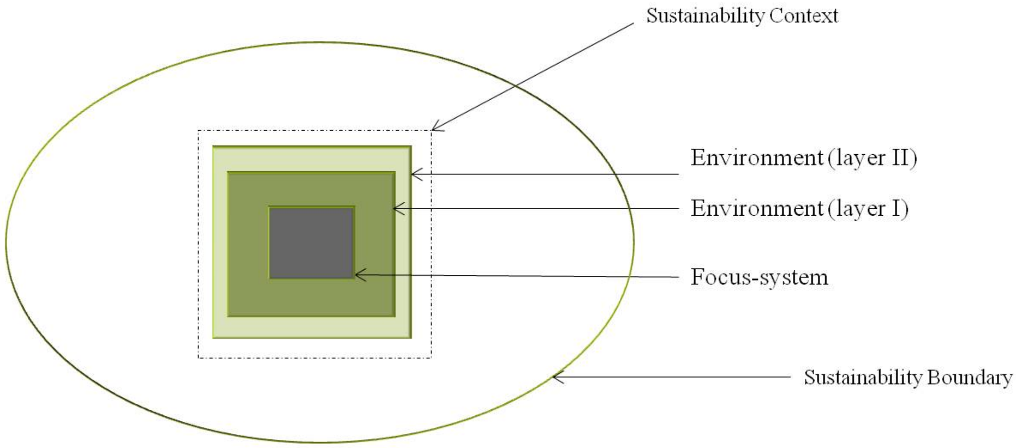

Fig 9.   Illustration of focus–system and the background layers
(Originally appear in Satanarachchi and Mino 2014)

Note: By separating focus–system and the background to it and observing them together, the focus–system is placed in a bigger context. In addition, by interchanging the backgrounds to focus system, Different part and whole relationships could be captured.

In figure 9, the background layers are shown in different colors. By changing immediate 'background' with which the system is observed, it is possible to conceptually view multiple sustainability boundaries. Interchanging the 'background' with which sustainability is observed involves a reflexive process. In addition, it is noteworthy that with every layer, each previous understanding constraints or support the new understanding of sustainability gained related to a separate layer. Therefore layer view-based method would set the foundation to see multiple sustainability boundaries for a system that would engage us reflexively observe the focus–system's sustainability. When one layer becomes the immediate background to the focus–system, the other layer goes to further background. Also, now there involves three separate cognitive distances (the term cognitive distance as mentioned, has specific meaning in the field of psychology, which is not what is intended here, however, it does not contradict this specific terminology). Conceptually analysing a focus–system relative to several of background layers enables us to recognize multiple sustainability boundaries. Note that, here still our understanding moves in the direction of part to whole, where scrutinizing the part, in a ‘differentiated’ manner allows to gain the understanding of whole (sustainability of the wide system).

In order to illustrate the layered view interpretation further, let’s go back to an example of the way sustainability is addressed as a concept in general. As described earlier sustainability takes different shapes and meaning in different contexts. Based on our earlier discussion, two significant layers to visualize sustainability can be recognized, namely; (i) sustainability/unsustainability visible in the form of issues (reactive sustainability) (ii) sustainability/unsustainability visible in the form of system relationships and their changes (proactive sustainability). When a certain focus–system is examined for its sustainability, these layers will provide the basis with which to understand sustainability in them. However, in order to connect these different contexts conceptually to sustainability boundaries, we need to closely explore a third entity, i.e., the observer’s understanding process. The understanding binds the step of observation with subsequent interpretations and evaluations, therefore also is a critical entity in sustainability evaluation. When we adopt the proposed method of observation, the observation process becomes a reflexive and iterative understanding.

Reflexivity refers to circular relationships between cause and effect. A reflexive relationship is a two way process with both the cause and the effect affecting one another. In sociology, reflexivity therefore comes to mean an act of self-reference where examination or action "bends back on", refers to, and affects the entity instigating the action or examination. In understanding or observing a phenomenon, reflexivity would reflect that the observer being aware of the observation process. When observing sustainability of a focus–system takes in to account its relation to its background we impose the features in the background to interpretations of focus–system. In the same manner focus–system also constrains what to consider as the background. In this process, the observer makes implicit choices in interpretation of focus–system, its background, and subsequently, the sustainability context. To make these choices each entity would support the others.

Iteration means the act of repeating a process with the aim of approaching a desired goal, target, or a result. Each repetition of the process also is called ‘an iteration’, and the result of an iteration would be the starting point for the next iteration. In the case of understanding a phenomena, an iteration would refer to the a already gained understanding bending back to inform a second understanding that involves factors which are novel to the previous process of understanding, i.e., reflexivity. Iterative understanding involves adding up one understanding after another to form a foundation to the next understanding. These two processes of reflexivity and iteration collectively engage differentiation and integration to form new understanding of sustainability.

3.4.4.2 Complex dynamics addressed by the foundational framework

At this point it is worth to reflect on how much this foundational framework addresses the complex dynamics related to human–natural systems. The observation process explained so far is closely related to complex systems themselves. In complex systems the parts describe the whole and vice versa. Depending on where we focus, what we see differs not only because of the characteristics of the focus–system but also because of background information that supports the focused understanding[60]. Their interaction creates the understanding of the sustainability boundary, which in this instance could be regarded as the whole. The reflexive and iterative observation process connects the part and whole. Further, a *cognitive process* that involves focus understanding and subsidiary understanding (Polanyi 2009, Polanyi and Prosch 1977) can be regarded as a complex dynamic process. In this way, the layer view-based method provides the foundation to observe sustainability boundaries in a complex dynamic sustainability context. Note that here we use the term 'sustainability/unsustainability context'[61] to denote a significant relationship between a particular 'focus–system' and its 'background'. 'Sustainability/unsustainability contexts' could contain prominent unsustainability issues (in terms of both problems and needs) and their direct implications for a particular system/systems and their evolutionary implications for sustainability. The complex dynamics that connect temporal states of the system may differ from the complex dynamics that connect the temporal states of the 'background'. In other words, the context connects multiple systems, subsystems, and issues in those systems, some of which become the focus while others move into background. We attempted to map these features of context to sustainability boundaries that conceptually have more evaluatory basis. Further, by making relatively simultaneous observations of systems at different distances, as the focus–system, its 'background' and several 'background' layers, and then interchanging them, would enable new forms of understanding to emerge, which subsequently allows us to view multiple sustainability boundaries as system of thoughts.

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[60] If we go in to the deep theory of complex systems, a key known type of visual complex systems is the fractals.

[61] At this point the explanation of sustainability context a s described in this thesis is not complete, even though the layer view-based method provide the basic foundation for that. An extension to this method would follow after the next section.

Systems as indicated earlier, are not just interacting wholes with similar organizing patterns, but also is an interpretation of such organization patterns. This is made extensively visible with terms such as 'social systems', 'cultural systems', and 'cognitive systems' being associated with everyday use of the word systems. Apart from basic characteristics, the idea of a 'system' carries within it the fact that its interpretation is a cognitive process, which starts at the outset of observation of system relationships, entities etc. These relationships, entities, etc spread across time, space, and organizing relationships, hence, the very idea of system may encompass the basis of complexity. On the other hand, by recognizing complex systems, we already step in the whole new dimension of complexities tied to the process of observation, which is inarguably conditioned by disciplinary training, internal mindsets, connecting patterns of insufficient and fuzzy data, so on and so forth. Also, it is noteworthy that the whole process of observing, interpreting, and evaluating sustainability engages the researcher in a process of developing meta–structures that aid in connecting different entities of observations in to one or several cohesive patterns that represent cohesive interpretations. For instance examining complexities in human–natural systems means observing the multitude of relationships it has among the systems, subsystems, and other system entities to make cohesive interpretations about the system. When observed in the light of complex systems, 'relationship' would basically mean that the parts are connected to whole and whole is connected to parts though relationships. In human–natural systems, the systems, and the subsystems, and system entities represent the wholes and the parts respectively. These systems, subsystems, and system entities vary from individuals to communities to more complex organizations. They would be connected to systems in the same level as well as in the higher and lower levels through energy and information. The process of understanding the interrelationships of boundaries that connect such multiple systems engages parts and wholes with respect to parts and wholes of such systems, subsystems, and system entities—that form focus and environmental relationship to their interpretations—and further, with respect to parts and wholes of understanding—that also connect focus-understandings to background understandings. This process can be viewed as creating an understanding that has emergent properties in its basis. Further, in observing complex dynamic systems, the information boundedness becomes one of their most significant characteristics to be aware of. In our context information boundedness has two-fold importance. Lazlo (1972) says, "Many things about the behaviour of a social system refer to the interaction rather than the individual of its members. Each social system manifests certain characteristics that it may retain even if all its individual members are replaced". The elements that characterize a social system are not only its members, but also the relationships of its members to one another and to the whole of the system they inhabit (village, city, country, planet). In a social system the relationships are formed by information-bonds, just as in a mechanical system the relationships would be formed by energy-bonds. As a result of the information bondedness, it is possible to observe properties that may be interpreted as emergent properties. There are two types of emergence that may occur linked to information. One is related to the understanding the complex dynamic nature of these systems. The second is the understanding sustainability as a complex dynamic process in them. The foundational framework does not yet differentiate between these two types of emergence linked to understanding. The highest significance of emergence in the context of sustainability comes with changes in sustainability. Changes in sustainability can take the form of changes in human–natural systems, and also in the form of changes in the sustainability understanding. When making an attempt to describe the change in human–natural systems a general idea of complexity automatically comes in. From a strict complexity perspective, change in systems or in sustainability point of view development in systems could be viewed as a natural and evolutionary process that is neither imposed nor random. These processes can be more comprehensively regarded as component parts of the whole system organization, which evolve over the time. Also as described earlier when we acquire sustainability understanding the understanding occur as an emergent process. Viewing human–natural systems as complex dynamic systems with the help of layer view-based method, the process of understanding interrelationships that connect multiple systems or parts of systems can be viewed as creating a system of awareness. When the general term of understanding is narrowly used to represent all the distinctive activities involved in recognizing sustainability/unsustainability conditions in human–natural systems, and those involved in problem recognition, it is possible to say that sustainability is understood through an interplay among multiple layers and a spatially and temporally dependent, inside–outside, focus–background relationship that engage varying cognitive distances in handling information. However, the whole process could also be visualized as one thought process that binds all these layers, and further metaphorically could be visualized as a path or a stream that connects multiple sustainability contexts across space and time.

Here, as a first step to observe sustainability contexts we select a frame that differentiates between a ‘focus–system’ and its ‘background’. The frame helps us be aware of the limitations of a sustainability analysis, while strengthening our understanding/appraisal by helping to project multiple faces of sustainability to sustainability boundaries. When viewing sustainability in human–natural contexts, in the face of multiple systems, we argue that a similar process results in multiple boundaries of sustainability. There are existing patterns of interactions in human–natural systems. With disturbances, these patterns may be altered to create new patterns of interactions. In understanding a system’s sustainability, the understanding process that is sensitive to these patterns of interactions itself can be regarded as a complex dynamic process. The framework is expected to capture the complex dynamic nature of human–natural systems and the process of understanding them. This observation method could be compared to systemic view methods such as that supported by the soft system methodology. Soft system methodology that we described earlier, is a method that adapts a systemic view to observe and frame systems having the aim to incorporate the diversity of understanding of stakeholders (Wilson 2001; Trochim 1989). Such conceptual models aim predominantly to reveal the value judgments behind a line of thinking and the analysis process. In this regard, the layer view-base method also has the capacity to reveal different sustainability boundaries and to surface the observation and understanding process behind it. However this is a first step, and for a solid analysis of sustainability, these boundaries also have to be recognized in an explicit manner. Additionally, it is preferable to recognize their interlinks, prominent dynamic behavior patterns, and their role in altering sustainability states in a sustainability path. These streams of understanding should not be viewed as linear relationships but rather as involving complex and dynamic mechanisms such as feedbacks, memories, and complex organizing patterns, which in turn involve visible driving forces, reinforcing conditions, and damping conditions between temporal states of awareness/understanding. Further the change in understanding involved in these attempts may differ from one another, specially the change that are related to a stable state and the change that are related to the transition processes. Therefore, it is necessary to study further the mechanisms that form stable states and affect the transition between them, forming what we call 'dynamic sustainability boundaries'.

3.4.5 Summery at the end of framework-Section II

Two main factors significant with relation to complex dynamics related sustainability observation are;

(i) There are complex dynamic interactions of the human–nature system form sustainability/unsustainability conditions, and

(ii) There are complex dynamics involved in observing these complexities

We recognize the two approaches as very much interrelated, and also they generate significant other implications such as multiple facets of sustainability.

We have proposed a foundational framework (the first step of a macro framework) that aids in visualizing sustainability in human–natural systems, in a relatively stable temporal state, giving enough significance to the complex dynamics involved in the observation process. To explore the visualization, we use a concept of the sustainability boundary. Two types of boundaries were illustrated and we argued that the observation involves soft boundaries of sustainability.

The key characteristic of the foundational framework is the layer view-based method. The layer-view based method introduced a system and background unit as a unit of observation that enabled us to differentiate general understanding of sustainability to partial understanding. With them we place the foundation to recognize sustainability boundaries in a reflexive manner. As examples we recognized two generally relevant layers that are useful in viewing sustainability in human–natural systems, namely the system-based views and the issue-based view of sustainability. Connecting them with the insights from the field of complexity we described the complexities associated with observing each of these layers. By introducing this first step of layer view-based method of observation, we lay the foundation to recognizing multiple and complex dynamic sustainability contexts. The reflexive and iterative process to observe sustainability boundaries supported by it in itself is a complex dynamic process that involves 'emergence' in sustainability understanding.

Finally, it is important reemphasize that boundaries of sustainability involve simultaneous consideration of multiple faces of sustainability, which reflects the complex dynamic characteristics of the human–natural system, and, that the recognition of boundaries also is a complex dynamic cognitive process.

Limitation and further steps

The framework up to this level explored the complex dynamics tied to the systems and the complex dynamics tied to the observation process, and their influence over the process of evaluating sustainability. In this stage it does not yet take in account variability in governing principles that inform sustainability/unsustainability in these systems in explicit manner, nor does it consider the variability in sustainability across a long period of time

Up until now we limited our discussion of complexities and results of complexities in to a relatively short period of time, and focused more on observing process than other processes involved in generating complex dynamic changes in systems. In this scope, with respect to sustainability principles, we stayed in general interpretation. We selected two prominent macro branches that lie in the interface of complex dynamics and sustainability, namely, problem–driven and planning–driven approach, and argued that implications of sustainability upon the systems we analyse vary depending on such conceptual orientation. In addition, while noting that there could be different types of contexts, the discussion was more focused on the contexts generated by multiple conceptual orientations (linked to present time implications of different forms of actions i.e., solving an immediate problem, and planning for long term wellbeing). However apart from them, there could be other types of contexts, such as, contexts generated by system interactions (spatial interactions as, interactions of social system with economy, a social system with nature, and temporal interactions as that of system states over past, present and future) and also contexts generated by sustainability principles such as limits to the natural resources, and intergenerational justice and intergenerational justice in terms of human–system's wellbeing.

Therefore the next attempt is to see if the already identified method to observe sustainability in a short temporal state can be extrapolated to interpret sustainability in a long-term changing complex dynamic context, while overcoming the limitations of the foundation framework.

Conceptual framework-Section III

3.5 MACRO FRAMEWORK TO OBSERVE AND EVALUATE SUSTAINABILITY IN A COMPLEX DYNAMIC CONTEXT

Overview

This section expands the theoretical development done so far to observe sustainability boundaries in a long-term changing situation.

It is strongly connected to the previous section where a method that supports in observing sustainability boundaries in a temporal stable state was explained.

We expand the layer view-based method with another complementary method, namely, the dimensional view-based method to interpret sustainability not only in a relatively stable but a changing context. Further we strengthen the framework to utilize sustainability principles to sustainability evaluation.

In this section, what those dimensions could be, and their roles in the observation, understanding, and evaluation of sustainability are explained.

Finally we discuss the framework's capacity to guide an evaluatory process in sustainability.

Keywords- dimensional view-based method, dynamic sustainability boundaries, sustainability sphere, driving force, feedback

3.5.1 Introduction

Visualizing sustainability boundaries related to focus–systems and background layers alone is not enough to come up with holistic and solid enough interpretations of sustainability. It is also necessary to refer to explicit sustainability/unsustainability informing principles and conditions to make solid interpretations. In this section we aim to incorporate general sustainability principles and context specificities for the process of evaluations. In the foundational framework, these factors were dealt in the form of pre-given issues, and the basic conceptual understandings of sustainability, such as the significance of special, temporal interrelationships, complex dynamic changes in systems, and concept's inherent value laden and normative features—mainly by discussing different possible ways of observing the context (issue focused observations vs. system focused observation). However, by stopping there, the evaluator is not made aware of the importance of the sustainability principles that could shed light to different contexts of sustainability. He/she is yet given unguided fuzzy terrain to deal with these principles rather unconsciously. Further without having proper guideline many of important local specificities may be missed. Therefore, this third section aims to strengthen the utilization of sustainability principles and local specificities in the evaluation process in a more rigorous manner.

Further, the layer view–based method enable us to address sustainability of human–natural system in a relatively small time scale. The method highlighted reflexive and iterative understanding-based observation within a small time span. This section, focus on expanding the observation method to see long-term sustainability/unsustainability changes in a bigger time scale. Such long-tem changes reflect the feedback processes that may involve several of temporal states and transition phases between temporal states. In order to expand the framework for a changing context, we could start by referring to questions such as, what would be the implications of the already described observing process on sustainability state changes, and how one would extrapolate similar understanding to observe changes in sustainability conditions over the time. How such a framework can be strengthened as an evaluation methodology? In such a framework what can play the role of the background layers of the foundational framework?

A simple point to start would be to separate past, present, and future states of sustainability. Just as in the case of sustainability state, to describe in between states, it is necessary to have a good idea of patterns and mechanisms of changes across the time scale. To interpret sustainability in present state needs the information path of the system in the past, and likely future paths. How we acquire such information is usually through observing past and future temporal states (usually as indicators/indexes), however, in addition to them by regarding sustainability as a path, we are equally interested in seeing the transitions between states. (Note that these states are necessarily evaluatory states, rather than actual sustainability/unsustainability states. Once again it is good to remind the earlier highlighted point, that, sustainability is a decision of an observer. The observer could be a practitioner, a decision maker, or a citizen. Further there may be multiple observers involved, all having the intentions of objective and scientific interpretations, still, there would always be the element of subjective evaluation involved. Therefore when we say past, present, and future states, among other tangible, measurable, and solid characteristics, their subtle features such as memories and future apprehensions for sustainability would also be reflected in these sustainability interpretations).

In order to see transition between states, first it is necessary to have some stable states as observing entities. It is important to note that with the complex dynamic patterns attached to the systems, the term 'sustainability state' may carry different and weighted meanings, such as implying a stable state of certain sustainability conditions, or a stable state in terms of interactions among systems' subsystems. When we recognize similar patterns of interactions between subsystems for a certain time period, then even if the interactions are continuously taking place (dynamic condition), still we can regard them as being in a relatively 'observer-point-of-view stable state'. The change of these interactions, or configurations of interactions may theoretically denote a transition to a new sustainability state. That means, when we observe changes in patterns, then no longer we can describe or analyze the system adapting same types of observations (e.g. focusing on some particular subsystems, system relationships or particular unsustainability issue as resource limitation). Further, we have to have an observing method that allows us to see what happen in between these 'dynamic yet stable temporal states'. In terms of recognizing conceptual patterns, it means recognizing similar complexities to what we observed in temporal states (that is across space)—not only across space, but also across time. In reality complexities across time as earlier indicated can be observed as habits, memories, past learning, future apprehensions, goals, etc. In terms of mechanisms the observation involves recognizing feedbacks, feedforwards, and also some emerging behaviors in the system. Such feedbacks and feedforwards connect two consecutive stable states. How this connection happen is in two ways, one is as in the earlier situation, without observer involvement in it. There can be internal changes that are strictly linked to the complex dynamic nature of the systems that we observe. For example (i) complexity theory seems to suggest that all living organisms are self-steering within certain limits (iii) complexity theory highlights the continuous emergence of new levels of organised complexity within systems. Even though we do not have enough basis to argue all human–natural systems would act as living systems, in the light of complex dynamic nature of these systems, forming new sustainability states can be in one way understood as formation of these new organized complexities. Further, beyond the actual changes in reality, in the interpretative level of observer changes in sustainability state is tied to the recognition of those actual changes, and also to the changes of his/her knowledge and views that bring new understanding from one level to another. This second way is important especially in situations where human–natural systems do not show strictly complex system behaviour. In such situation still the observer can recognize (possibly through a reflexive process as described under the layer-view based method) sustainability states as going through stable conditions, where interactions complement each other to maintain the system stability with respect to those interactions, and changes to such stability creating new stable states (Fig 10). In this later instant, the observer can also explore the factors that drive such changes.

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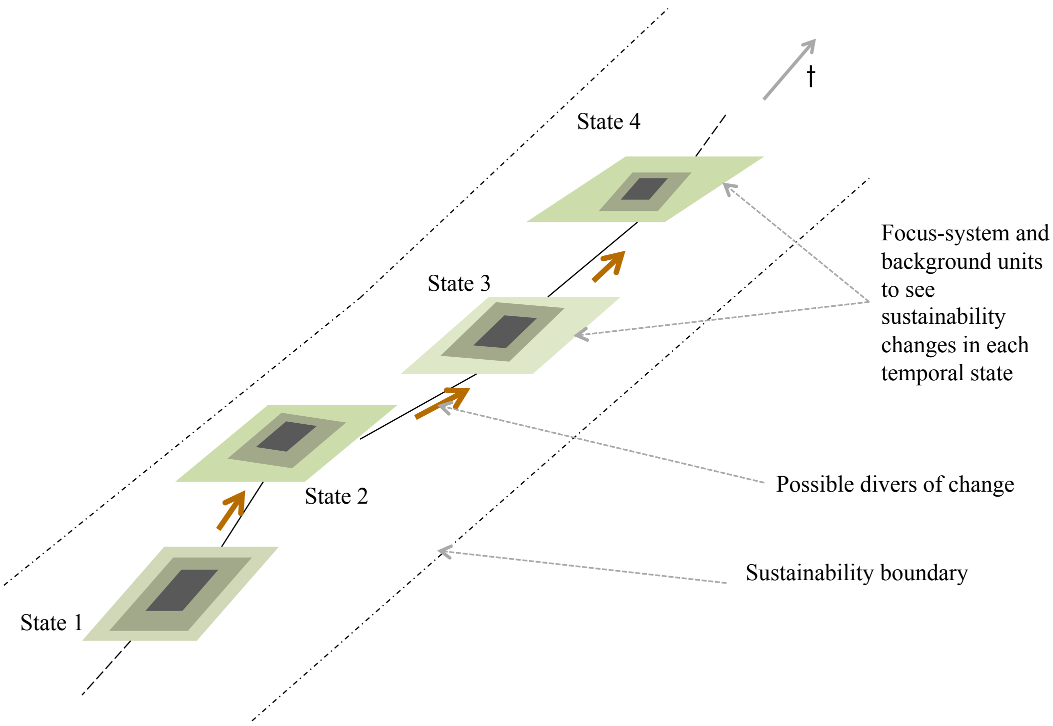

Fig 10. A possible way to recognize patterns and mechanisms of sustainability change in human–natural systems

Note: The drivers of change could be the effects of feedbacks and feedforward between each state that may solidify the current state or transform to a new state

Observing changes involves observing patterns as well as mechanisms of changes. At this point not only complexities and strictly complexity related dynamic patterns, but also other general changing patterns need to be considered. When interpreting changes, it is required to examine the changes that occur in what we call as stable temporal states, and also between temporal states. In the vein of complexity, exposing the emergent properties that can characterize these changes such as, self-organization, self-regulation formed by feedbacks as recognizable patterns is one way of interpreting these changes. The observing methodology needs to provide a structural basis to visualize these factors. In order to provide such a structural basis following features in the interface of complex dynamic and sustainability need to be considered.

First since our aim is for sustainability evaluation, to interpret sustainability in a specific human–natural system, we need some form of guidelines to see sustainability in them. For this to a certain extent the observer has to rely on some general principles of sustainability. As mentioned in the section I of the framework, some principles as the intra and intergenerational justice, wellbeing, limitation of natural resource base, can be used as easy directional guidance. However not always we can rely on general sustainability principles to determine what is sustainable and unsustainable for a system. Therefore secondly, contextual features play a key role in generating sustainable/unsustainable conditions. Thirdly, when we say changes between temporal states, these changes can be characterized in to two significant categories.

i. The changes that are occurring in human–natural systems
ii. The changes as practitioners and evaluators we perceive in human–natural systems

It is important to make the distinction between these two ways of seeing complex dynamics. As we argued in the first section, separating them allows us to make the observing process a reflective process, which can then address the 'complex complexities' described in chapter 2. Further, we need to incorporate the very basis of the idea of methodology. Earlier we summarized some useful ideas in the outset of developing the methodology.

i. The methodology has to be structured, and structure should be visible and should have the capacity to guide a thinking process
ii. It has to be flexible (to be able adopt in different contexts)
iii. It has to be explicit to provide a defensible audit trail

These factors imply that the framework has to have the balance between complexity (information richness, and ability to incorporate diverse information) and simplicity (aggregated presentation of information, and logical consistency); and also a balanced degree of generality and contextuality. Such a balance is likely to be supportive for the cognitive process between observation and evaluation. Also it could guide the observation of actual complex dynamic changes in the system. Finally the framework has to be explicit enough to create dialogue between multiple stakeholders.

Recognizing these requirements the second step of the framework introduce a dimensional view-based method to visualize sustainability/unsustainability changes in a system.

3.5.2 Dimensional view-based method

In addition to the basis given by the foundational framework, we also need some specific directions to make rigorous evaluations. Usually with sustainability indicators or sustainability metrics we try to achieve such rigorous evaluations. However in the very preliminary stage of sustainability analysis, to go immediately to well-established indicators is a difficult task. Not only difficult, sometimes it can be erroneous as the requirements of specificities in indicators, or other similar techniques can often lead the observer away from significant contextual features and may lead to generalized or skewed evaluations. To utilize such general and erroneous evaluations in subsequent activities such as future planning could be harmful. Therefore it is important that the evaluation methodologies are able to adequately capture the context specificities, preferably in a systemic manner. In the absence of a systemic observing approach that can extrapolate contextual understanding to generalized understanding, then there would be the situation that one recognizes that complexities exist, however without having means to integrate them to evaluations, place them all as the normative, subjective, immeasurable, or ideal forms of softer (and deeper) side of sustainability, and eventually navigate away from them. The end result would be as same as a situation where one would not be aware of the complexities in the first place. Therefore we emphasize that there should be systematic way to observe human–natural systems'[62] sustainability that can surface the complexities. In order to achieve it, in this section, we combine the earlier proposed method to visualize the complexities of human–natural systems and the avenues along with which we usually view sustainability via a set of dimensions. The dimensions, as we regard them, need to fulfill some key roles;

i. Aligning with basic sustainability principles
ii. Acting as an indicator and acting as a variable
iii. Incorporating problem-based and future-planning-based understanding of sustainability
iv. Incorporating both soft and hard types of sustainability boundaries.
v. Allowing the complexities to be translated to a systematic view method.

[62] Please refer to the literature review and the section I and II for an extended discussion on human-natural systems and the selection of the terminology.

There are some specific principles or characteristics that form sustainability or unsustainability understanding. For instance the physical resource limitation/availability is one common entity in interpreting sustainability both in global and local contexts—even though in which form the limitations are experienced in each context would vary. Also the notion of sustainability implicitly carries long-term perspectives, elimination/avoidance of catastrophic conditions. Further as mentioned, the role of the dimension here is to provide an easy bridge with which the complexities of human–natural systems and complexities in observation process can be tied to sustainability understanding. Rather than strictly defining what is sustainable and unsustainable in all-inclusive manner (as the meaning of dimensions in another context may suggest to provide), their role here is to bring the observer's understanding close to an assessing journey in itself. Therefore the dimensions need to have some form of sustainability/unsustainability indicating capacity. In addition, from the very outset our interest is to see sustainability as a changing process. Therefore, the dimensions with which we try to see the changes and the boundary conditions need to be able to reflect these changes either in quantitative or qualitative manner. Also as mentioned earlier, depending on the approach we adopt, i.e. whether as problem solving, or planning for sustainability, the conditions that become significant will vary. It is understood that both approaches are equally significant therefore need to be taken in to consideration in identifying dimensions. The fourth point, which also was discussed in section I and II in framework, is related to the fact that there are different types of sustainability boundaries. Usually the more physical and easily recognizable and measurable types of boundaries (referred here as hard boundaries) are easy to recognize. However as extensively argued in the whole of the thesis, there are non-physical and not easily recognizable or measurable boundaries existing—such as socio-cultural boundaries that represent groups, the cognitive/perceptual boundaries that represent individuals—that influence views on sustainability. In the cause of selecting dimensions these variations also have been taken in to account. Last, but not least is that the basic idea behind selecting these dimensions were to translate the complexities in a system based observing method, hence, from the very outset their role in generating, increasing, reducing, and mobilizing complex dynamics were regarded. These dimensions do not claim to define sustainability, rather is proposed to direct/guide sustainability observation in a human–natural system. Also in specific contexts there may be some other dimensions that resemble sub-dimensions to what proposed here. They would be more readily visible, therefore need to be highlighted.

The selected dimensions are;

- ***(i) Sustainability-linked knowledge***
- ***(ii) Sustainability-linked worldview***
- ***(iii) Resource related limitation and availability***
- ***(iv) Well-being views***
- ***(v) Policies, rules, regulations, and governing practices***
- ***(vi) New creations, innovations, and artifact***

In the following sections we would briefly describe those dimensions and their role in sustainability observation and evaluation.

3.5.2.1 Sustainability–linked knowledge

The term knowledge is a broad topic. If we go to general interpretation of knowledge, even if we stay in the domain of sustainability, still the discussions can be extremely deep and boundless. However, it is also important to start with some form of general understanding. According to Holzner (1972) "knowledge can only mean the 'mapping' of experienced reality by some observer. It cannot mean the "grasping" of reality itself [...] rather may defined as the communicable mapping of some aspect of experienced reality by an observer in symbolic terms (Holzner, 1972: Adapted by Holzner and Marx, 1979). This mapping can take different forms in individuals and groups such as locals and experts, and be acquired in different ways such as product of personal understanding, or a product of a guided experience etc. By sustainability–linked knowledge, we mean the knowledge that is predominantly connected to unsustainable issues, and to systems that are experiencing those issues. In pragmatic sense, knowledge of resources, wellbeing, policies, regulations, artifacts etc., inform sustainability/unsustainability conditions. In theoretical sense, there are different types and categorizations found within knowledge relevant to sustainability, such as; philosophy oriented knowledge as personal, procedural, and propositional knowledge (Polanyi 1974); reality based knowledge as explicit and tacit knowledge (Polanyi 2009); context based embedded knowledge as local and disciplinary knowledge (Ramakrishnan 2000; Berkes et al. 2003) [63]etc. They inform varying principles with which

[63] Explicit knowledge is formalized and codified, and is sometimes referred to as know-what (Brown and Duguid 1998), therefore, more straightforward to identify, store, and retrieve (Wellman et al. 1992; Wellman 1997). Tacit knowledge was originally defined by Polanyi in 1966. It is sometimes referred to as know-how and refers to intuitive, hard to define knowledge that is largely experience based. Because of this, tacit knowledge is often context dependent and personal in nature. It is hard to communicate and deeply rooted in action, commitment, and involvement (Horvath 2000; Nonaka 2002; Collins 2010).

sustainability/unsustainability is interpreted for a system. Collectively these different knowledge types can be argued as giving the observer the variable interpretation grounds with verifiable capacity. Their significance in sustainability evaluation would vary depending on the adopting intervention or research approach, such as problem-driven or planning-driven interventions and descriptive, analytical, or transformative research methods (Watzlawick 1974; Holzner and Marx 1979; Heylighen 1988; Salas-Zapata et al. 2012; Wiek et al. 2012a,b; Ness et al 2010). In addition, recognizing changes to knowledge also is significant to observe sustainability change. Gross (2007) distinguishes five different types of dynamics forming knowledge, namely, ignorance, non-knowledge, negative knowledge, extended knowledge, and nesciences. Ignorance denotes knowledge about the limits of knowledge in a certain area that can increase with every state of new knowledge. Non-knowledge denotes what is not known, yet, is being taken into account for future planning. Negative knowledge addresses what is not known, but considered as unimportant or even dangerous, and nescience, the lack of any knowledge that leads to surprises. All of the above mentioned types of knowledge and nonknowledges go through a further process of forming the understanding, acceptance, and interpretation of sustainability in the human system.

Specially in terms of nonknowledge, Gross (2010) argues that, coping with issues of ignorance requires trust among key stakeholders, as when decisions to be made quickly, stakeholders need to rely on each other's expertise and flexibility. Deriving on an earlier argument that trust can be seen as a hypothesis between knowledge and nonknowledge he further observes that preliminary knowledge derived from nonknowledge can be a starting point for new planning activities. There cannot be any nonknowledge without knowledge. At least a minimum amount of knowledge is necessary before nonknowledge is perceivable. Extending his interpretation, we recognize that these different types of knowledge represent interconnected stages that could lead from one to other over the time. Additionally, it is important to note that linked to ne-sciences and nonknowledge, there is an important aspect to note, i.e., uncertainty. Most of the issues that appear in sustainability as mainstream, and also the mechanisms and policies involved in handling changes towards a more sustainable state as they claim, are linked with uncertainty. In fact with complexities we go through an era of uncertainty. In this case the idea of trust become significant as most of the planning, and decisions necessarily involve trust to some degree. In addition knowledge effects how the policies, regulations, and governing practice come in to

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Embedded knowledge refers to the knowledge that is locked in processes, products, culture, routines, artifacts, or structures (Horvath 2000; Gamble and Blackwell 2001). Knowledge is embedded either formally, such as through a management initiative to formalize a certain beneficial routine, or informally as the organization uses and applies the other two knowledge types.

existence, and further, how these new entities will be absorbed, face friction, and conflict. Also sustainability evaluations in systems would highly depend on the value positions, objective views regarding sustainability, or often some internal and more prominent need that the society is driven with, such as the need for development. However, it is also noteworthy that individuals or societies do not form understanding or make decisions completely relying on knowledge (especially explicit knowledge). The understanding is tied to a deeper meaning making process inside the individuals. In the same way their actions also would not always be well thought actions based on explicit knowledge, rather often would be relying upon day to day common-sense, internalized wisdom, etc. *These factors clearly indicate internal or subtle dimension in personal or collective domain that interact with knowledge to form dynamic conditions that can push our understanding in to new levels*.

3.5.2.2 Sustainability–linked worldviews

Fig 11. Old and young woman often used to illustrate different perspectives source: Heuer Jr.,1999 Psychology of intelligence analysis[64]

Similar to knowledge, worldviews are closely tied to the understanding process. Worldviews in general and in conceptual sense can be regarded as a set of images and assumptions that the human system holds in observing reality. Depending on the context, it is identified with variety of concepts, such as gestalts, mindsets, mental–models, mental–structures/frameworks, and frames of mind (Gardner 2011; Covey 1991; Marcum 2009;

[64] It was noted by the author that the picture was originally published in Puck magazine in 1915 as a cartoon entitled "My Wife and My Mother-in-Law."

Binder and Scholl 2009; McEwen and Schmidt 2007; Moutuari 2005; Gidley 2010), and often is visible through metaphors, paradigms, inquiries, disciplines, and so on. Koltko-Rivera (2004) describes worldviews as coherent systems of beliefs that shape how individuals interpret and interact with the world by shaping how they think and, consequently, what they think about it. They define what can be known and done, and what goals should be pursued, functioning at a level more abstract than the level of theory and observation (Grunig and White 1992). In other words, worldview of an agent represents its value orientations[65]. They form and strengthen meta–structures[66]—with which agents observe and analyze surrounding—by utilizing subtle meaning making processes (Polanyi 1977) and ethical justifications (Heylighen 1988; Funtowicz and Ravetz 1993; Allenby 2006; Armand 2012; Beckers 2012) that are crucial in interpreting sustainability.

Further, worldview has a close relation to idea of a society's attitude and orientation towards change. Nussbaum provides a list of capabilities that are considered as relevant for human well being as, physical integrity, imagination, thinking, emotions, reflections, other species, games, political and material control over one's own environment. Further, Van Egmond and De Vries (2011) suggest that sustainable development in the Bruntland definition implies the continuation of certain capabilities, where capabilities among other factors depend on a person's *'value orientation'* for his or her individual perception of the good life, making the idea of sustainability to be grounded upon multiple normative standpoints that the human system holds for its notion of wellbeing (Van Egmond and De Vries 2011). In practice, affinity to specific value base (e.g. of quality of life) will coincide with affinity to specific beliefs about how to achieve these ends by quality of life means. As with controversial complex issues such as causes and consequences of climate change, application of genetically modified organisms (GMOs) and large-scale development of nuclear power, the values will inevitably play a role in how to assess the potential for real solutions, the interpretation of risks involved, and hence the relevance of the corresponding capabilities (Van Egmond and De Vries 2011).

In parallel, we also argue that capability is a function that links the value orientation, or the underlying human worldviews that connect with, not only the human wellbeing, but also several other dimensions that influence sustainability evolution of a context. In one side, the choices are being made at different levels in society, the individual level, society level,

[65] By agents we mean the individuals and cohesive groups as networks and societies.

[66] While meta-structure is a term found in studies of ontology, Beckers (2012) introduces the concept of meta-structures to analyze these clusters in detail. He defines a meta-structure as a historically evolved structure composed of four elements—(i) basic assumptions, (ii) basic evaluations, (iii) driving forces, and (iv) institutionalizations—that substantially affect societal and individual thoughts, actions, and relationships. The author explores the implications of meta–structures in formation of ethical understanding of sustainability. A meta–structure related to the observation can be further identified as a system of thoughts (Jenks 2004).

policy level etc that also can range from local to national to global scale. Their perception of wellbeing also is tied to one or several of these levels. In addition, the relationship between wellbeing, capability and the value orientation show a close relationship with the resource availability/limitation in terms of how the limitations are perceived. Therefore, how the sustainability or unsustainability boundaries are understood also directly affect not only the choices of wellbeing, but also the current and future orientation of oneself and one's society in elation to sustainability. How does worldview supplement in understanding a context's sustainability with regard to interconnectivity and the evolution? Answering this question is linked to understanding the relationship between *pattern* and *structure* in visualizing a context related to its sustainability. In this understanding, it may be possible to consider worldviews to act as a binding factor. On the other hand worldview also could be the reason for the conceptual diversity in sustainability. McKewan and Schmidt (2007) states, "Sustainability is as much about the mindset through which the world is seen as it is about the activities taken in support of it". Varey shares that "at this stage of the development of the concept by discourse, no one can tell you what sustainability means, only what they mean by it" (Varey, 2003). Francisco Varela further illustrates this statement by saying, "in contrast with what is commonly assumed, a description, when carefully inspected, reveals the properties of the observer" (1975, p.22). In a complex, and dynamic context landscape what role the worldview will have in mapping, understanding and addressing? Beyond the role in generating conceptual diversity as such the worldview or mind-sets have even more process-oriented implications, especially with relation to formal observations and evaluations. Cook–Greuter (2004), a developmental researcher, clarifies that there are two primary ways we develop in understanding: horizontally and vertically. Both are instrumental in human growth; yet occur in different ways at varying rates. Horizontal development refers to increasing capacities related to knowledge and skill development within a current mindset, whereas vertical development refers to a transformation of someone's entire way of perceiving and experiencing the world.

Further, worldviews are often visible through metaphors, paradigms, and sometimes as modes of inquiries, disciplines etc as underlying guidance principles in structuring explicit knowledge such as meta–structures (Becker, 2012). Capra (1996) identifies three different types of views linked to sustainability;

Holistic view	*Functional whole*
Ecological view	*Functional whole along with perception on how it is embodied in a natural and social environment*
Perennial Philosophical view	*Spirituality, philosophy, traditional cultural views etc*

The Web of Life, Capra (1996)

While holistic view[67] as indicated here, can be argued as a particular guiding/ directional role in sustainability, ecological view can be argued as representing an understanding mechanism for sustainability. Philosophical views on the other hand can be argued as creating a discourse of ethics (Cairns, 2003 Armand, 2012) that is implicitly linked to sustainability evaluation. Table 1 shows how some of the sustainability–linked worldviews could take the form of metaphors. We could expect that the worldviews with the influence to and by other dimensions may speed up adaptation of system entities to new states (ex. new sustainability interpretations), and further may play a role in consolidating current or new states. Apart from that, they also would create background to sustainability understanding, or providing multiple different contexts to sustainability. The idea of context as described earlier is closely tied to what Becker (2012) refers as meta–structures or in a slightly different way of visualizing, what Bohm (1998) referred as systems of thoughts. Also, these worldviews change and develop over the time (Lynam 2012), influencing the change in an agent's sustainability interpretations. Therefore, worldview could be regarded as operating in a subtle level, to define and change the sustainability conditions as well as the sustainability understanding of a system.

Table 1. Dominant Views and Metaphors that are explicitly linked to sustainability discourse[68]

	Human and nature relationship, contexts	
Resource limitation	*(forms)*	*(functions/mechanisms)*
Finite earth, Footprint	Machine, Organism	Conflict, survival, Negotiation, growth, anti-growth
Machine, Organism	System	Co-evolution, co-existence, adaptation
	Culture	
	A Story, An art	

[67] Please note that we have given a separate and elaborated interpretation of holistic view elsewhere in this study. The same term of original text is mentioned here.
[68] *Metaphor is* A figure of speech in which a word or phrase that ordinarily designates one thing is used to designate another, thus making an implicit comparison.

3.5.2.3 Resource related limitations and availability

The discourse of sustainability is highly linked with the increased attention towards resource limitation, especially when considering the limitations faced by the planet as a whole. The dialogue of limitation goes back as far as the limits to growth (Meadows, 1972), and is closely tied to concept such as finite earth, ecological footprint, which are in the planetary scale. Also in the regional and country level, issue such as depletion of forest cover, biodiversity etc., have created the understanding that the human impact on earth system has severe and long term effects that exerts limitations to the necessary balance to the eco-system, and subsequently for human survival and well-being. The meaning of resource limitation spans across a wide scope to include limitation related to not only the often-discussed physical resources, but also other forms such as human, social, and cognitive resources. The Bruntland report by addressing 'needs of current and future generations', also highlights the limitations to meet those needs across space and time. In other words, the idea of equity and justice over time and space can be regarded as one of the key underlying themes in the early interpretations of sustainability. However over the years there it was understood that "the development that meet the needs" as it is, opens up a paradoxical situation where needs are unlimited and unknown. Also it is erroneous to understand the limitations that a system is facing only in terms of the limitation of resources as resources per se. For instance, Sen (2009) argues that poverty is not a reflection of resource deprivation, instead in strict sense, a 'capability' deprivation, therefore, GDP/GNP are not accurate representations of sustainability. Resource deprivation/limitation can be seen as a function that is one step ahead of capacity. To ensure sustainability in a limited resource scenario, empowerment of people also needs to be a focus instead of focusing solely on saving the resource base. Ensuring sustainability would be conditioned not only by current limitations, but also by factors such as the society's capacity to create and innovate, and its capacity to utilize the social and human capital for new pathways, and so on. Rather than making functional differentiation, these two factors could be seen as having two different underlying views embedded in the way of interpretation. They are the views of the limitations as resource—as an external factor—limitation and views of limitations as capacity—as an internal factor—limitation, where the latter has the agency power to change (The idea of capability also is liked with the freedom as it gives a central role to a person's actual ability to do the different things he/she values of doing. In other words it shifts the focus from means of living to actual opportunities).

Generally, the limitations could easily create instability in systems, triggering them to change to face the limitations. These changes could be of the forms of short-term adaptations as well as system reorganizations that have significant long-term implications. Therefore, limitations not only would define sustainability conditions in a system, but also, may trigger significant sustainability/unsustainability changes that alter its path in long run.

3.5.2.4 Well-being views

As the flip side of limitations, well-being views specify what conditions individuals and societies apprehend as sustainable/unsustainable, therefore, become essential considerations to interpret sustainability of a human–natural system (Dasgupta 2001; Nuemayer 2004; Alkire 2002). The ideas of wellbeing are old as human discourse and are generally reflected in numerous discussions of the 'good life' and the 'the good society' (Dodds 1997). Well-being and its implications on sustainability need to be a key interest in indicators of sustainability. However Neumayer (2004, 2003) rightly indicated that in the early discussions most indicators of well-being have ignored sustainability and most indicators of sustainability have ignored well-being. United Nations Development Programme's Human Development Index (HDI) characterizes the former, whereas the World Bank's Genuine Savings (GS) characterizes the latter. This trend appears to have continued till recent days in both policy and academic discussions of sustainability. One reason could be its inherent value-laden nature, therefore the difficulty to measure. Sustainability as a concept being fuzzy enough on its own, it is most likely that the scholars have evaded mixing the two concepts. However, it is also noteworthy that in its own, wellbeing has acquired stringent analytical and quantitative basis, such as that found in the methods and indicators of natural capital. With the concept of natural capital, the economic systems and natural systems are integrated to obtain some degree of measure of well-being of the cumulative system[69]. Yet, the implications of well-being upon sustainability are far-reaching and they are not always

[69] "Many authors have felt uncomfortable with extending capital theory to the ecological domain and treating nature as capital. One argument is that in treating the natural environment as a form of 'capital' one implicitly assumes its substitutability and reproducibility by other forms of capital. Another criticism is that the notion of NC, arguing that it is not an adequate description of dynamic ecological systems that should be sustained. Further according to other authors, there is a deep incoherence in the notion of NC and that the very conception of nature as capital provides little protection for the natural world. Dobson (1998) has persuaded that, however, clear we make the distinction between different types of NC, the description of nature as a form of capital, 'is to look at it [nature] in a certain light, as economic asset of some description'. These doubts are legitimate when we read the most cited definitions of NC: 'Natural capital is the stock which produces the flux of natural resources: the population of fishes in the ocean generating the flux of fish going to the market; the forest generating timber; the oil reserves whose exploitation provides petrol' (Daly, 1994). In this definition, NC is seen as a mere source of material goods for production and consumption activities. Such an appraisal of nature as capital simply reiterates the reductionist and utilitarian vision of neo-classical economics" (modified from Chiesura and Groot, 2003).

measurable. So there must be a way to incorporate them at least qualitatively in sustainability analysis. First it is helpful to explore some dimensions of well-being in itself as their implications on sustainability could be slightly different from one another. There are diverse theories of well-being—or ones in this context could be regarded as sub-dimensions of well-being. Some of such theories are categorized by Dodd (1997) as, (a) well-being as a state of mind (b) well-being as a state of world (c) well-being as human-capacity (d) well-being as the satisfaction of underlying needs. Based on his discussion and other similar reviews and key documents written of well-being, we would reinterpret these categories that will fit better to our own interpretations.

(a) Well-being as a state of mind

This is a widely known approach to well-being that adopts a utilitarian perspective. In this perspective subjective–well-being is the focus implying the well-being and happiness are essentially the same (In academia often happiness is referred to as subjective–well-being). Following Tatarkiewicz (1976), Veenhoven (1988), it is recognized that they can be interpreted as having two basic meanings; the first as emotion related and second as judgement related. The emotion related well-being, often accompanied by pleasure, denotes an experiential quality related to the degree to which feelings, emotions, and moods are pleasant ones, and is often an intense and therefore short-lived state. The second, termed 'contentment', refers to the cognitive component of individual well-being arising from 'satisfaction with one's life in general' or the fulfilment of desire. As this involves some degree of implicit self-reflection and assessment, contentment is considered to be more of a judgment than an emotion (Dodds, 1997). In addition the difference between leisure and comfort in forming the understanding of well-being is addressed by Scitovsky (1976). The exact separation of sub-dimensions is difficult as the categorization given by different authors reflect some overlap.

(b) Well-being as a state of world

Beyond well-being being interpreted in personal, and individual domain, with the collective identities and organizational behaviours of the individual it extends to collective domain to indicate collective well-being, which reflects the well-being of a family, a community, a village, a country and the world, in other words, well-being that represents the state of a system. Further in collective domain, both human well-being and the well-being of non-human environment will be integrated in the similar conceptual basis. For instance, the human–well-being and the natural–well-being could not be separated in describing a country's or the planet's well-being. The noteworthy factor is that when the views of well-being are extrapolated to collective domain, in addition to subjective and objective regard of what constitutes, the factors that already define positive conditions for the system would be integrated. For example factors as balance, integrity, may define the collective understanding of well-being for a system. These represent both structural and functional characteristics of systems. To define these characteristics, one step earlier, having an adequate understanding of factors such as the needs and the preferences is helpful. Needs are closely tied to the views held in the system. Likewise criteria that describe the collective well-being of a system would be connected to different scales and domains.

(c) Well-being as human-capacity

Happiness is considered as a significant factor that describes an individual's well-being along with other mental states, however they are not considered sufficient guide to collective action that ensures well-being in a future state. The *agency*, which is also termed as *'well-being of freedom'*, is argued as important as much as *'well-being achievement'* (Sen 2009, p.36). In the context of justice, capacity is argued as playing a significant role in deciding well-being where the idea of capability accompanies the substantive freedom. Capability gives a central role to a person's actual ability to do the different things he/she values doing.

(d) Well-being as the satisfaction of underlying needs

Another strong factor that is acknowledged in describing the well-being is the satisfaction of different types of needs. The well known example for this approach appears in Maslow's hierarchy of needs (Maslow 1954; Lester 1990). Maslow argued that people are motivated by five type of needs presented as five stages of the development of human needs. Changes to the original five-stage model have been proposed to include a seven-stage model and an eight-stage model, developed during the 1960's and 1970s respectively.

i. Biological and Physiological needs – air, food, drink, shelter, warmth, sex, sleep, etc.

ii. Safety needs – protection from elements, security, order, law, limits, stability, etc.

iii. Belongingness and Love needs – work group, family, affection, relationships, etc.

iv. Esteem needs – self-esteem, achievement, mastery, independence, status, dominance, prestige, managerial responsibility, etc.

v. Cognitive needs – knowledge, meaning, etc.

vi. Aesthetic needs – appreciation and search for beauty, balance, form, etc.

vii. Self-Actualization needs – realizing personal potential, self-fulfilment, seeking personal growth and peak experiences.

viii. Transcendence needs – helping others to achieve self-actualization.

In addition to that Manfred Max-Neef holds the view that quality of life depends on the possibilities people have to adequately satisfy their fundamental human needs (Max-Neef et al. 1991; see also Dodds 1997). He then distinguishes between needs and satisfiers, stressing that fundamental human needs are finite, few and classifiable [...] and are the same in all cultural.

The implications derived from such a wide scope of interpretations are important not only to achieve sound conceptual basis of sustainability, but also to reach more stringent evaluation practices. Just as the limitations, well-being could be understood as directly indicating sustainability or unsustainability conditions of a system. Further, the gap between the present well-being and the past and future-anticipated well-being in general could drive a system's sustainability/unsustainability changes. Aligning with these arguments we conclude that well-being takes different forms that become significant in different contexts, and if a dimensional view is adopted to interpret the role of well-being in interpreting sustainability in human–natural systems, then these different contextual significances need to be identified as sub dimensions.

3.5.2.5 Policies, rules, regulations, and governing practices

Governance for sustainability lies at the heart of the concept. The earliest conceptual developments have embedded the responsibility of humans to regulate within limits into sustainability understanding, hence have repeatedly highlighted the need for better governance. In addition to explicit discussions on sustainability governance (Adger and Jordan 2009; Jäger 2009), there also are other branches as global governance (Lövbrand et al. 2009), governing commons (Ostrom 1990, 2009, 2010), adaptive governance (Folke et al. 2006, Folke et al. 2005), and reflexive and path dependant governance (Voß and Kemp 2006; Leach et al. 2010, 2012: Geels 2011), that address different means of conduct within identified limitations. They highlight varieties of formal laws, and socio, economic, and political practices with varieties of frameworks. Especially in a dynamic context where past, present, and future are important considerations, rules and regulation support concrete envisions of possible future-solution-spaces (Wiek et al. 2005) at decision points. Depending on the existing policy and governing structures, these solution spaces would be envisioned differently in different contexts, mobilizing different sustainability/unsustainability paths.

3.5.2.6 New creations, innovations, and artifacts

In general, new creations, innovations, and artifacts have the capacity to shape human interactions and determine the paths with which societies would move. They play a prominent role in a human system’s capacity to create, co-create, and transform itself. A society's orientation with respect to this dimension also shapes its anticipation of future possibilities; therefore, influence how both present and future sustainability boundaries are perceived. Also it is well recognized that we live in anthropozene (Steffen et al. 2012; Crutzen 2006; Lövbrand 2009; Rockström 2009; Kearney, 1995; Mathias 2004; Pulver and Van De Veer 2009; Reid 2010), meaning that increasingly creations and artifacts become distinctive in directing the thinking and behavior patterns of agents, and as a result, directing the human–natural systems' sustainability changes.

3.5.3 Characteristics of dimensions and their role in sustainability evaluation

3.5.3.1 Significant characteristics of dimensions

I. The dimensions aggregate varying conditions that indicate sustainability/ unsustainability of a system (Fig12).

There are varying types of resources such as natural, human, and man-made resources, giving availability of resources a wide scope of interpretation. Also, the views about well-being change from person to person, across societies, and across time spans, and there are different sustainability/unsustainability linked worldviews such as materialistic and minimalistic views. Also, varying types of knowledge have strong implications on informing what is sustainable and what is not. Multiple and sometimes conflicting data and information are available around a specific issue. In the same manner, different governing practices, rules, and regulations exist. For instance, economic practices include local economies as well as global market economies; resource-governing rules include local soft rules and formal state rules. In terms of new innovating pathways, there also exist multiple possibilities that can tilt a system towards sustainability and away from it. These entities could be considered as different points of observation along the dimensions. While it may not always be feasible to give measurable units, with them either quantitative values or qualitative interpretations that indicate specific sustainability/unsustainability conditions could be recognized. These conditions would be heavily context-bound.

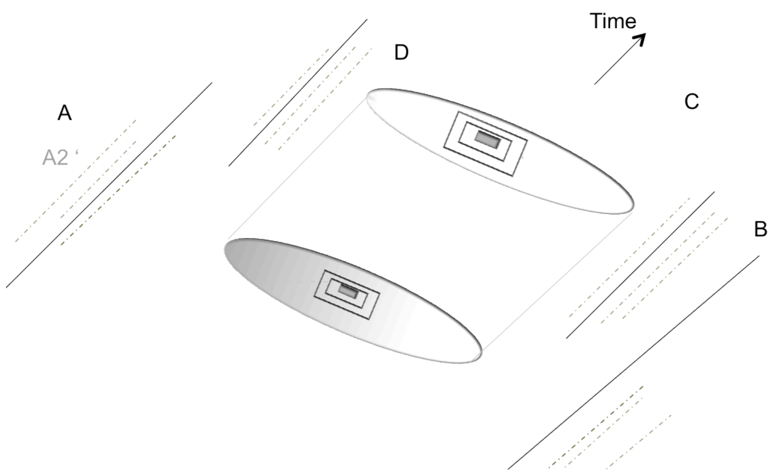


Fig 12. The dimension can have subcategories that are visible especially in one specific context than in others

II. Observations made of systems with respect to dimensions in a fixed time frame can lead to different interpretations of sustainability within that time frame.

Such interpretations can be made by referring to varying points along the dimension, and to varying focus–system and background combinations. The dimensions provide windows of observation to the later. Not always all the dimensions can be given a measurable unit, however there can be either quantitative values or qualitative states. This particular point is important to note, as it carries one of the key implications of the methodology, that is, its capacity to function as a platform for indicators of sustainability. While the two dimensions of resource availability/ limitations and well-being is somehow directly connected with indication of sustainability/unsustainability, all of these dimensions play the role of indicator of sustainability boundaries in different degrees.

III. Observations made of systems with respect to different dimension along time, allows recognizing systems' time-dependent complex dynamic changes.

For example, changes in values/attributes can represent system changes that mark significant emergent changes that lead to new sustainability/unsustainability states, or the ones that solidify the current state. In-depth attention to these patterns and mechanisms would allow us to see which dimension/dimension-combination is likely to trigger a significant change in the system. Furthe, The characteristics aggregated in the dimensions may be represented in measurable units that could be either qualitative or quantitative (Fig 13).

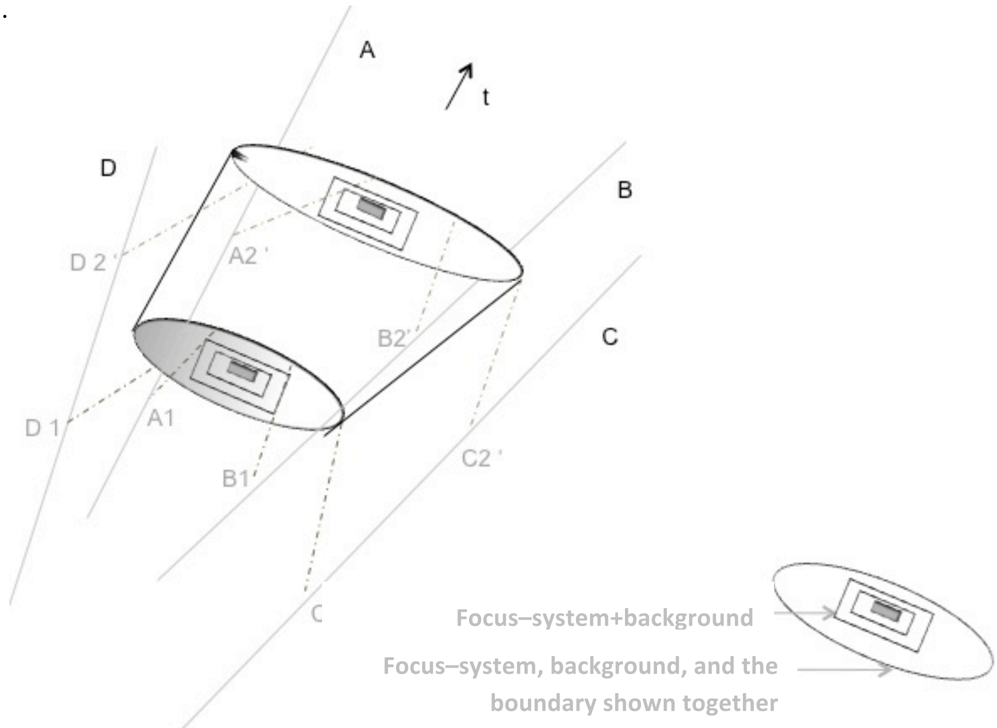


Fig 13. The characteristics aggregated in the dimensions may be represented in qualitative or quantitative measurable units

IV. Just as variability along dimensions, observations of variability generated through their interactive influences are important in recognizing sustainability changes in systems.

For instance, knowledge change over the time can give verifiable capacity to a particular wrong resource usage practice, however, without interventions such as policy and regulation change, the knowledge alone would not lead to change initial practices. Such policy, regulation changes would also rely upon active changes in other dimensions. Therefore, changes would involve time lags and interconnected feedback processes, which means, change related to one dimension would not necessarily lead to immediate changes in other dimensions. Additionally, it is noteworthy that changes observed in systems with respect to each dimension is characteristic to it, therefore the time lags involved might be different from each other. The usual bird-eye view we employ to scrutinize systems tends to miss especially changes across time, making changes between system's sustainability states appear as a result of sustainability/unsustainability conditions change in similar speed with similar patterns and mechanisms. However, the feedback loops that work along and across dimensions may trigger different dynamic patterns in system.

V. Dimensions may have the capacity to drive the system changes.

While providing different contexts to observe sustainability of the system, depending on the context, some of these dimensions also may have the capacity to make significant sustainability/unsustainability changes to the system by acting as driving forces. The implication is that right selection of dimensions to observe systems would enable us to recognize not only significant sustainability/unsustainability conditions, but also the factors that can drive significant changes in the system.

VI. Dimensions would mark increase or decrease in sustainability space.

In very simple sense, visually the change in values can denote increase or decrease in the safe operational space of the system without getting in to collapsing situation, in other words, what is referred here as the sustainability space could be made increased or decreased. In the Fig14 and Fig 15 it shows a decreasing and an increasing situation respectively. Here the basic role of the dimension is to provide value-based indicators of sustainability.

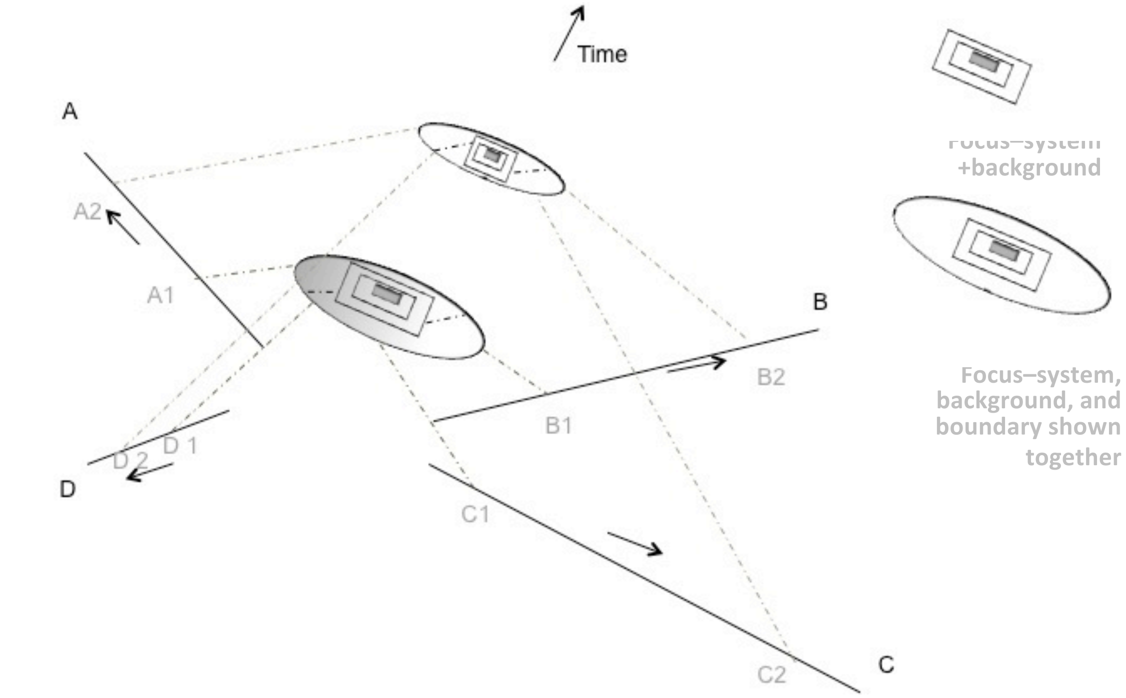


Fig 14. Effect of dimensions can alter the boundaries of sustainability; the figure shows a situation where they collectively contract the sustainability space for the system

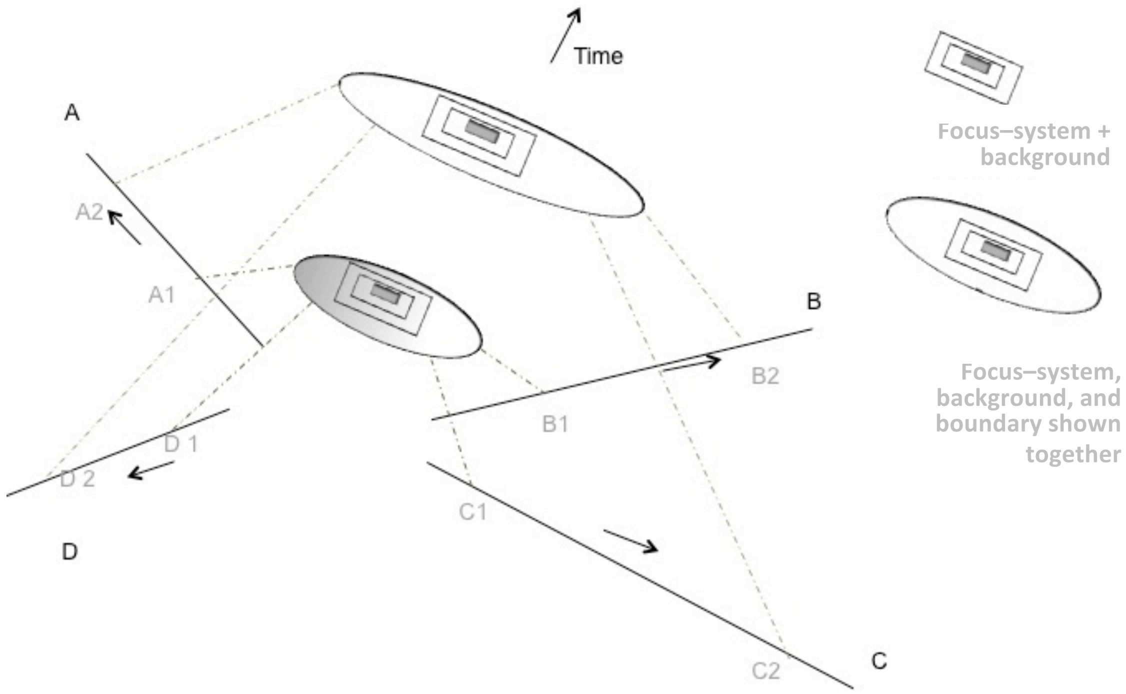


Fig 15. Effect of dimensions can alter the boundaries of sustainability; the figure shows a situation where they collectively expand the sustainability space for the system

IV. Changes in the values and attributes of dimensions could mark system's intrinsic patterns changes.

What is described here is strongly linked to complexity. Changes visible through some dimensions may indicate significant emergent changes and reinforcing changes (when sustainability could be shifting from one state to next), or some of them could solidify the current state. This has strong implications when one is keen on recognizing which dimensions can really trigger a state change.

V. The change of values in each dimension is characteristic to the dimension. The time lags involved with the changes also are different from each other.

Why this factor is important is for several reasons. Usually in the bird eye views that we adopt in recognizing indicators, we tend to miss interpret the changes. For example if we didn't be careful changes between states, can look as all dimensions change in the same speed with similar patterns and mechanisms, therefore we could expect similar stability conditions with respect to each one of them at a given time. One significant reason is that we tend to forget about the feedback loops that may work along and across dimensions.

VI. Change in one dimension does not mean there will necessarily be immediate changes in other dimensions.

E.g. Resource amount change → knowledge change on limitations

knowledge change → view change → policy changes

This is partly why we need to regard the impact on sustainability with relation to these dimensions separately. The variability along dimensions and how they can influence sustainability/sustainability conditions/ sustainability understanding of a system is slightly different from, the variability generated through their interactive influences.

One example is the knowledge change over the time can give verifiable capacity to a certain wrong resource usage practice. In the viewpoint of sustainability the new knowledge obviously can mark reduction in the action/operation space, therefore can reduce sustainability space. However without interventions as policy, regulation change, etc the knowledge alone would not lead to change the practice. Similar arguments can be made with relation to other dimensions as well.

It is noteworthy that change in one dimension could lead to change in other dimensions. The implication is that hypothetically dimensions have the capacity to, degenerate old states and co-create a new sustainability state (Fig 16).

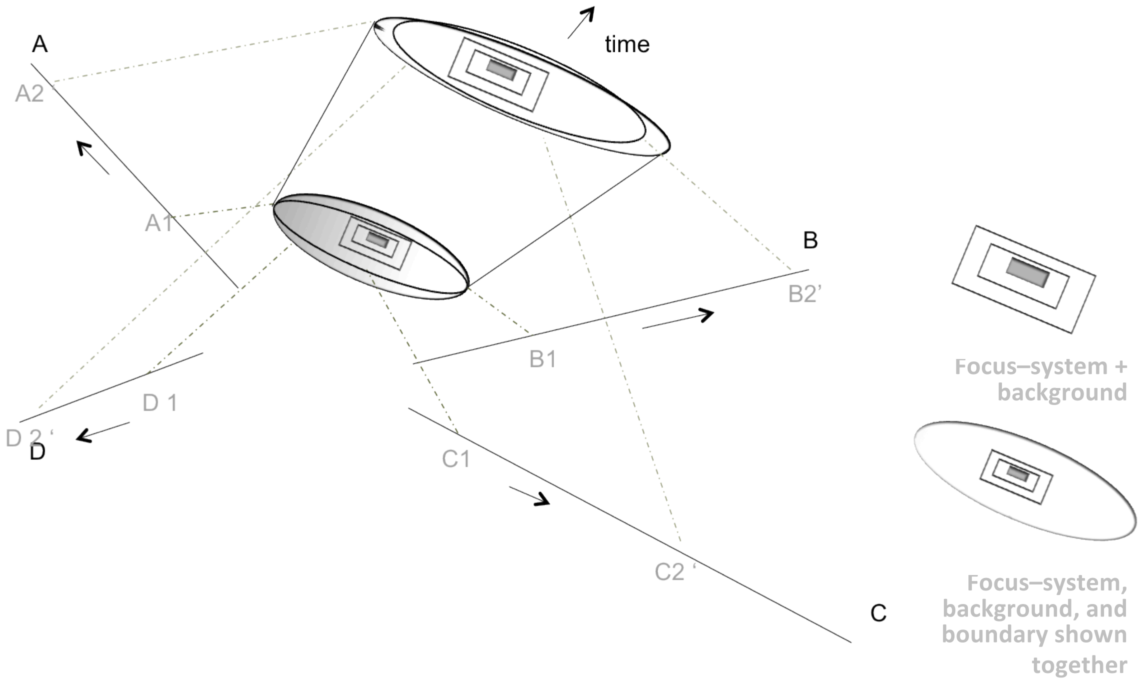


Fig 16. The dimensions collectively can co-create new sustainability states

Note: More than providing different contexts to observe sustainability of the system, some of these dimensions also may have the capacity to drives the changes

3.5.3.2 Dimensions' role in internalizing complex dynamics in to the evaluation process

There are several significant roles that the dimensions play in the framework to strengthen its capacity to observe and evaluate sustainability in a way that the preceding observation process would internalize the characteristics of complex dynamics in to the evaluation process. These complex dynamic integrating roles could be summarized as follows.

I. Mutually interacting with each other in a complex way to form/change the sustainability conditions in the system

The basis of this argument is similar to what was elaborated in first two sections. However, their reference to general sustainability principles was done instead of explicit reference to them as dimensions, and the temporal variability was not included. The dimensions consider the long-tem changes and the changes in between stable states. Further the dimensions are linked to determining sustainability/unsustainability conditions that subsequently lead to sustainability boundaries. These conditions and boundaries implicitly have the capacity to change the direction of a system. A basic example can be given using the dimension of resources limitation and availability. Once a certain amount reached resources can alter the way system entities interact with other dimensions (e.g. changes in resource usage practices, new conservation policies etc). Resource limitation would trigger generation of new knowledge in alternative resources and usage practices, trigger changes in governing practices, trigger innovation for new creations and artefacts and also would trigger changes in views regarding well-being and even the very idea of sustainability. Likewise not only that one dimension would change system interactions, it also could prompt other dimensions' changes, inducing compounded sustainability changes in the system. One implication of the interactive nature of the dimensions and the system they influence is that, a small change with respect to one dimension could create accelerated and proportionately very large impacts on the system's sustainability/unsustainability[70]. Further, the mutually interactive influence the dimensions would have on systems could take the form of feedbacks and could also take both negative and positive forms. Disregarding these dynamics could cause disproportionate results. The conventional related governance tools, specially with relation to resources, has been characterized as crisis-response models,

[70] This idea of disproportionate and divorced-from-original-place type of impact are described by the phenomenon, 'butterfly effect'.

because in constraining management systems to optimize for few narrow targets invites larger and larger feedbacks that ultimately compromise the resilience of the systems (Berkes et al. 2003; Folke et al, 2002; Folke 2006, 2010). Over time it is observed that these can lead to collapse of systems, which clearly denotes that a response with one dimension could lead to harmful results. Also it is necessary to the situations where such mutual interactions are absent, especially in the situations where the dimensions are utilized to play a positive role in sustainability in the system. One example is in efforts to restore eco-system balance. Ensuring balance in terms of physical entities (physical resources in the system) need to be coupled with other long term governing tools that not only maintain the ecological balance in long run, but also can create emerging properties in the system that can continue to improve the balance on its own.

II. Dimensions, both individually and interactively, provide the sustainability context for the systems.

Sustainability context as earlier described, and we would see later on, are derived by referring to specific set of conditions that represent sustainability in the system. They are reached through some general and contextual principles via dimensions. Therefore, one of the fundamental roles of the dimensions in this framework is to lead the observer to gain multiple different sustainability understanding for the system, by referring to multiple different priorities or principles. This is where the dimensions link with the boundaries of sustainability (value based sustainability/unsustainable understanding) and also where the role deviates from usual idea of indicators. Providing context means that some of these dimensions would be significant contributors to form meta–structures with which the focus–system can be understood/evaluated. There are two types of meta–structures that are included here, first is the ones that describe a system's sustainability and sustainability changes, the other is the ones that describe the changes to understanding process of an observer. As we would see later, rules, regulations, policies and new creations, artefacts directly come under the first category; while sustainability-linked knowledge and sustainability-linked worldviews come under the second category. In this way, by providing meta–structures of observation, the framework would actively engage the observer by making him/her to be aware of the observing process. This would lead to positive outcomes such as making the assumptions more visible.

III. Mutually interacting with each other as a reflexive and iterative process to form/change the observer's sustainability understanding

This occurs in several ways. In one way, the dimensions could act as indicators to see different sustainability conditions over the time. In anther way the dimensions allow us to see their influence on the system over the time to create these sustainability or unsustainability conditions. This observation in itself hints us of the possibility to reach multiple sustainability boundaries, and also the changes in them. Beyond merely acting as indicators to show these changes, by comparing the systems relative to the dimensions would surface interdependencies. A detailed description of how reflexive and iterative understanding form sustainability understanding (represented in the form of sustainability boundaries) were described in section II (observing sustainability in a temporal stable state). A very similar pattern of interactions can be identified in terms of the way the dimensions aid in making sustainability understanding, which can be shown in consecutive steps as follows.

As described under the sections of sustainability-linked worldview and sustainability-linked knowledge, the very basis of sustainability understanding can be regarded as being formed by interplay of these two dimensions. It also can be regarded as providing the basis for emergent understanding of a complex phenomenon (in this case, sustainability of complex human–natural systems) (Fig 17).

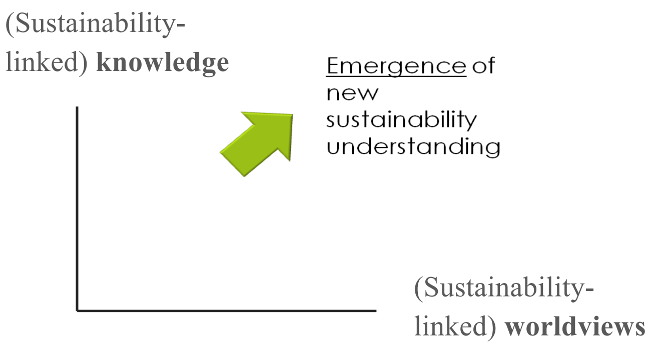


Fig 17. Illustration of interplay of dimensions to form iterative understanding (a)

With that basis we try to gain sustainability understanding further by referring to other dimensions. By the interplay of a new dimension—for instance resource limitation/availability—along with the previous two dimensions (knowledge and worldview) we would gain a new context to observe sustainability. So, in the second step shown (Fig 18), the reference dimension is a combination of (worldview +knowledge), new context forming dimension is resource limitation /availability. The first sustainability boundary would be a result of interplay of all of them.

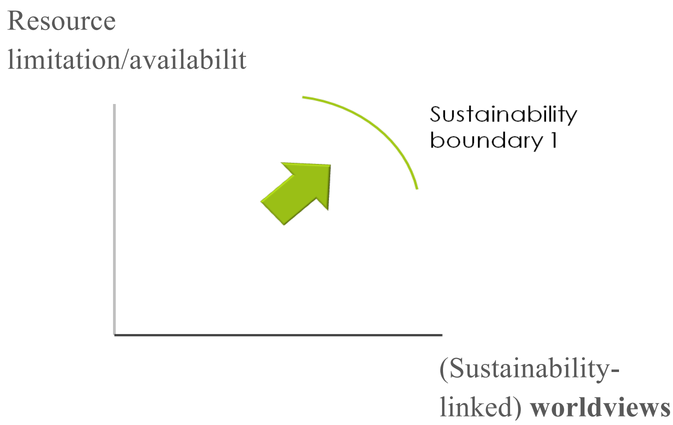


Fig 18. Illustration of interplay of dimensions to form iterative understanding (b)

Here in this instance, the boundary may represent a specific amount of resources. In order to gain second sustainability boundary, we take the previously considered dimensions collectively as reference. In other words, we have an already obtained knowledge of sustainability/unsustainability condition that will influence the next step (Fig 19). The next step, as shown here, could be the selection of a context related to governing practices. In other words, once the limitation are recognized, then a usual step would be towards identifying possible governing practices to address those limitations (Fig 19). The existing governing practices will address the already identified limitations, most probably as a priority. Likewise, the previous understanding would inform the new understanding (and subsequently the new sustainability boundary) reached relative to a new dimension. This pattern could be regarded as consisting of *iterative steps* of forming sustainability understanding, where the meaning of iteration denotes building upon previous step.

Also it is noteworthy the relationship between consecutive understandings need not always have an iterative relationship, rather can be independent as well. In Fig 19 and Fig 20 it is illustrated as an additional step using the same example. When the limitations of resources have given certain understanding about sustainability, instead of trying to find a solution with regulation, another possibility is to innovate or create artefacts that can expand the efficiency of resource usage at least up to a certain level. This sort of independent role of dimensions leads to a *reflexive type understanding*, that is the alternative understanding gained through referring to contexts that represent alternative preferences (regulation vs. creative solutions).

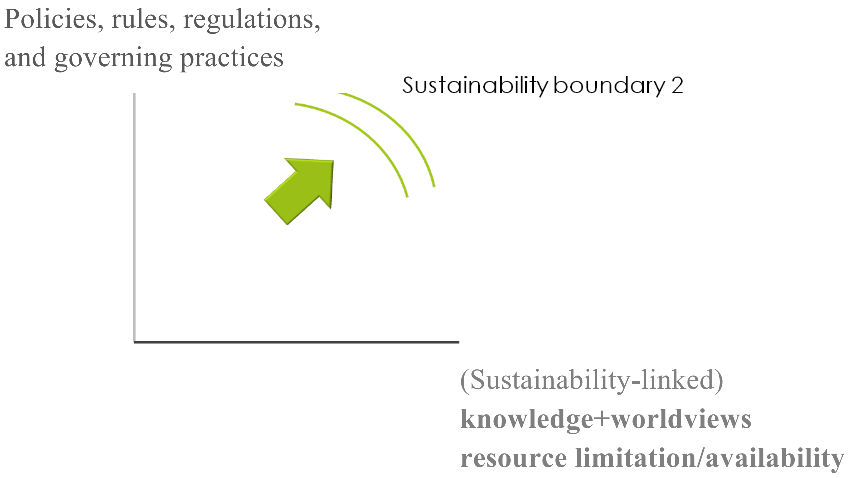


Fig 19. Illustration of interplay of dimensions to form iterative understanding (c)

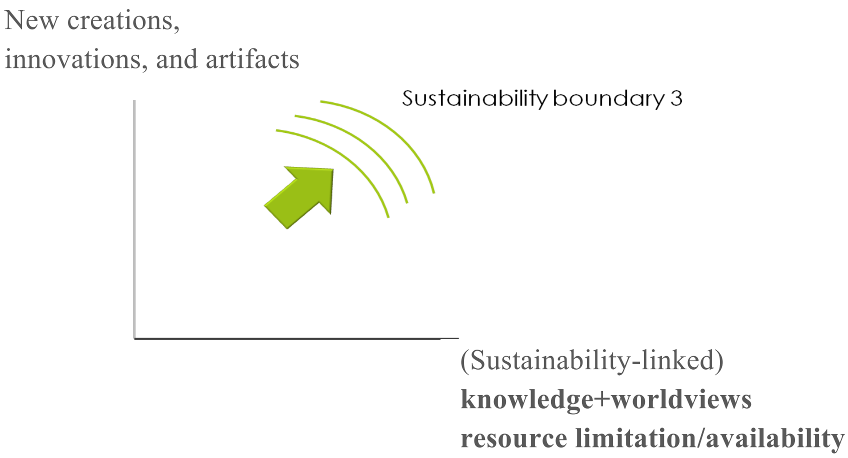


Fig 20. Illustration of interplay of dimensions to form iterative understanding (d)

IV. Working as a reinforcing or damping forces for new sustainability states

It is important to note that, the influence of one dimension over other dimensions and their subsequent effect on sustainability of a system is not a linear process. In a given instance one or a set of dimensions could easily have significance than others. Not just in magnitude comparing to others, but some of them may be able to trigger, collapsing conditions (theoretically extremes chaotic situations, where systems structure collapse) or emerging conditions (theoretically making the subsystems and system entities to self-organize to rapidly reach a new stable system structure) in the system that makes them critical dimensions than others in that particular instance. Systems undergoing critical dynamic processes such as creative destructions, and re-organization of component relationships, where in a relatively short period of time rapid change can occur; that the new system emerges is fundamentally different from the previous,[71] would show such characteristics. On the flip side, some of the dimensions would actively maintain the system in a particular stable state (or a basin condition as referred in complex-adaptive system terminologies), reinforcing the conditions that keep the system in the same state.

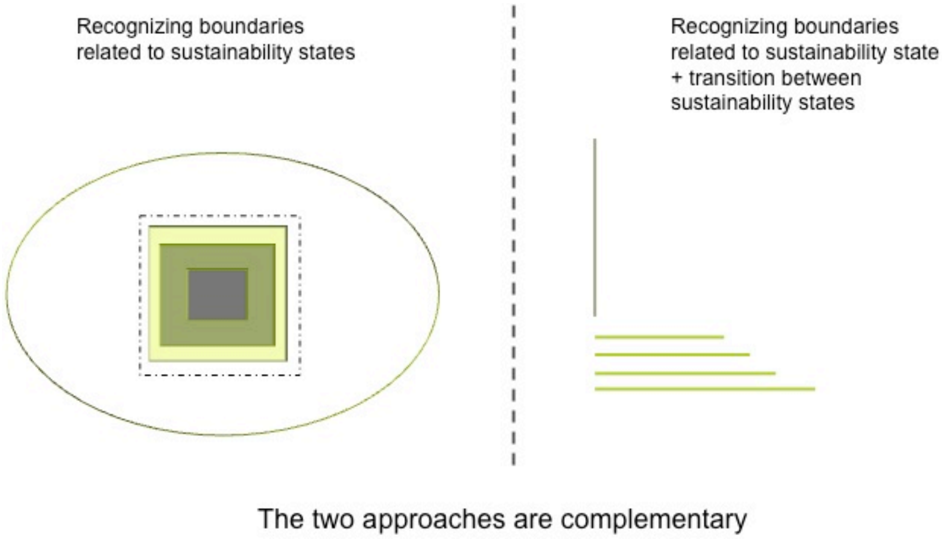
[71] Please refer to Holling (1986), Berkes et al (2003) for details about the creative destruction process mechanisms explained in detail.

3.5.4 Comparison and Synthesis of Layer view-based method and Dimensional view-based method—Final framework

Now that the two significant steps of the framework that proposed a way to view sustainability in a temporal stable and a changing state is explained, it is important to compare them to highlight the common underlying argument that binds them together.

The Section II of the frameworks took in to account the contextually significant features and principles of sustainability in the form of background layers. A layer view-based method was proposed to observe sustainability in a reflexive way. Here the basic consideration was the selection of the focus–system and the relationships it has to its 'background'. The 'background' was described as consisting of information of subsystem relationships and contextual factors such as the prominent issues in the system. Depending on which relationship or issue we focus, the 'background' with which the focus–system is observed would change. We further proposed to interchange the focus–system and the backgrounds. It was argued that the observation process that involves separate cognitive distances would provide a deeper understanding of the system's complex relationships. Also we mentioned that in the process of interchanging the backgrounds, every previous observation informs the next observation, therefore the understanding—though it may not be readily visible—involves both reflexive and iterative step of sustainability understanding. If compared with the part and whole relationship in complexity, the process can be seen as allowing 'holistic understanding' (that is in this case sustainability understanding) by focusing first on 'parts' (systems and backgrounds), and second on 'whole' (emergent understanding gained through the system and background units).

In Section III, the iterative understanding was made more visible by clearly differentiating some of the general and seemingly independent dimensions of sustainability. Therefore sustainability understanding can be regarded as a second-degree emergent understanding that is informed by both parts and wholes. Here it was possible to make such clear differentiation mainly for the reason that there are some general and distinctive principles of sustainability that were established over the years. Their distinctiveness demands that a system and background unit to be compared with them individually to gain sustainability understanding. Further with the dimensions we could gain more specific interpretations and evaluations of sustainability. Also the dimensions enabled us to treat system's sustainability as continuous process over the time, and therefore to integrate the cause and effect relationship patterns to evaluations more effectively.



Layers and dimensions lead us to different contexts with which a focus system would be observed. Both approaches adopt steps of interchanging understanding (reflexive understanding), and further, in both cases the new understandings are grounded on previous understanding (iterative understanding). Therefore the two methods are compatible in their role. Further, they both connect parts and wholes to reach holistic sustainability understanding (i.e., sustainability contexts and sustainability boundaries).

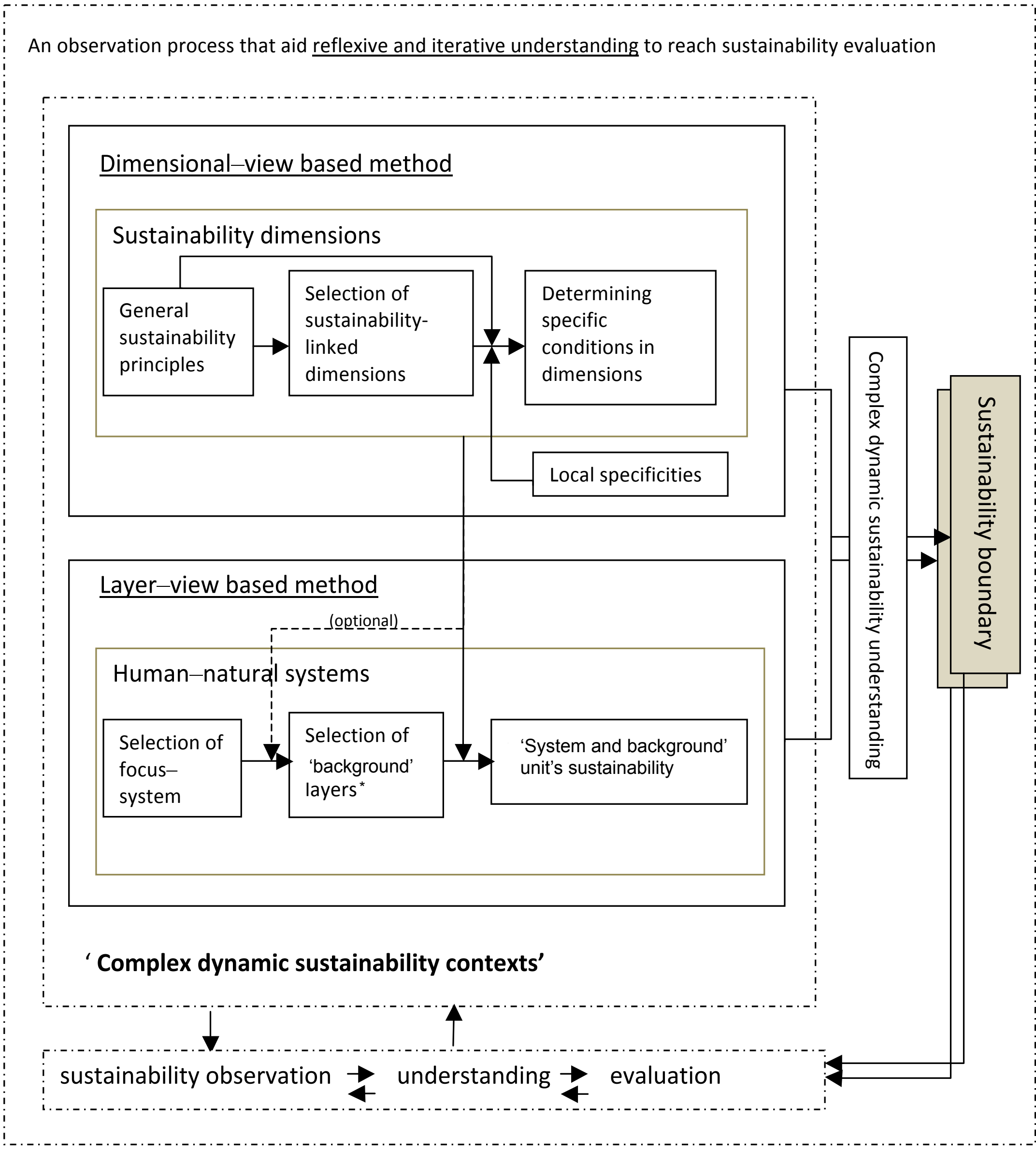
Fig 21. Comparison of underlying methodologies utilized in the framework

It means that the backgrounds and the dimensions have similar functions in making the framework evaluations to be complex dynamic sensitive. Both methods acknowledge the parts and their capacity to form a whole (here a whole that represents understanding), and they both acknowledge the interactive nature of parts in this process, especially the interactive cognitive process that they support. They could be regarded as complementary methods that has same outlook towards complex dynamics (Fig 21).

Once the layer view-based method and dimensional view-based methods are combined, an overall framework can be proposed to observe sustainability contexts as shown in Fig 22 & 23. Observing different system and background units by referring to different system relationships (and issues related to those relationships) and different dimensions along the time, multiple sustainability contexts can be observed. A sustainability context in this case resembles a meta–structure of observation. The layers and dimensions together generate a meta–structure with which a focus–system can be observed and evaluated. There are two types of meta–structures it supports; first is the ones that describe a system's sustainability and sustainability changes, the other is the ones that describe the changes to understanding process of an observer. By utilizing a set of meta–structures or contexts, the framework actively engages the observer by making him/her be aware of the observation process. Such awareness in turn could lead to positive outcomes such as making assumptions that observer make in the evaluation more visible. In addition, by referring to a context, the observer is localizing the general understanding of sustainability to gain specific interpretations that would in turn lead to a holistic understanding. According to Polanyi and Prosch (1977), localizing related to understanding is affected by the available information, awareness, and other similar factors. Such a localizing process can be different for each agent with specific knowledge, expertise, pre-understanding, mental-frames, future orientation etc. By adopting the framework, such diverse localizing processes could be made visible.

The proposing framework maps sustainability contexts to conceptual sustainability boundaries. Further, the changes in the boundaries are made visible as changes between relatively stable levels and changes within such levels. The idea of emergence seems to suggest that the process of change can occur in steps and can create strong outcomes such as new temporal stable states. With relation to sustainability these temporal stable states could represent new epochs or levels of realities[72] that describe sustainability of a system, in other words, new sustainability states of a system. Or, it could create less strong outcomes such as new sustainability/unsustainability conditions within the same state. Or else, it could also create causal 'laws' that function as driving forces across states. Some of these driving forces would have the capacity to degenerate old sustainability states and co-create new sustainability states for that particular system. With such patterns of change, the obtaining boundaries along time can be visualized as spiralling boundaries, which we refer to as sustainability sphere. The space within the sphere represents a sustainable operating space, and, by interchanging layers and interchanging dimensions, hypothetically the space can be visualized as expanding or contracting over the time (Fig 23).

[72] Accordance to terminology and definition by systems scientists (Miller 1978, adopted from Bailey 1994).

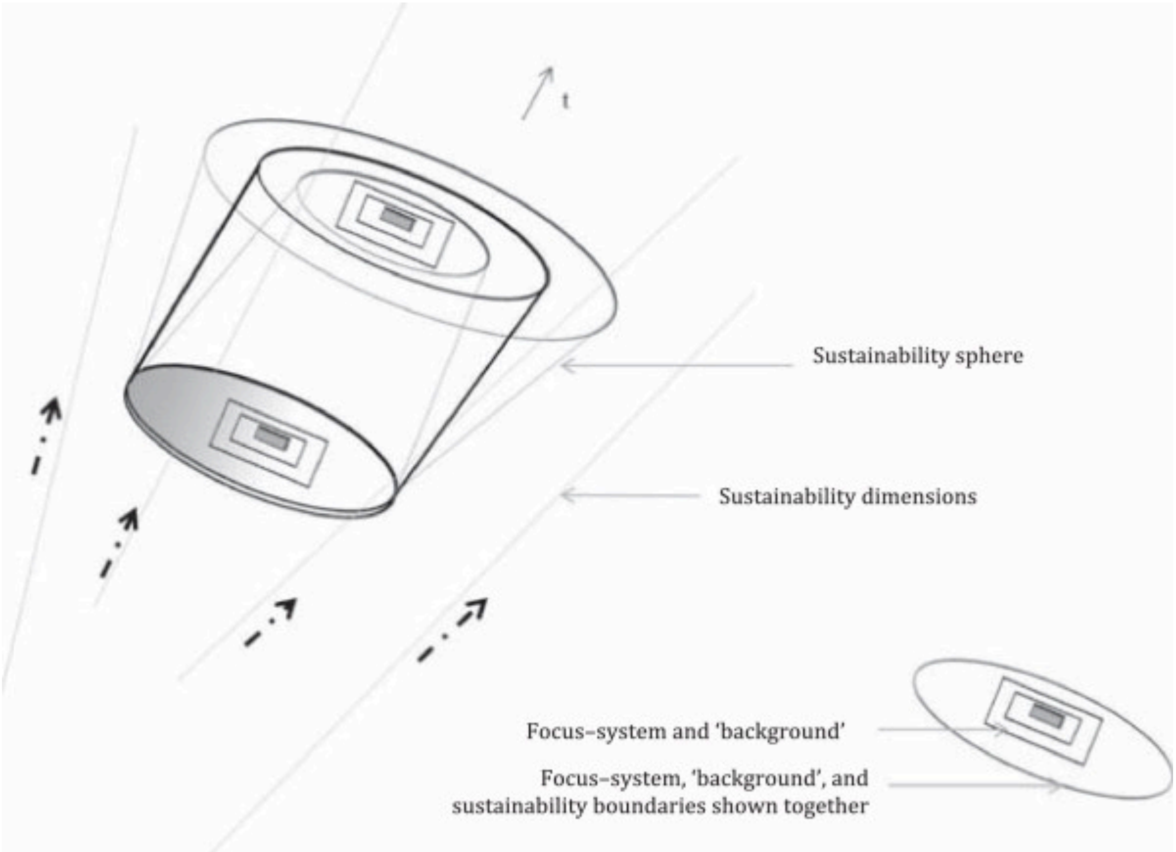


Detailed illustration of the observation process supported by the framework.

Note: *The 'background' layers are selected by referring to system relationships and unsustainability issues.

(Satanarachchi and Mino, 2014)

Fig 22. Detailed Illustration of the observation process supported by the framework (Satanarachchi and Mino 2014)



Visual illustration of the conceptual framework. Note 1: The proposed framework maps sustainability contexts to conceptual sustainability boundaries. Apart from acting as windows of observation for sustainability boundaries, the dimensions also represent change mechanisms such as driving forces between consecutive states (shown by dashed arrows in the diagram). Some of these change mechanisms would lead to the co-creation of new sustainability states for the system. Such changing patterns in sustainability boundaries across time can be visualized as a spiral, which we refer to as a sustainability sphere. Note 2: Only four dimensions are shown to maintain the clarity of the picture. As illustrated, the changes triggered by the dimensions can hypothetically expand or contract the sustainability sphere. The figure shows three scenarios; i.e., contracting, constant, and expanding spheres over time.

(Satanarachchi and Mino, 2014)

Fig 23. Visual illustration of the conceptual framework (Satanarachchi and Mino 2014)

In overall, there are several significant roles that the framework plays in a complex dynamics focused sustainability evaluation process. Out of them the prominent ones are as follows;

(i) *Helps to recognize multiple sustainability contexts and multiple sustainability boundaries*

(ii) *Engages a complex dynamic observation process that leads to reflexive and iterative understanding*

(iii) *Allows to surface complex dynamic sustainability changes.*

One of the fundamental roles of both layers and dimensions in this framework is to lead the observer to gain multiple different sustainability understandings for a system by referring to multiple different contexts. It is where the framework significantly deviates from a usual indicator approach[73]. It helps to map sustainability contexts to sustainability boundaries in several ways. One is by indicating different sustainability conditions relevant to different 'focus–system' and 'background' relationships. Another way is by highlighting the temporal influence of one sustainability/unsustainability condition over others. Such observations allow us to see multiple sustainability boundaries and their changes across time. In addition, by comparing different systems relative to different dimensions and variable conditions that they aggregate, conceptually, it is possible to recognize the interlink of these boundaries.

The observation process supported by the framework can be viewed as an emergent process of understanding of a complex phenomenon, which is in this case, the sustainability of a complex human–natural system. We noted that sustainability/unsustainability changes in human–natural systems would be best interpreted as complex dynamic changes. However in practice, often we tend to focus on one dimension and one particular subsystem. For this reason the conventional problem definitions, solution trajectories, and governance tools could take the form of crisis-response models, where optimizing for few narrow targets could result in large and unpredicted feedbacks that ultimately compromise the resilience of a wider system (Berkes et al. 2003). Failure to recognize multiple contexts and their mutual dependencies-induced changing patterns from the outset can easily lead to system collapses. In other words, a response with only one system and background unit would generate harmful outcomes in long-run. At the same time, one subsystem may become significant than others to interpret a human–natural system's sustainability/unsustainability at a particular instant. Similarly, one or several of dimensions can have heavy significance than

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[73] Theoretical and conceptual implications behind some of the well-known sustainability indicators could be found in Bossel (1999).

others. Some of these system and background combinations may be able to trigger system collapses (theoretically extreme and chaotic situations where system's structure collapse) or novel emergent conditions (theoretically making the system entities to self-organize to rapidly reach a new stable system structure), making one combination more critical than the others at that particular instant. Such phenomena are visible in processes as creative destruction and re-organization of entity relationships, where rapid change occurs in relatively short period of time giving rise to fundamentally different system structures and functions.[74] Or else, some of these combinations would maintain the system in a particular stable state by reinforcing the conditions that keep the system in the same state (Fig 24). In this way, the framework facilitates in foreseeing system's nonlinear sustainability changes by consciously looking for these changes.

[74] A detailed explanation can be found for the creative destruction process mechanisms with relation to complex-adaptive systems in Holling (1986) and Berkes et al. (2003).

3.6 SUMMERY AT THE END OF FRAMEWORK DEVELOPMENT

In a complex and dynamic context landscape, both solving existing issues as well as planning for future sustainability of a context is a highly challenging task. The question of what approaches are necessary to understand the interface of complex dynamics and sustainability—without losing the significance of the complexities but also provide a navigatable and simple enough path to work with—is highly relevant in sustainability evaluation in human–natural systems. In order to address this broad question, an entry-level mapping process would be quite supportive, yet also is difficult to materialize for multiple reasons. At utmost such a mapping process needs to take in to account two key challenges. One challenge is to come up with a comprehensive enough system-based view that pays enough attention to understand complexities in a deeper sense. Another challenge is to see the actual dynamics that create sustainability and unsustainability of the context relative to the identified complex interactions. To understand complexities it is necessary to visualize how multiple factors interact with each other both across special, time, and scales that would generate organizing relationships. Also observing complexities involves a complex-dynamic thinking process. In this situation, not only having thorough awareness of complex dynamics linked to human–natural system relationships, but also having awareness of the complex dynamics linked to the observation process, which is closely tied to the understanding and subsequently interpreting sustainability in these systems, also becomes an important factor. Once the observation is aligned with the actual complex dynamics of the system, we may be able to see dynamic changes that may not be visible in the absence of a complex dynamics sensitive observation process.

Keeping these in mind, the section one of the framework tried to establish a way of looking at systems and its sustainability in a systemic manner. To do that we referred to some key ideas of complex dynamics and human–natural systems, and to factors that would be useful in sustainability visualization and interpretation of systems. In section II, along with introducing one observing methodology, the way that the observations generate sustainability understanding was explained. However we did not go deep enough in to discussion of all the aspects that influence sustainability observation and understanding.

Also we did not go as far as to identify the aspects that would lead to changes in sustainability understanding. Addressing mainly these limitations the framework was extended to include the complementary dimensional view-based method that strengthens framework's evaluatory capacity. The dimensions proposed were namely; (i) *sustainability–linked knowledge* (ii) *sustainability–linked worldview* (iii) *resource limitation/availability* (iv) *well-being views* (v) *policies, rules, regulations, and governing practices* (vi) *new creations, innovations, and artifacts.* The layers and dimensions link the complex dynamics, contextual understanding, and sustainability, first by enabling the observer to recognize multiple sustainable boundaries for the system, and second by enabling to foresee the likely changes in those boundaries. Their significant characteristics and roles were summarized one by one. One emphasised aspect is that the dimensions could both indicate and drive sustainability change. Also, by comparing the two methods, it was argued that together the layers and the dimensions produce a set of observational meta–structures in a complementary manner. When considering the interactions among dimensions, their subsequent effect on sustainability of a focus–system is not a linear process. Theoretically, some of them also may be able to trigger collapsing conditions (theoretically extremes chaotic situations, where systems structure collapse) or stabilizing conditions (theoretically making the subsystems and system entities to self-organize to rapidly reach a new stable system structure) that make them critical dimensions than others in that particular case/situation.

Observing systems relative to layers and dimensions represent different sustainability contexts for the focus–systems. Changes across dimensions could represent the changes between relatively stable levels and the changes within levels. Emergence may suggest that the process of change could occur in steps, and also may result in one of several types of outcomes. In this instance therefore, in one side, emerging changes could bring out ' a new level of reality' [75], which could be correlated with a new temporal stable state. Or else, the emergent changes could occur within an existing state of reality by creating new properties—such as new sustainability/unsustainability conditions, and new sustainability understanding—or by creating new casual laws that solidify the existing state. In other words, the emerging changes may take the form of patterns of internal structuring or a whole–system emergence that generates an entirely new epoch or level of reality. Note that, here the whole–system may denote sustainability states both with respect to systems' internal structure and with respect to observer's understanding. In this way, evaluation based sustainability interpretations that reflect both systems' internal changes and observer's understanding changes could be obtained. The process of observation is

[75] Accordance to terminology and definition by systems scientists (Miller 1978).

explained as an iterative process that connects the complex dynamic patterns, mechanisms, and contexts of sustainability.

Further, we indicated that sustainability-related understanding could be regarded as a complex dynamic process. Sustainability is understood and viewed by different entities in different manner. Usually, how individuals understand a phenomenon can be viewed as a process of localizing information. In other words, there are multiple narrations that an individual's mind can make, which connect the past, present, and future multiple systems to explain the sustainability of these systems. This can be regarded as a localizing process. To a certain extent, we usually identify such a localizing process as a 'context'—the context as in everyday language. According to Polanyi and Prosch (1975), localizing is affected by the availability of information, awareness, and other similar factors (Polanyi and Prosch 1975). The contextualizing or localizing process would be different for each individual. The same applies for groups that work as one organizing system, with similar knowledge, pre-understanding, mental frames etc.

Also, we support our discussion with existing ideas on what may constitute the background. The process of focusing on one subsystem/issue, allowing others to form the background, involves separate cognitive distances[76] (illustrated in Figure 6 by using different colours). This may involve a form of 'subsidiary understanding' (Polanyi 1975; 2009)[77]. The 'subsidiary understanding' encompasses both 'personal knowledge' (Polanyi 1975) and 'tacit knowledge' (Polanyi 2009). These different types of implicit knowledge remain in the background. More than explicitly understood system–subsystem relationships, aspects such as the memories of past sustainable/unsustainable conditions, and the internal thought process of the individual between multiple sustainability contexts and boundaries also in reverse would affect how the focused system and background are perceived. The 'background' may store memories, information to make the understanding of the focus–system an emergent process in itself. This phenomenon is of course related to what commonly referred as 'subjectivity' and 'normativity' that hint unconscious biases; however, the activity also involves a conscious reflexive observation. In the process of making a conscious and unconscious selection, the thought process always forms a boundary that marks the region within which consideration given and the region within

[76] The term cognitive distance is not used in a strict sense; however, it does not contradict how it is used in the field of psychology. In psychology, the term cognitive distance refers to people's beliefs about distances between places in large-scale spaces, places that are far apart and obscured as not to be visible from each other, while in contrast, perceptual distance refers to people's beliefs about distances between places that are visible from each other. Here in the context of the distance involved for focus and background layers, both the information perceived and that not explicitly perceived are involved, and the term cognitive distance is regarded as more appropriate (Montello 1991).

[77] For a detailed description of subsidiary understanding please refer to the literature review's section of 'observing complexity'.

which consideration not given. Also it marks what becomes the focus, and what stays in the environment forming distant backgrounds. It could be argued as forming *streams of understanding* that connect systems and their spatial, temporal, and other complex forms of interrelationships (such as change [along with degrees, capacity etc] could be reflecting in the thought processes in different individual minds).

In overall, the process of observation supported by the framework could be summarized to steps as follows;

i. Differentiating general idea of context to parts. This includes identifying focus–system and background, and identifying a set of general and contextual sustainability dimensions to observe system and background unit.

ii. Seeing the interrelationships between parts. This includes observing the focus–system with relation to interactions it has with its background, and interpreting those interactions with relation to sustainability dimensions.

iii. Observing with purposefully interchanging the parts, to obtain the understanding of the whole. The process involves interchanging the focus–system, the background (the background with the interactions of focus–system are observed), and the dimensions.

These steps can be regarded as representing an integrated differentiating, analysis, and synthesising (by integration) process that continues as shown in Fig. 23 and 24. The methodology allows multiple contexts of sustainability be addressed in a systemic manner, that in tern increase the observer/researcher's capacity to reflect the complexities and to be consciously engaged in dealing with them. In this way, the framework would enable to address sustainability dynamics, not in a deterministic but in a reflexive manner that would allow active view changes in the system and in the observer alike.

4. FRAMEWORK APPLICATION WITH EMPIRICAL OBSERVATIONS

Overview

The following two examples would illustrate the application of the framework. The examples were selected in a way to make the logic behind the framework further visible to enhance its application potential in sustainability evaluations, and in addition, to show how the framework can be used in an actual field research that aims for similar assessments and evaluations. It is difficult to demonstrate all the aspects of the framework with one example. Therefore they were chosen in a way that some aspects of are addressed in-depth than the others. To check the framework's applicability in systems of different scales, examples of different scales were engaged—one in global scale and one in local scale. The two examples also differ in terms of the entry point of observation and the preliminary understanding that direct the observation. The first example starts with an explicit issue-based understanding of sustainability. The second example starts with a system-based understanding of sustainability.

4.1 EMPIRICAL OBSERVATIONS–PART1

An issue-based sustainability evaluation of a globally significant unsustainability issue—Ozone layer depletion[76]

4.1.1 Overview

As the first application, we use an example of a global unsustainability issue. We examine the events that followed on from the discovery of stratospheric ozone depletion to the enactment of international legislations to remedy the issue. This example aims to show the way to utilize the framework to obtain an evaluation-based holistic sustainability understanding of a system that goes through an unsustainability issue.

4.1.2 Issue description

Ozone depletion is known as one of the key globally significant, complex dynamic unsustainability issues. It is also significant as paving the path to international environmental policies and laws. In the early 1970s, scientists first observed the damage to the protective ozone layer by man-made atmospheric pollutants. In 1974, they predicted that chlorofluorocarbons (CFCs)—a widely used substance in supersonic jet fuels, aerosol spray cans, and refrigerants—could be the main cause of the damage. In 1985, almost a decade after these predictions, scientists produced direct evidence that ozone depletion was actually occurring, and that the rate of depletion in the ozone over Antarctica was high. In 1987, the Montreal Protocol—the world's first international environmental convention—was created to set limits on the use of CFCs. Following further research in 1990, measures were taken to strengthen the Montreal Protocol by introducing phase-out commitments for ozone-depleting substances. This included not only CFCs, but also halons and other ozone-destroying chlorine compounds (Levi et al. 1997; Morrisette 1989; Montzka et al. 2011; Andersen and Sarma

[76] The results and discussions illustrated in this section appear in the content of Satanarachchi and Mino, 2014

2012). With the enacted policies of the Montreal Protocol, the target complete phase-out year for Ozone-depleting substances (ODSs)[s] was 2005 and most ODSs were to be phased out by 2000. In spring 2006, the ozone hole over Antarctica was arguably the largest recorded. In about the mid 21st century, a notable decrease in the size of the ozone hole is expected to be observed (Newman et al. 2006; WMO 2007; Fahey and Hegglin 2011). However, very recent studies show that still there are harmful substances released to atmosphere that pose threat to ozone (Laube et al. 2014).

(Source: Oltsman et al. 1998; Oltmans and Levi 1997; Levi et al. 1997; Scheel et al. 1998; Mackenzie and Mackenzie 1998, Tietenburg et al. 2000)

4.1.3 Issue-analysis

In the process of addressing ozone depletion as a globally as well as locally significant issue, several concerns have competed in the discussion arena for a long time. The perceived environmental and health risk, the perceived economic impact, and the uncertainty of the issue's causes and its extent were some of the prominent concerns. Even though it was known by the mid-1970s that CFCs were accumulating in the atmosphere, CFC industry stakeholders and scientists—both in global and national arenas—were sceptical of the need for urgent responses. Because most of the predictions were at a hypothetical stage and were supported only by laboratory model results, many argued that direct evidence of the ozone depletion and the relative magnitude of CFCs as a source of stratospheric chlorine were not yet adequate for concrete actions. CFC manufacturers and customers have argued for delay in regulatory responses until the scientific research could answer these outstanding questions, even though health and environmental organizations continued to insist on rapid actions (Morrisette 1989; Taddonio et al. 2012). Therefore, this issue was observed for a considerable amount of time before the policies to address the problem became effective. Furthermore, the policy initiatives were to be made by global environmental organizations that did not have the capacity to enforce direct regulation in individual countries. The stakeholder network around this issue had also been complex with nodes connecting global, national, and institutional levels, which means there were complex feedback and time lags between knowledge generation, worldview changes, policy agreements, and the policies' actual implementation.

By using the framework, we can attempt to re-evaluate the problem so that we recognize the complex dynamic relationships that have played a part in the process of solving it. The focus–system and the ‘background’ layers could be selected as follows.

> Focus–system: A country (that includes the subsystems of economy, society, and eco-system where the issue is experienced)
>
> ‘Background’ layer 1: Economic growth or development (that highlights the subsystems of economy and society)
>
> ‘Background’ layer 2: Health and ecological conditions depletion (that highlights the subsystems of society and eco-system)

The two layers provide two significant backgrounds with which the focus–system would internalize the issue. To reach an adequate interpretation of sustainability or unsustainability conditions and their changes over time, the mentioned dimensions and, if necessary, some other dimensions could be employed. In our interpretation, we use the same dimensions as those that appear in the description of the framework.

Tables 2 and 3 summarize the sustainability contexts and sustainability boundaries in the form of a matrix. The ‘background’ layers and dimensions together indicate different complex dynamic sustainability contexts (Table 2). Different sustainability boundaries could be obtained by referring to those contexts (Table 3). The boundaries reflect the diverse possible evaluations of sustainability. They could be mapped using actual measurements through indicators, indices, and so on. However, some contexts would not lead to distinctive boundaries, but rather would act as drivers to change the boundaries directly or indirectly by mobilizing feedback processes. For instance, knowledge and technology transfers that were predicted through new governing practices that involve networking and collaborations did not play a role in deciding a specific boundary at a specific state, but being closely attached to the dimensions of ‘sustainability-related knowledge’ and ‘policies, rules, regulations, and governing practices’, have created feedback mechanisms that cumulatively influence other dimensions, and later such as ‘sustainability-linked worldviews’, that in tern have made significant perceptual changes of the system. This reciprocal process has changed the impact of each individual dimension upon the system’s sustainability change. This was reflected through overall sustainability boundaries. Once the contexts and boundaries are observed for several states across time, the change in sustainability boundaries can be visualized as shown in Figure 25.

Table 2 A matrix showing complex dynamic sustainability contexts[a] related to stratospheric ozone depletion issue (originally appear in Satanarachchi and Mino, 2014)

'Background' Layers / Dimensions	Sustainability-linked Knowledge [b]	Sustainability-linked Worldview[c]	Resource limitation/ availability	Well-being views	Policies, rules, regulations and governing practices	New creations, innovations and artifacts	'Sustainability-linked Knowledge' + 'Policies, rules, regulations and governing practices' [d]	'Sustainability-linked Knowledge' + 'Sustainability-liked worldviews' + 'New creations, innovations and artifacts'
Economic growth/development	Sustainability/unsustainability understanding derived from, (i) knowledge of long-term impact on growth/development of the country related to costs of national health treatments and cost of eco-system restorations (ii) knowledge of impact on growth/development in the process of adopting alternative substances and related technologies[f] (iii) knowledge of different types of stake-holders targeted for ODSs reduction (e.g., in developing countries the stakeholders vary as, importers of products or components where ODSs used, users of ODSs in other manufacturing, producers and users of ODSs[g] etc.)	Sustainability viewed as, (i) the continuous economic growth and development without setbacks (especially from industries' point of view) (ii) positive international trade (and geo-political) partnerships; Sustainablity-views influenced by predominant economic (and related legal and political) views (e.g., those that emphasize the legal rights of citizens (both as global and local citizens) and manufacturers).	Unsustainability issue identified as, (i) the limitation in affordable substitutes to ODSs (CFC-123, CFC-124, HCFCs in early stages and Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulfurhexafluorides (SF6) etc later on)[h] (ii) the limitation in applicability of the potential substitutes (e.g., application of compounds in refrigeration, air conditioning, aerosol applications, fire suppression, foam blowing, sterilants, and solvents) that create additional cost of replacement in appliances (iii) the limitation of data and knowledge[i] of cost-effective ODS-substitutes (iv) the limitation in technologies[j] to produce cost-effective ODS-substitutes (v) the limitation of domestic technologies, networks etc to absorb the economic benefits of trade partnerships.	Unsustainability issues identified as disruption of well-being, where well-being is viewed as, (i) the ability to maintain desirable (material) standards of living (that may involve high ODSs emission, such as that of supersonic transport) (ii) the continuous improvement in the living standards (e.g., continuously reducing economic risks related to replacement of ODSs, health research and treatments)[k] (iii) the ability to satisfy same functions, and use same facilities with minimum change to consumption patterns (that involve ODSs and the services and industries that use ODSs such as aerosols, refrigerants etc) to reduce economic impact (iv) the ability to maintain flexibility and adaptability in economic decisions and activities.	Solutions with policies and laws related to, (i) agreements, adaptation schemes and change mechanisms for new substances (e.g., first international discussions under United Nations Environment Programme [UNEP] and World Meteorological Organization [WMO] that lead to 'International Plan of Action' in 1977; agreements in Vienna convention [1985] by major CFC producers to regulate the compound; commitments with Montreal protocol [1987] to ban the import of ODSs and the discouragement of technologies used for ODSs manufacturing for nonparties (ii) establishing Multilateral Fund [MLF, 1990] for the implementation of the Montreal Protocol, especially to assist developing countries[l] during the transition process (iii) the establishment of research networks for global, regional, national and sector-level socio-economic data accumulation.[m] (iv) each country's domestic adjustments to encourage major ODSs producers and small-enterprises for the shift through effective trade mechanisms.[n]	Solutions supported by, (i) new evaluator models (e.g., Chemistry-Climate Models [CCM] and related General Circulation Models [GCM][o]) (ii) new technologies that offset additional costs of alternative substances to ODSs (e.g. low cost methods of producing HFC as a refrigerant) (iii) innovative technology transfer mechanisms for adaptation of new substances (e.g., government and industrial partnerships that gave confidence to other manufacturers and part-suppliers to invest on the transition process; industrial leadership pledges for developing countries[p]) (iv) innovative market mechanisms to encourage the shift to substitutes, and to eliminate black markets around ODSs and ODS technologies disposal (e.g., the establishment of the grace period, where developing countries could voluntarily reduce ODSs).	Solutions supported by, (i) reevaluating and revising the protocol based on new scientific data and market information [e.g., London Amendments of 1990, the Copenhagen Amendments of 1992, and the Montreal Adjustments of 1997 and 2007, with accelerated phase-out targets, new ODSs and supportive implementation mechanisms] (ii) adopting mechanisms such as trade permits, new global reclaim and recycle mechanisms to reduce the cost of transition while ensuring proper destruction of ODSs.	Sustainability achieved through, (i) continuation to look for innovative solutions supported by long-term investments (e.g., research on Geo-Engineering Solutions as solar radiation-management [SRM], where SRM aims to reduce solar wave radiation before it reaches earth via methods such as injecting aerosols to atmosphere to reflect sunlight (ii) continuation of international partnerships to generate cost-effective alternative solutions (e.g., produce and use more ozone friendly as well as energy efficient technologies and appliances that have added benefits to both producers and consumers).[q]
Health and ecological conditions depletion	Sustainability/unsustainability understanding derived from, (i) knowledge of environmental related health impact of the issue (e.g., ecological imbalance, cancer by UV-B) (ii) knowledge of ODSs (chemistry of substances and reactions) (iii) knowledge of ozone depletion chemistry, stratosphere conditions and cycle patterns (e.g., polar stratospheric clouds [PSCs], dynamical structure of polar winter and spring stratosphere, stratosphere and troposphere coupling) (iv) knowledge of alternative substances and technologies with their added environmental benefits (v) nonknowledge and nesciences on future conditions (e.g., future discoveries such as, the additional UV-B impacts on human health, ODS-substitutes' impact on phenomena such as global warming, the health impact distribution among countries, changes to the expected trends due to unanticipated causes[r] etc).	Sustainability viewed in terms of importance/non-importance of, (i) sustained human health (ii) eco-system well-being and the perceived degree of autonomy and responsibility for them; Sustainability-linked views supported by world-centric and group(nations, locality)-centric ideas on the environmental (and related health) impact, and by the related sense of responsibility; Sustainability-liked views that influence the extent of comfort with health and ecological risks (risk in the face of dread, familiarity and extent of exposure).[s]	Unsustainability issues identified as, (i) the limitations in known substitutes for ODSs[t] (ii) the applicability in existing appliances, technologies for the new substitutes (iii) limitations in available scientific data to verify the extent of the health and ecological impact (iv) the limitations in available technologies to reduce ODS emissions (difficulties faced in producing non-harmful CFC varieties by CFC manufacturers) (v) the limitations in available scientific data to verify the extent of the health and ecological impact (e.g., the lack of evidence of ozone depletion and specific causes, and other scientific uncertainties related to ODS-substitutes).	Unsustainability issues identified as disruption of well-being, where well-being is viewed as, (i) the ability to maintain desirable (health and eco-system related) living standards (ii) positive conditions to support good human health and eco-system balance (e.g., reduced level of UV-B radiation through reduced ozone depletion rate) (iii) the continuous improvement of the (health and eco-system related) living standards (e.g., continuous reduction of cancer risks and negative effects on aquatic biochemical cycles[u]).	Solution with policies and laws related to, (i) ODSs emission reduction and complete elimination mechanisms (Supported mainly by the Montreal Protocol) (ii) global, regional, national research network establishment for new health and ecological related data accumulation (e.g., commitments for assessments of national limits set for ODSs production and consumption in every four years; national policies that support research on UV-B effect on health, and on terrestrial and aquatic eco-systems; international policy initiatives such as World Plan of Action for the Ozone Layer [1977] by United Nations Environment Program [UNEP]).	Solutions supported by, (i) technologies to produce and utilize alternative substances with improved health and ecological benefits (e.g., producing HCFC as an alternative for CFC (especially producing HCFC-225 between 1990 and 1994, to replace CFC-113)[v] (ii) efficient technology transfer mechanisms for efficient adaptation of new substances (e.g., partnerships between government supported environmental agencies [e.g., Environmental Protection Agency-EPA] and major industries in assessing and adapting new technologies, that accelerated the substitution process) (iii) innovative trade, policy mechanisms to encourage the shift to substitutes and further research.	Solutions supported by reevaluating and revising the protocol based on new scientific information (e.g., London Amendments of 1990, the Copenhagen Amendments of 1992, and the Montreal Adjustments of 1997 and 2007 that introduced new ODSs and accelerated the phase-out targets, such as the accelerated phase-out plan for HCFCs and methylbromide considering their underestimated rate of threat to ozone layer and their contribution to global-warming as a green house gas; supportive assessments made in 1989, 1991 and 1994 with panels representing science, economy and technology).	Sustainability achieved through, (i) continuously look for innovative solutions to reduce health and ecological impact (e.g., research on Geo-Engineering Solutions as solar radiation-management [SRM], where SRM aims to reduce solar wave radiation before it reaches earth via methods such as injecting aerosols to atmosphere to reflect sunlight (ii) continuation of international partnerships to reduce ODSs (iii) improvements of recycle and reclaiming technologies and mechanisms (iv) treating environmental issues not as isolated issues, but interrelated issues of global human–natural system (e.g., produce and use more ozone friendly as well as energy efficient technologies and appliances).[w]

[a] These contexts as described elsewhere, are observation metastructures in the evaluation process.

[b,c] To maintain presentation simplicity, only the key dimensions are shown as the column titles. However, it is important to note that in addition to the shown explicit roles, the two dimensions of sustainability-linked knowledge and sustainability-linked worldview also play background roles to other dimensions in the process of defining sustainability contexts.

[d,e] Similarly, other dimension combinations also would enable us to see more contexts by supporting a reflexive and iterative understanding process; we show only two significant examples.

[f] E.g., new compounds and related technologies in refrigeration, air conditioning, aerosol applications, fire suppression, foam blowing, sterilants, and solvents.

[g] As specified by Munasinghe and King (1991); adopted from Taddonio et al. (2012).

[h] In the early stage, the chemical industry was working to produce new chemicals such as CFC-123, and CFC-134; however, these developments were controlled by the chemistry and the market (Morrisette 1989). The limitations of the available ODS-substitutes made them essential resources in this issue.

[i,j] Just as ODS-substitutes, the related knowledge, and the technologies to produce them also are considered as resources.

[k] Beyond the distinctive catastrophic nature, the health risks also generate long-term economic impacts for a country.

[l] Developing countries that consume less than 0.3 kilograms of ODSs per person per year are known as 'Article 5 countries'.

[m] E.g., International Council of Scientific Union (ICSU), United Nations Environment Programme (UNEP), the World Meteorological Organization (WMO).

[n] E.g., The domestic policies adopted by the European Commission (EC) to allow the use of HCFC as a solvent and foam production supplement, but ban for the use in some types of refrigeration and air-conditioning services; and later to ban all use and imports of products that use HCFC. This stepwise approach is believed to have encouraged the small and medium scale companies to be more innovative in developing alternatives, and to transfer to HCFC-free technologies (Taddonio et al. 2012). Another such mechanism is the tradable permits that were adopted by many countries, which aimed for flexibility during the transition process, while at the same time ensuring the phase-out schedules are met and the ODSs are destroyed effectively.

[o] Of World Meteorological Organization (WMO) and United Nations Environment Program (UNEP) (Eyring et al. 2005; Perlwitz et al. 2008).

[p] E.g., Pledge by automotive community to (i) recycle (ii) phase-out CFC-12 (in 1988 and 1990); Voluntary phase-out of CFC foam in food packaging; Pledge by Japanese enterprises to phase-out ODSs use at their facilities in developing countries within one year of the phase-out at domestic facilities (in 1990) (Taddonio et al. 2012).

[q,w] Such change in direction of the nature of envisioned solutions is heavily influenced by changed worldviews, which may have influenced by factors such as, increased acceptance of irreversibility of harm already occurred, acceptance of the close connection of ozone depletion issue and global warming issue (such as the man-made nature, and the possible dynamic interrelation [Andersen and Sarma 2012]), the increased trust towards the functionality of global protection initiatives, the increased dependency upon technology based solutions, and so on. Further, they require views that support nonknowledge-based actions, which may have become more acceptable with time.

[r] Such as the effect on ozone concentration by stratospheric sulfate particles from volcanic eruptions (e.g. Mt Pinatubo eruption in 1991), varying temperature in stratosphere (due to winter time polar vortex circulation and solar cycle variations), atmospheric dynamics (which is heavily influenced by increased carbon dioxide emissions), abundance of trace gases such as water vapour, methane and N_2O (atmospheric N_2O has increased in recent times due to high fertilizer use), and so on (Weatherhead and Andersen 2006). These dynamic factors would continue to exert uncertainty for the rate of recovery of ozone and its future stabilizing concentration.

[s] Factors that affect the risk perception as categorized by Slovic (1987); adopted from Morrisette (1989).

[t] With limited scientific knowledge of exact cause of the ozone layer depletion, only few substitutes were identified in the beginning.

[u] The disruption to aquatic biochemical cycle is found to reduce the production of phytoplankton, and to lower the reproductive capacity of aquatic life such as fish, shrimp and crabs (Worrest and Häder 1989).

[v] Resistance from key producers to halt CFCs without adjustable alternatives had been one of the key bottlenecks in implementing the Montreal Protocol. Finding alternatives for CFCs—especially for the widely used ones—is believed to have accelerated the process (Taddonio et al. 2012).

Table 3 Possible sustainability boundaries related to the identified sustainability contexts related to stratospheric ozone depletion issue (originally appear in Satanarachchi and Mino, 2014)

'Background' Layers / Dimensions	Sustainability-linked Knowledge	Sustainability-linked Worldview	Resource limitation/ availability	Well-being views	Policies, rules, regulations and governing practices	New creations, innovations and artifacts	'Sustainability-linked Knowledge' + 'Policies, rules, regulations and governing practices'	'Sustainability-linked Knowledge' + 'Sustainability-liked worldviews' + 'New creations, innovations and artifacts'
Economic growth/development	Boundary: Maximum acceptable cost values related to replacements of ODSs; Minimum accepted negative change in values of growth rate, per capita income, gross national production etc, related to ODS-replacement and long-term health impact costs; Thresholds that represent the predictive capacity of development and growth rate changes.	Boundary: Values of growth and development related sustainability indices (especially with respect to values that reflect public perception of investments in environmental issues, degree of responsibility, and associated economic risk).	Boundary: Minimum accepted change in values of growth rate, per capita income, gross national production and related sustainability indices that reflect the costs of ODSs-replacement process with available substitutes and appliances; Related sustainability index values.	Boundary: Accepted same-lifestyle based well-being index (and related sustainability index) values (that consider the economic impact of ODS non-replacing scenario, such as the increased long-term costs on health research and treatment); Accepted alternative lifestyle based index values (that consider the long-term economic impact of the replacement of ODSs, general perception of economic risks, impact of trade partnerships etc).	Boundary: Minimum achievable (and acceptable) development and growth values predicted for the optimal function of, regulations and mechanisms in Montreal Protocol, supporting trade policies, and domestic reduction policies; Sustainability index values that take in to account the expected impact of the policy mechanisms.	Boundary: Values from new sustainability evaluation models (that incorporate new cost indicators, long-term growth and development indicators that consider the impact from adoption of new technologies, ODS-substitutes, new recovery rates, new market mechanisms, and new technology transfer mechanisms).	Boundary: Sustainability index values that consider the maximum accepted negative changes in cost, growth, and well-being indicators from new reduction and phase-out targets (with newly recognized ODSs, and improved substitution-, trade-, and disposal-mechanisms).	Boundary: Sustainability index values measured considering new phase-out methods supported by emerging technology-based solutions, improved trade mechanisms, holistic scientific models, and the changed perception of sustainable solutions.
Health and ecological conditions depletion	Boundary: Minimum recoverable ozone level with ODS-substitutes; Threshold of available verifiable scientific data related to issue; Minimum knowledge to predict possible catastrophic conditions (e.g., discovery of ozone hole over Antarctica, proof of cancer risk); Boundaries of nonknowledge and nesciences related to the issue; Boundaries of knowledge specified in other cells.	Boundary: Values of public perception based sustainability indices that reflect the projected impact on health and eco-system, the degree of responsibility for environmental issues, and the level of associated health and ecological risk.	Boundary: Minimum recoverable ozone level with available ODS-substitutes and related alternative appliances; Stratospheric ozone layer recovery rate; Threshold of available scientific data related to the issue; Already available technology level to ensure the ODSs replacement; Related sustainability index values.	Boundary: Alternative/same-lifestyle based well-being index (and related sustainability index) values that consider the measures of health and ecological depletion/improvement, (e.g., stratospheric ozone layer recovery rate, rate of reduction/increase of ozone hole size over the Antarctica, ODS level in stratosphere, current emission reduction and freezing capacity of ODSs, and reduced/increased cancer risk).	Boundary: Minimum achievable environment protection/replenishment targets predicted by the optimal function of, regulations and mechanisms in the Montreal Protocol, supporting trade policies, and domestic reduction policies; Sustainability index values that take in to account the expected impact of the policy mechanisms.	Boundary: Values from new sustainability evaluation models (that incorporate the impact on health and eco-system-sustainability by considering new technologies, ODS-substitutes, new recovery rates, new market mechanisms, new technology transfer mechanisms, and related ozone recovery rate).	Boundary: Sustainability index values that reflect health and eco-system well-being improvements from new reduction and phase-out targets (with newly recognized ODSs, improved substitution-, trade-, and disposal-mechanisms, and new values of the expected ozone recovery rate).	Boundary: Sustainability index values that reflect health and eco-system well-being improvements (measured considering new phase-out targets supported by emerging technology-based solutions, improved trade mechanisms, holistic scientific models, and the changed perception of sustainable solutions).

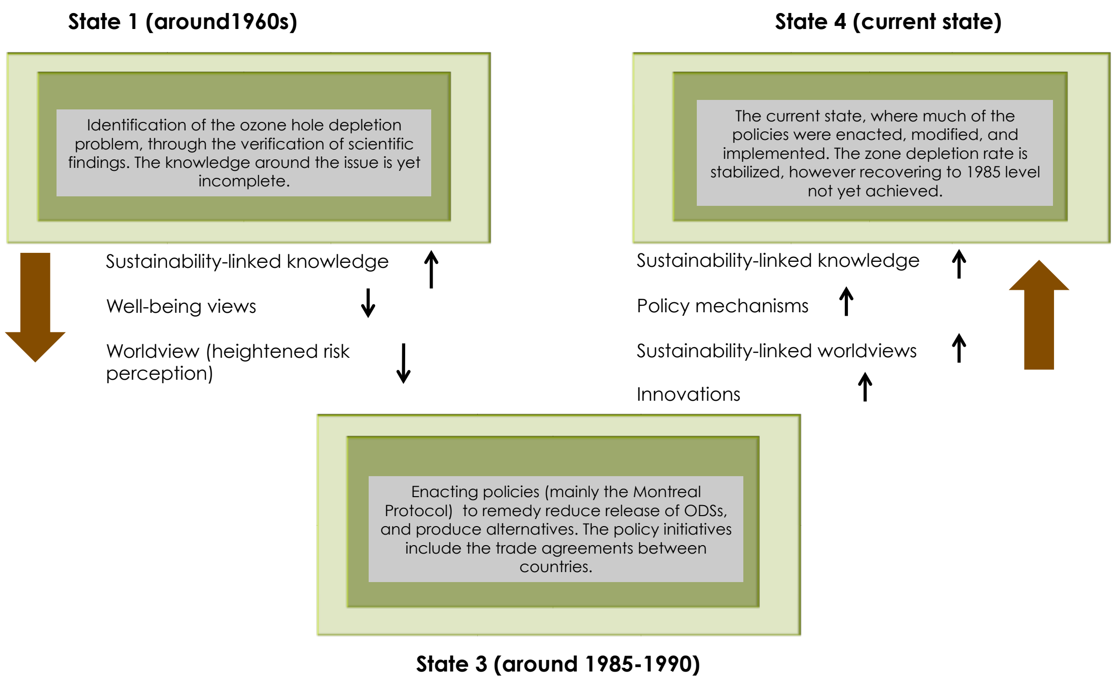

Fig 24. Interpreting sustainability/unsustainability states and their changes for a country related to the ozone depletion issue

Note: Individual drivers of change between each state are indicated with small arrows, the wider arrow shows the cumulative effect.

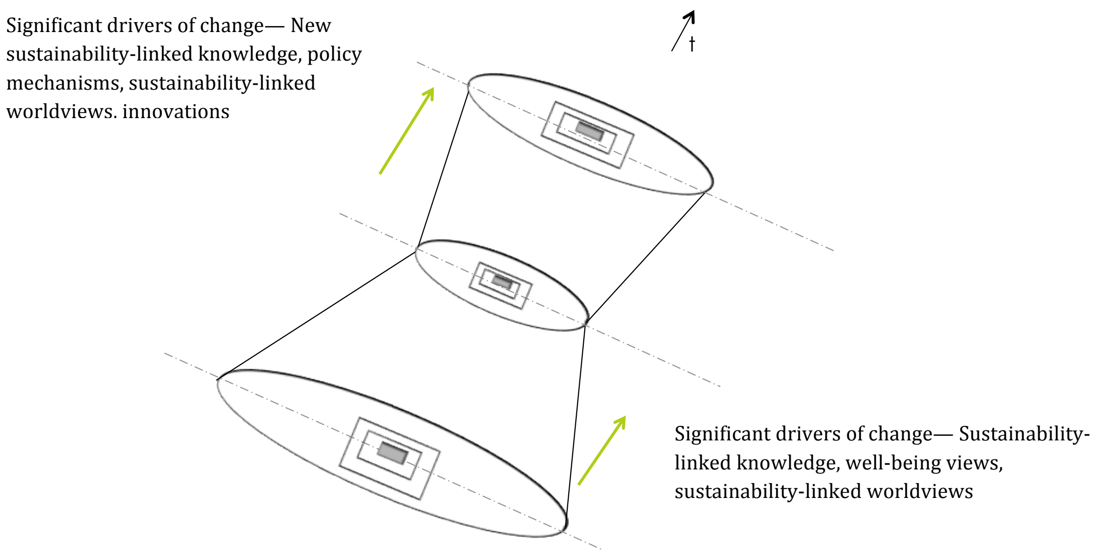

Fig 25. Dimensions can drive changes in sustainability boundaries of two consecutive states of a system and background unit

(originally appear in Satanarachchi and Mino, 2014)

The scenario as indicated in the matrix method can be further visualized as in the Fig 24 & 25. The identification of the problem through the discovery of the ozone depletion and the ozone hole represent a state where the perception of well-being was significantly reduced for global citizens in general. It made the sustainability boundaries to shrink than they were as perceived before it was discovered. In addition, the sustainable operating space of the planet earth was decreased with new information that confirmed the issue. The new knowledge related to the health effects and the geographically dispersed nature of the impact of the issue created a relatively stable state around the issue (the vulnerability for skin cancer was recognized as geographically uneven, and also the responsible stakeholders also were geographically, sectorally etc scattered). Further, to discover the harmful substances, and to discover the alternative substances that can replace them to offset the impact, have taken more time. To come up with a sound mechanism that flow across global, regional, national, and sector levels, with the needed policy initiations and them to reach satisfactory operating level, it has taken even more number of years. In Fig 24 this situation is reflected by the change in the boundary in the bottom half of the sphere. The middle cross-section shows a situation where negative (sustainability) drivers and conditions are over-passed by the positive (sustainability) drivers and conditions. Such a measure is achieved considering, not only the at-the- moment conditions and feedback/feedforward effects, but also the anticipated future conditions and effects. Sphere's upper section with expanding boundaries suggests the continuation of the same pattern. Here the feedbacks could be take the form of changed views and perceptions of the human–system towards the global environment, sense of responsibility towards global well-being etc. However since the past actions have already created a certain degree of irreversible harm, conceptually the sustainability boundaries would have to be visualized in a way that the sustainability operating space remains shrunk than it was in the past (before the issue was discovered).

4.1.4 Discussion

In this first case study, we have utilized the framework with minimum change to its original development. The dimensions that were selected to observe the sustainability were same as the original framework dimensions, therefore, they carry the same meanings as described earlier. One significant aspect to note is that the utilization of both dimensions and dimension combinations (as shown in Table 2, 3) to observe the system background unit. The contexts represent specified sustainability understanding. Especially the contexts reached through dimension combinations reflect the iterative understanding that the system has gone through (with respect to dimensions) and also the evaluator's own iterated understanding. This iterated understanding could also be seen as a complexification of our interpretations.

Once the sustainability contexts were indentified we have identified relevant boundaries for each context. Based on these boundaries (that reflect partial and refined understanding of sustainability), we have come up with a general trend in boundary change in the system. Because we have stayed in qualitative interpretations, and also the evaluations were made in a provisional manner, this last step is a synthesis of the general understanding gained through those interpretations and the provisions for evaluations to overall sustainability evaluations.

The dimensions also have enabled us to se see the drivers of change. Generally all of them to some degree have influenced the change of sustainability. These influences as we saw were both positive and negative. Out of them we indicated what seem to be the most significant drivers of change (change of the system from one sustainability state to another). In these selections we have focused on both positive and negative impact of the drivers (positive and negative defined according the predefined expansion [positive] and shrink [negative] of sustainability boundary). Therefore it is important to note that before deciding if the drivers had a negative or positive impact we ourselves had to make a value-decision about sustainability/unsustainability. Further it is important to note that in our case interpretations, we have considered the drivers' functions, and based on them made general observations, but not explicitly discussed differentiating their functions from one another. The drivers had different roles. Some of them such as sustainability-linked worldviews appear in several context and boundary interpretations, and have had direct impact on sustainability or unsustainability perception of the system, therefore have had a reinforcing role. This reinforcing role could be further described as reinforcing the change that has already occurred. For instance there was the impact of worldviews that positively regarded material comfort/luxury (also may have had accompanied more deeper-held views and ideologies such as individuality, growth, development) that have brought issues, directly influencing the sustainability of the system. Further the worldviews that had positive regard for other aspects such as human-health (in individual level), global responsibility (in a more external group level) have brought upon other changes to the system. When such change was a dimension itself, for instance, the policies, then it is an example where one dimension has brought change to the system, not directly bring about a visible issue or solution to an issue, but through bringing in a driver of change. And even further worldview has also played a role in solidifying the impact of the other dimensions by supporting their change. This could be viewed as synthesising the changes to a new stable state of sustainability. These are examples of different types of dynamics that are generated by the same driver.

Also it is noteworthy that, in this analysis, we have considered the whole process starting from the discovery of the issue to the point where the solution was visible to the issue as one continuous transition process that goes through different sustainability states. The main reason was that the process had been relatively quick and highly interconnected process, that it is difficult to interpret different temporal states that mark clear transition points, at the out set of the problem analysis. However as we would some times there would be instances that clear differentiating temporal states could be supportive for the analysis and subsequent evaluations.

4.2 EMPIRICAL OBSERVATION–PART2

System-based sustainability evaluation of a village-forest socio-ecological system—Meemure village in Sri Lanka

4.2.1 Overview

The second case study is based on a village-forest socio-ecological system, located in the central mountainous region of Sri Lanka, where socio-ecological sustainability related historical changes are observed within a relatively smaller spatial boundary. The changes in resource related economic and governing practices have occurred in a slower pace in the past and in an accelerated speed in the recent times.

4.2.2 Case selection and data collection

This case study played a significant role in shaping the thesis work. Even though the formal analysis of the study was done after the theoretical development was completed, I have known and visited the location before starting the case analysis process, therefore, have been aware of the complexities in interpreting sustainability in this context. Not only this particular village, but some previous other field studies have raised the question of how to take in to account similar complexities and changing patterns in usual environmental or sustainability analysis, and how to ground these analysis processes in deeper understandings of complex dynamic systems. Therefore it is possible to say that the case in some way has given direction to this thesis. Another related similar aspect that made me interested in the case was the gap between top down and bottom up governing practices that were observed to ensure sustainability, particularly with respect to initiatives for economic development of the village and the initiatives for conserving the surrounding forest reserve. These initiatives have taken the form of macro-development project attempts and rapid changes in the conservation policies. Mainly because of the unidirectional nature of the activities, these attempts, while have done important service, in my understanding has created mistrust from the ground for such developmental and conservation activities. I was mostly interested in this factor, because not only in the viewpoint of the gap between the top and bottom approaches, but also in the viewpoint of interpretations of human–natural system relationship, the system boundaries and so on, we are forced to deal with multiple partial understanding of the system. With these significant 'parts' the system is bound to provide paradoxical stories of sustainability, which needed to be analyzed deeply. Other than that familiarity with language, the ability to get deep in to the case (preferable adapting a research approach closer to anthropological research), capacity to maintain enough distance to be objective in observations (up to the extent that a meta–level observation can be achieved[77]), and several other similar factors, also had to be taken in to account in selecting the case study location.

Challenges in Observing sustainability

As any other socio–ecological system, researcher or a planner that aims to observe and interpret sustainable and unsustainable conditions in this village system faces several fundamental challenges.

(i) It is difficult to frame the boundaries of the socio-ecological system. The meaning of village in this particular situation cannot be defined geographically alone. Even though territory vise the village holds a specific area in terms of economic, social, and cultural activities the region expand far outwards. In other words it is difficult to recognize the system boundaries clearly in this context.

(ii) Within the village sustainability is linked to diverse aspects. Sustainability is directly visible through socio-economic activities, and the relationship had with the surrounding forest-ecosystem. However these system interactions are complex and separating the subsystems and identifying interactions are difficult.

(iii) Meemure cannot be observed with a complete objective lens. Just like every other local situation the context carry context–significant features. For example this village is considered as a historical location, which has archeological value attached to the place. Local people's identity is heavily tied to the geographical, historical identity of the village. However that does not make the villagers entirely distinctive to a point that does not allow seeing common evolutionary patterns as other places in the world, specially in terms, socio–economic development and socio–ecological etc changes over the time.

[77] Please refer to the literature review's sections of transdisciplinarity, complexity thinking and complexity in observation for a description of meta–level observation and related other concepts as meta synthesis, meta–point-of-view.

(iv) In order to understand sustainability of the village system, not only the context specificities, but also the history of the system is extremely necessary. The very process of identifying separate system demanded recognizing the system entities, as well the boundaries, that range not only across space, but also significantly across time. Interpreting economy of the village does not involve identifying the agents and transactions between agents alone rather also the type of transaction historically the system has adopted. Observing the changes in village economy over the time required modifying system boundaries to reflect the changes in composition of the economy.

(v) The other significant challenge was related to the form of data that were necessary for the process of evaluation.

What listed above are some of the challenges that observed in the very beginning of the study. Some of them are common challenges of researchers of sustainability face, especially in the empirical domain. Some of them are tied to complexities and changes of the system, and some others are linked to the limitations faced in observing these systems—partly because of lack of methodologies to observe the complexities and changing patterns. In addition to that, identifying especially the complexities marks that as a researcher I was in the domain of 'complex complexities', therefore it is necessary to be aware of my own observation process. Also I had to be aware of the target groups and individual that I interview also are subjected to such complexities in the process of interpreting their environment, therefore it was necessary to have a tool to recognize these complexities.

Procedure of data collection

1. Preliminary Observation

In order to observe sustainability in the village, several key braches had to be selected. For this matter the previous understanding about the location and the general understanding of sustainability (in terms of basic principles) were utilized. In order to obtain these preliminary understanding several key branches and sub branches as focus areas were selected (Fig 26).

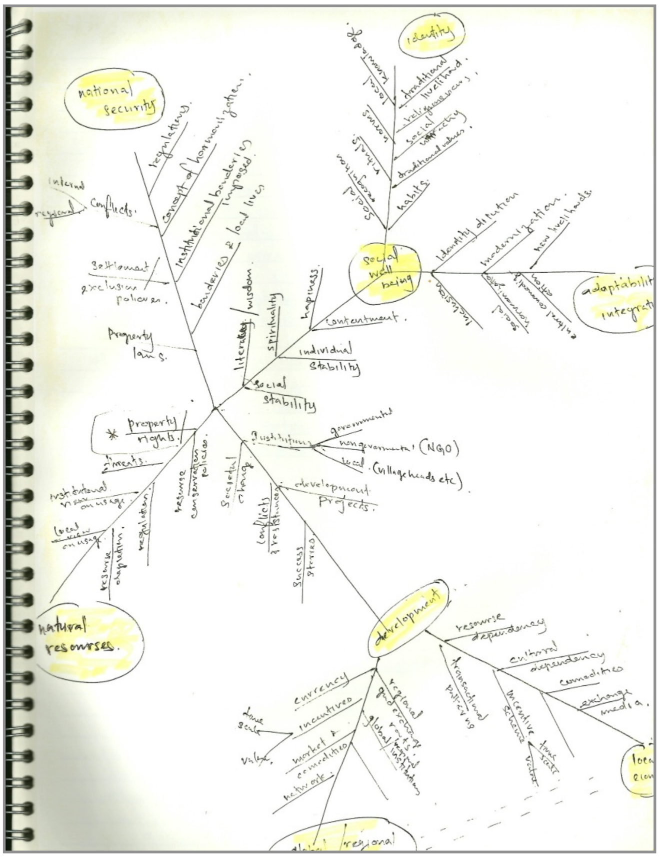

Fig 26. Tree diagram, utilized in the preliminarily analysis stage

The information obtained under each branch aided in formulating interviews, and collecting other forms of data. With increased understanding about the context this preliminary graph was later modified in several steps.

2. Data Collection

In the process of conducting the case study, the preliminary method had been to identify key driving factors that, (i) Drive changes in the village-forest system (ii) Mark sustainability/unsustainability of the system in different periods. Once identified these two types of factors, which defines sustainability related changes that occur in the system, they were further analyzed relative to subsystems (e.g. social, economical, ecological; individual, collective systems). While aligning the complexities with different subsystems, different types of categorizations were adapted to gain a comprehensive enough understanding. Then the observations were made for different background units to recognize relatively stable states that the context passes through. The stable states were selected in a way that they describe the major sustainability changes that occurred in different stages in history.

The preliminary observations were done in two directions.

(i) View point of the village

(ii) Viewpoint of from outside

First it is important to distinguish between these two types of knowledge research relied on. Usually views from inside tend to be linked to direct concerns that the villagers hold. These views are shaped often by traditional knowledge (e.g. traditional ecological knowledge (Pierotti and Wildcat 2000) indigenous knowledge (Agrawal 1995), which are both direct experience based knowledge as well as more tacit types of knowledge embedded in folk laws, beliefs, rituals and so on. Viewpoints from outside often works in different blueprint, often with different regulatory features, which are not necessarily directly linked with the resource usage pattern, and are often structures on top of the community than being embedded in it. Even though looking from outside, they may appear to be integrated, the two knowledge types are fundamentally different in their role in forming sustainability interpretations. Also the experiential bases of theses knowledge are divers. One may base on resource availability in the context, while another may be derived from already foregone experiences. Some may be linked with local habits and patterns, while the rest may be based on different forms of proved and observed understandings, which are often filtered to be objective enough to be implemented in a alternative location.

In this case, the viewpoint from inside included observing the system–subsystem relationships limited to the interviews obtained from village, which represented individual and collective perspectives from the village. Viewpoints from outside relied on the interview data from stakeholders who are mainly independent researchers, practitioners, and also data from literature (Semi-structured interviews were conducted during visits to the location in 2010 and 2011. In addition key-informant phone-based interviews [informants from village and the researchers and the developmental authorities] were conducted in 2010, 2011 and 2014). Mainly the documented data about the Knuckles socio-ecological region were supportive in this case. Some of such information were not directly describing the small village, however similar settings or collectively as the watershed. Because of many similarities that can be observed between this particular village and some other such surrounding places, information of them also could be used.

One strong observation from the viewpoint of village was that many of the resource usage/governing practices have had strong influence both from culture as well as economic needs. Also it was noticed that the awareness towards the dependency of natural resource pool for survival triggers the practices to keep the balance in extraction and replacement. In addition it was possible to recognize some collective attitude change in village towards nature, and they could to a certain extent linked to economic needs, as well as externally induced governing practices, such as conservation policies.

4.2.3 Interpreting sustainability and unsustainability in Meemure

4.2.3.1 Case description

The village Meemure, is a unique socio-ecological system located in a valley surrounded by Knuckles mountain region in central province of Sri Lanka[78]. The forests in the Knuckles Mountains, which spread across two districts of Kandy and Matale, are considered as having very high biological value not only for the country, but also for the region and the planet as a whole (Bandarathillake 2005; Badenoch 2009; Medawatta et al. 2011). Apart from a few number of small human-settlements the forest has remained mostly as an untouched natural forest to this day (Bandarathillake 2005). It is mostly because of the early recognition of its ecological and biological value that led to conservation policy enactments. However, because of conservation policies the forest dwelling villages in the Knuckles have faced some bottlenecks to their socio-economic development (Badenoch 2009). Lack of productive land and the interlinked poverty, population depletion, urban sprawling, and the lack of support for aging community[79] are some of the interlinked pressing issues that the villages currently undergo. Factors such as the limited access to energy-, infrastructure-, and technology-facilities also have aggravated these unsustainability conditions. In order to holistically understand and evaluate sustainability in this village-forest system, it is important that we look at the historical development of the significant unsustainability issues and the factors

[78] The observations that we document in this paper are based on semi-structured interviews and are supported with documents and scientific-article reviews. To obtain knowledge on indigenous communities, focus-group method was used.

[79] Sri Lanka's population is predicted to age very fast during the next 50 years (Vodopivec and Arunathilale, 2008). In developed countries, challenges of population aging are associated primarily with the negative impact of aging on economic growth, and the need to plan for additional public and private outlays for old age income support and healthcare (MacKellar 2000). In Sri Lanka these challenges would be compounded by several facts for the lack of government assistance (Worldbank, 2008) for the aged, and their heavy reliance on family support, where family support-structure also have gone through a rapid change in recent past due to less birth rates, rural-to-urban youth migration, high female employment, and higher education leading to differences in attitudes towards the obligation to provide family support (Vodopivec and Arunathilake, 2008). Social issues related to rapid aging are more significant in remote villages such as Meemure, whose population size only about 400, and also are comparatively disadvantaged with national infrastructure and welfare facilities, who's youth urban sprawl involves cities that are significantly far.

that have contributed to them. That would enable us to correctly understand the current issues, and also more importantly, would enable us to predict the issues that the system may face in the future.

Fig 27. The village of Meemure

Historically Meemure village has evolved developing a culture linked to the surrounding forest. These climate conditions—suitable for both wet and dry cultivation[80]—have attracted the early settlers to this remote valley, whose climatic conditions have well matched with their agrarian life style[81]. The village has evolved closely tied to the forest resources and the seclusion that it provided. For the major part of the history, the income of villagers of Meemure had mainly come from paddy cultivation, supplemented by shifting cultivation and harvested forest products. The folk stories in the region suggest that in the past, the geographical location of Meemure was valued for its remoteness by outside ruling institutions (especially by the Kandyan kingdom) as it functioned as a hiding place during the times of unrest, and also as a place for exiled outlaws (Rajapaksha 2007), suggesting that the lack of access and visibility may have considered as positive features from both by villagers and outsiders, and have helped to materially sustain the village. However along the time, how the state looks upon the remoteness of these villages and their forest-dependent lifestyle has changed[82]. Along with the global recognition of threat to the natural forests and the biodiversity that they support[83], the livelihood of villagers threatens the forest's well-being

[80] Where wet-cultivation is mainly comprised of paddy cultivation, and dry-cultivation comprised of other supportive crops such as vegetables and spices, and is also known as 'chena- or shifting-cultivation'.
[81] The initial settlements are considered as taken place few centuries ago, approximately late 12th century, however the village has recorded history from about 1800s.
[82] Over the years, the institution structure of the outside state has changed from a central kingdom, to a state[82] that no longer has its capital in the vicinity of the region. A
[83] Most of Sri Lanka, especially the central highland regions like the Knuckles, falls within one of the world's 34 biological hotspots – a place on earth with extraordinary high concentration of biodiversity and exceptional levels of endemism, and further in 2011 Knuckles forest was nominated as a UNESCO world heritage (Conservation International 2011; Lindstrom et al. 2012).

also had developed within the country[84]. These views were mainly supported by records of activities such as forest logging, cattle grazing, and tea and cardamom cultivations within the forest largely by outside private owners, and to some degree by the forest-dwelling villagers. To some extent these views also were influenced by incomplete knowledge on the responsible stakeholders, general speculations based on examples documented in other places—particularly the scholarly examples, and conflicts of interests among departments in governing forest resources. The changes to the way a village–forest system is perceived from outside of village had not been the same as the changes of similar perceptions that occurred from inside. Over the years most villagers' relationship with the forest had remained tied to the same resource extracting practices, folk-laws, rituals, and wisdom traditions. Current traditional activities demonstrate that in the past village and forest have not been separate from each other, rather, the forest is looked upon as an entity that protect and support the life through resources, wildlife, medicines, positive climatic conditions, and spiritual powers, therefore, need to be both protected and feared of. Further, the village-forest system could be regarded as having resembled an extension of Kandyan forest gardens. Kandyan gardens have won attention of scholars for their diversified and economically viable land-use and other sustainable features such as the minimum control and close integration with nature (Jacob and Alles 1987; Halladay and Gilmour 1995; Mattsson et al. 2013, 2012). Also in terms of vegetation, the mixed nature of the crops generates blurred territory boundaries of what is usually known as village and the forest. A similar pattern can be observed even today. Further, when it comes to land-use, the villagers seem to have maintained a remarkably restrained attitude. In early days, in most part of the country, land-use practices can be interpreted as having been shaped by a somewhat power-laden nonverbal agreement with kingdom to use the land for the sustenance. This is an agreement that generated a land-use attitude that resembles 'borrowed to consume' than to 'own by birthright'. Even though tenor laws in the country have changed over the year (Mattson 2012; Bandarathillake 2005), and the property ruling body of the country have changed to state, ministries, and departments, the villagers' views on the ownership and the use of land seem to have not changed much until very recent, contrasting their views significantly from similar views of outside settlements where the legal rights have been clearer and well-established[85]. Some change to these views can be recognized with cardamom gaining a significant commercial value from about 1965 onwards. According to some scholars cardamom is known to be native to South Asia. The

[84] The term state in this context need to be further clarified at this point. The state has differed from the kingdom, government, local authorities, provincial authorities, departments (E.g., Forest conservation department) and so on. Various research organizations, and the international organizations, which has partnerships with the energy and infrastructure projects could be identified as another set of stakeholders in this regard.
[85] The necessity to explore the power structures related to modern day forest related land use (in somewhat related yet a different context) is discussed in Sato (2003).

climatic and geographic conditions have well supported its growth and the harvest[86]. The villagers having adapted to both wet- and dry-cultivation for years to support their livelihood, changing their focus more towards the new forest-based crop has not been difficult. Increasing market to the new crop has significantly increased the income of some of the villagers. However, this economically viable state had lasted only for few years. In 1985, Knuckles region was nominated as a National Conservation area, and through 1990s to about 2001, a series of forest protection regulations that include strict demarcation of forest borders were enacted (Bandarathillake 2005)[87]. With the recognition of the natural value of the forest, with forest conservation policies, particularly the cardamom cultivation was first discouraged and then banned (Cardamom plant needs forest cover for its growth and also creates negative conditions to the biodiversity, limiting the undergrowth cover in the vicinity of the plant[88]). Although the conservation policies and regulations were very much desirable steps to protect the biological value of forest reserve, naturally they conflicted with sustenance of forest-dwelling villages such as Meemure, whose income have become closely attached to the forest resources, and the land that now belonged to the forest reserve (Even though the planed policy changes have been adequately communicated to the villagers to support slow adaptation). In Meemure, the increased population size immediately after economically viable times, and its decrease in size and growth rate later on—mainly due to urban sprawling and improvement in health and family planning—have led to the current demographical state where elderly dependents are rapidly increasing while young and middle-aged working force is decreasing. This state accompanied by the reduction in legally cultivatable land and lack of other occupational opportunities in the vicinity, has created a feeling of entrapment among many villagers, which seems to have significantly altered their perception on forest-village relationship.

Today the village of Meemure could be described as a nature-, economy-, culture- and technology-embedded socio–ecological system whose pressing unsustainability issues are not yet solved. Recently, this village along with some other villages within the Knuckles reserve has gained recognition as a location with potential for eco-tourism. The geographical and

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[86] It is not clear whether the crop has been always there in Knuckles, or whether it has been introduced from other areas after recognizing its increasing commercial value.

[87] The natural values of the Knuckles area have long been well accepted and the area has a conservation history that dates back until 1873 when parts of the area was declared a climatic reserve. In 1985 a government proposal was made to make Knuckles as a conservative forest and it was declared later on However the Forest Reserve the boundary of the protected area was not well-established until 2001. In the villagers' view most parts of their agreeable land has been acquired as the reserve area. However the forest department of the country also have declared buffer zones where are a limited amount of human activities are allowed (Weerawardene and Rassel 2012: Wickramasinghe et al. 2008; Bandaratillake 2005).

[88] The records related to the forest reserve and the villagers' interpretations suggest that the years where the villages benefited most from cardamom have been prior to about 1990 when the likely ban of the crop was communicated to the villagers.

historical significance, scenic beauty and some unique garden and architectural features have strengthened its positive outlook both among foreign and local visitors. Also the village is slowly being regarded as a place (and a community) to be preserved. If succeeded, this new form of preservation is essentially different from previous forms of preservation that focused on natural conservation and the community sustenance as separate entities. It may be interpreted as the conservation attitude moving further from nature-intensive to include culture-intensive attitude (that encompass both the confinement and the outside of village) that blur the boundaries of nature, society and the individual. It also reflects the impact of changes made on the guidelines of conservation and development activities (especially the grassroots level activities) of domestic and international organizations to adequate engage the communities in decision-making processes. The recognition of the significance of collective human–natural systems, rather than of just human or natural systems could also be seen as aligning with the change in global paradigms from nature conservation to development, and further, to sustainable development. However, it is important to note that this change in attitude may not always bear positive outcomes, as the tendency to the process of establishing such culture intensive attitudes, among other aspects, also have the risk of commoditizing the culture and human relations, just as the commoditization of village-forest relationship occurred in the past with cardamom cultivation. Further the governing bodies and structures that influence the system are diverse, hence the isolated attitude changes alone may not have adequate impact on maundering the system towards sustainability.

4.2.3.2 Case analysis

Significant questions to consider in sustainability interpretation of Meemure

In order to gain a holistic understanding of sustainability/unsustainability in this system, there are few fundamental questions that we need to address.

One question is, what critical issue/issues are there in the system that threatens its sustainability? Critical issues are often governed by factors such as immediacy and proximity. A threat of an immediate system collapse would make some issues more significant than others. In the same manner, issues experienced currently (therefore often in close proximity) would render more significance than an issue whose effects are not experienced yet. Further, the issues connect multiple subsystems and other issues within those subsystems, therefore often integrated. In this village, there are two distinctively significant and also interrelated critical issues that have been visible for a long period of time—namely the need for socio-economic development, and the need for nature conservation. These issues seem to provide distinctive background narrations to interpret the village's sustainability. While human system's sustainability is closely tied to aspects such as socio-economic development, retaining historical significance, its current and future well-being and so on, natural system's sustainability is tied to the conservation and regeneration steps to maintain the forest reserve for its ecological and biological values that have national and global significance.

Another question is which principles of sustainability that we could adopt to interpret sustainability? Some of such commonly known principles are the intergenerational justice and well-being needs, natural resource-limitations are some well-known principles. These general principles employed in a specific system as ours could direct us to different contextual facets of sustainability by enabling us to see sustainability from different angels. Further, depending on whether our focus is on socio-economic development or on natural conservation, they would provide different interpretations of sustainability or unsustainability. The meaning of resources would also differ accordingly. In the context of development, the resources could be seen as creating commodity values alone. Alternatively in the context of traditional notion of forest conservation, they could also be seen as highlighting environmental values alone, neglecting the human settlements' dependency on the forest and their role in the sustenance of conservation steps. Similarly differences can be identified with respect to other mentioned facets as well. With the help of these facets we could reach a detailed understanding of the significant unsustainability issues in the system.

Another question is, to what extent we should incorporate sustainability or unsustainability concerns outside of the territorial boundaries of village and the immediate forest for the system's evaluations? In other words, which spatial as well as viable scale we need to consider? The spatial scale would determine the extent to which the human impacts upon the long-term viability of the macro-ecosystem (the forest range) would be considered and vice versa. Further we would have to perceive system boundaries beyond the readily-visible and hard boundaries, such as physical and administrative boundaries to encompass less-visible and soft boundaries that signifies aspects such as resource usages, livelihood practices, watersheds, historical and cultural identities, and so on. Then only would we be able to see complex dynamic relationships that combine several of systems within the macro human–natural system, and how these relationships influence its sustainability or unsustainability. Drawing imaginary village boundaries such as resources linked socio-economic boundaries, biological and ecological significance linked natural boundaries, cultural boundaries and so is one way of visualizing less-visible boundaries and cross-boundary relationships. Further systems such as social system, economic system and the natural systems, could be visualized as the village's subsystems, whose spatial implications go beyond the physical territories of the village and the immediate forest[89].

A further related and relevant question is, which temporal scale needs to be considered for sustainability interpretation? In this regard, all past, present and future conditions are significant. This is especially so in a system where changes such as development have taken place in a relatively slower speed. Further, when we address sustainability interpretations of the locals, individual interpretations also would be tied to distinctive temporal scales. In this village, while the idea of sustainability differs from one person to next, it also is strongly linked to long-term well-being that ensures life support systems, and in overall, to the development of the village. Some elders in particular have a strong affiliation towards the notion that the individual well-being is connected to the long-term well-being of the village. In this regard, they are more past oriented and think in a longer time scale. Further, their interpretation of village highlights both the human (socio-economical-cultural) and natural ties. Their idea of well-being is strongly connected to the identity derived with relation to these ties. This way of interpreting well-being is somewhat ecological—highlighting the balance in varieties of relationships, continuous—retaining the past identity is held as significant, and also restrained to some degree[90]. While the economic development is considered as a necessity, they however do not prioritize over other forms of developments (such as psychological and moral development of young). Additionally, their focus of human relationships seems to be largely confined to the village itself. Among others however (especially among youth and some elders as well), the well-being is detached from traditional philosophical orientations, and is more connected to the trends in the rest of the country, emphasizing more on pressing needs such as access to energy and infrastructure, access to improved education and training facilities, more entrepreneurial capacity, having similar social facilities as outside of the village, occupations that are accessible from village, and so on. No longer the self-sufficiency or even the dependency on state welfare are considered as adequate well-being states. Further these views are embedded in change instead of preference towards stability, therefore in relatively shorter timescales as well. Among other factors, some of these views are formed as a result of being employed outside of the village, and the close contact with the research and training organizations. Although not necessarily the generation gap may accompany such view differences, there is a clearly observable variation across

[89] It is important to note that systems of economy, nature, and society could also be regarded as isolated systems on which the village is embedded. Further social system can be viewed as being embedded on economy or vice versa. While arguments behind these different ways of viewing systems with respect to its environment differ from each other, for the current study we would regard economy, society, and the nature as three subsystems of the macro village system.

[90] The individual wellbeing that disrupt the harmony of relationships not only among villagers but also across generations, or that do not comply with their philosophical beliefs, are heavily based on traditional wisdom.

different age groups of the time scales considered in well-being interpretations. These different time-scales could be influenced by the degree to which the stability and the change are embraced and perceived as important/unimportant for sustainability. While some seem to derive current interpretation of sustainability (in this instance as interpretations of well-being) from information oriented in the past of the system, others derive from information of anticipated futures that are predominantly based on observable trends from the outside. These differences are ultimately reflected in the general conflict that the village face in the process of determining their future sustainable pathways—i.e., of selecting the direction among traditional and modern life-style. The fact that the improved access to the city seems to be somewhat debated among them clearly resonates this conflict. The village has its only one road connecting to the outside of the reserve, at Loolwatta Junction close to Hunnasgiri town, and is about 40 km of length (Badenoch 2009). While as a village they wish that their living conditions to be enhanced than the current status, and see the difficulty to be accessed as one of the key bottlenecks, some still tend to regard that the remoteness and the wilderness have created positive conditions that encourage quiet and harmonious lifestyle which in one villager's words goes in a slower pace. Such alternative views of sustainability are significantly related to their mental frameworks and worldviews of the flow of time, and orientation with respect to time (past-, present- or future-orientation)[91].

These questions indicate that there are diverse issue-based understanding and reference frames of sustainability that have diverse spatial and temporal, and organizational (scale wise) significances, which tend to have a significant influence on how we understand sustainability in a system. Often these questions are hidden in the complexities and are not dealt in a systematic manner, that would easily lead to simplistic or ad-hock evaluations. As a result factors that only linked to immediate interest for the purpose of evaluation would come to the surface. By adopting systemic frameworks that enable us to explore the complexities, we would be able to address these aspects to our evaluations.

Illustration of Meemure's sustainability/unsustainability with the framework

The procedure followed in observing sustainability change is as follows.

Adapting a systemic view is the first step. When using a systemic view it is possible to identify scales of systems—both macro systems and subsystems. Usually observing with a

[91] It is noteworthy that, these views are also connected to the perceived economic growth and development. The outsiders recognize the location as a model village of Sri Lanka. Along with that, the villagers also increasingly recognize the economic benefit of maintaining its detached remoteness and the combined traditions contrasting their preference from urban areas in the vicinity.

lens of sustainability involves focusing on one particular system, and seeing the influence that the other systems have on the focus–systems or vice versa. In this study the focus–system is selected as the village-forest system that encompasses its economy, society and the immediate forest reserve.

In Step 2 systems were reinterpreted in to focus and its background. The subsystems and the significant issues highlighted to those subsystems could provide background understanding to the selected focus–system. These background understanding—considering their capacity to give spatially and temporally interconnected information to interpret sustainability of focus–system—appear to provide narrations of sustainability for the system. Two of such dominant narrations that are linked to village's sustainability/unsustainability—namely socio-economic development and the nature conservation—are considered as providing separate background layers to the focus–system to interpret its sustainability (Fig 28 and Fig 29)

The selected dimensions are same as that described in the framework, namely, sustainability-liked knowledge, sustainability-linked worldviews, resources limitation/availability, well-being views, policies, rules, regulations, and governing practices, and new creations, innovation, and artifacts. [92].

Relative to the dimensions and the system background unit, it was possible to approximately recognize stable temporal states through which the sustainability of the system change over the time. The historical change of the human–natural relationship of Meemure village can be observed with relatively stable states with respect to their sustainability/unsustainability. These states are phases of gradual transition that the village went through for years. Distinctive features and clear transition points of these states can be identified with background layers and dimensions. Therefore, the village's path through history can be viewed as connecting several different sustainability/unsustainability states over the time.

Then relative to the dimensions we could recognize specific sustainability/unsustainability conditions in system and background unit, and based on them interpret sustainability/unsustainability as 'sustainability contexts'. Table 4, 5, 6, 7 shows sustainability contexts across four different time spans in the form of a matrix. Each layer and dimension combination leads to a distinctive context of sustainability. In addition they function as parts of a story that solidified a sustainability/unsustainability state. Some contexts indicate the instabilities of the system in the current state. Others indicate why the system is stable in that state.

Finally we can interpret sustainability/unsustainability as sustainability boundaries by interpreting complex dynamic conditions in transition state referring to driving/damping

[92] Note that the system and background unit include the focus–system, its background seen as layers, and the supportive principles to evaluate its sustainability as dimensions.

capacity in dimensions. Some of the contexts show why it is necessary for us to consider the different system boundaries for sustainability interpretation. Focusing on parts enable us to consider cross boundary issues more effectively. With respect to these contexts we can recognize distinctive sustainability and unsustainability defining boundaries (sustainability boundaries). Recognizing boundaries from contexts involves a mapping process[93]. A set of generally possible boundaries is shown in Table 8. The combination of boundaries and the critical ones among them that heavily determine system's sustainability/unsustainability would differ in each temporal state. One example is the amount of available resources. In state 1, 2 and 3 the village had aspired to be self-sufficient with respect to resources. This has made resource availability or limitation as a critical boundary that defines its sustainability. The need for self-sufficiency is also attached to their views of well-being. Therefore in these states, the well-being views have provided another closely interlinked boundary. In the state 4, their well-being views have changed to align more with a market-based economy. The socio-economic activities related boundaries of the village have become permeable to integrate the working-force that is employed out side of the village. In the same manner the protective attitude towards the nature also have changed from a perception of treating nature as an inclusive entity (state 1 and 2) to and outside entity (state 3), and finally to co-existing integrated entity (state 4). Such views are formed to some extent as results of conflicts (conflicts of human–natural relationship) in pervious states. In this way, we could recognize that the boundaries that define sustainability/unsustainability for this system is changing as an adaptive process. Also we can recognize some of the dimensions that indicate those boundaries have driven the system to new stable states.

Sustainability contexts and sustainability boundaries are illustrated in the form of a matrix (as shown in Table 4,5,6,7, and 8). Matrix rows contain the background layers. The columns contain the sustainability dimensions.

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[93] By the term mapping, what is meant is that the process of observations of one entity (system relationships) is placed on top of observations with anther entity (dimensions) to obtain a combined description.

Table 4 : A matrix showing sustainability contexts for temporal state 1 (prior to year 1960s)

Dimensions / Background Layers	Sustainability-linked knowledge	Sustainability-linked worldview	Resource limitation/availability	Well-being views	Policies, rules, regulations and governing practices	New innovations, creations and artifacts
Socio-economic development	Sustainability/unsustainability understanding (of the village) derived mainly from traditional knowledge of forest resources, resource use practices (e.g. land use practices for paddy cultivation, chena cultivation, forest resources such as food and medicinal plants extraction), and wisdom traditions. These have shaped the social structure and the economic activities.	Sustainability/unsustainability is mainly viewed as survival with limited resources, keeping a self-sufficient and harmonious life style that is supported with enough consumable resources, and with limited economic activities with the outside of the village.	Unsustainability is interpreted as resource limitation, where resources include the forest related resources such as food and firewood, cultivated products (both through wet cultivation and dry-cultivation), cultivatable land, savings, available production technologies etc.	Unsustainability issues interpreted in terms of well-being where, well-being is predominantly tied to kinship and traditional lifestyle, resource availability, economic opportunities, and social harmony, (where social harmony is considered as being supported by kinship, physical and social distance from outside, and significant economic and social ties).	Solutions to unsustainability issues are achieved through, strictly set rules and regulations that represent local implicit rules, and property laws exerted by government, however due to the remoteness of the location more flexibility to consume the forest resources. Traditional rules are based on wisdom traditions and enforced through kinship hierarchy. State set rules are not properly disseminated to the local setting.	Solutions to resources linked unsustainability issues are achieved through traditional methods and techniques of food production, new experience based improvements to those methods.
Nature conservation	Sustainability/unsustainability understanding derived from the traditional, indigenous knowledge of forest species, weather cycles etc. However, explicit verifiable knowledge on thresholds of ecological balance and impact from human activities are minimum. Most knowledge of forest issues are tied to natural events that occurred in the past, such as forest drying, decertification etc., and fear-based beliefs that control the human activities in the forest.	Sustainability/unsustainability is not explicitly viewed as the importance/non-importance of forest's well-being (as a separate entity). Some exception are observed with wisdom traditions attached to local medicine culture, religious views etc); Generally there is a group-centric and inclusive view to the relationship with the environment. The forest is viewed as an entity to be feared and respected, and an entity that provides life-support and protection.	Significant unsustainability issues related to forest resources are not explicitly interpreted from the village. Globally the conservation of natural forest eco-systems (especially the primary forests as Knuckles) is considered as essential (these forest in this instance is regarded as a global endangered natural resource). The local knowledge of the global significance of the forest (where such knowledge could be considered as a resource for forest protection) is limited.	Significant unsustainability issues with relation to natural well-being are not interpreted by the village. Well-being is tied to well-being of natural system (forest) in the manner that it facilitates the well-being of the village (through of supporting resources, scenic beauty, weather conditions, village identity etc). In this stage significant human-stresses on the forest are not visible however the threats from forest to the human-survival are also reflected in folk-stories, beliefs, rituals etc.	The human relationship with the forest-eco-system is managed through local flexible rules that are based on wisdom traditions (enforced through kinship hierarchy). State-set rules (such as the boundaries that mark the forest territories and laws that prevent illegal encroachment) are not adequately disseminated to the locals.	In general the human-impact (including that involve man-made artifacts) on nature are minute. Where human system and natural system interact, the environmental sustainability is ensured with traditional methods, inventions and ways of human interaction with nature, which to a great extent have maintained the harmonious balance of eco-system and the human place in the eco-system.

Table 5 : A matrix showing sustainability contexts for temporal state 2 (approximately from 1960 to 1985)

Dimensions / Background Layers	Sustainability-linked knowledge	Sustainability-linked worldview	Resource limitation/availability	Well-being views	Policies, rules, regulations and governing practices	New innovations, creations and artifacts
Socio-economic development	From the village Sustainability/unsustainability understanding derived from, traditional knowledge (similar to the temporal state 1), new knowledge of cardamom cultivation, and income generation out of cardamom as a commercial crop. From the outside that represents the expert organizations, the economic development of village is interpreted in terms of indicators such as household income and in terms of its contribution/significance to national indicators such as GDP, GNP etc. The social development is interpreted through social indicators such as the access and the level of education.	Sustainability/unsustainability is viewed predominantly as harmonious life style, visible growth in income, savings, food production surplus etc. **Self-sufficiency of resources is generally viewed as an essential condition for sustainability.**	**Sustainability is interpreted as the economic growth related to the resources.** In this stage the resource pool have significantly increased due to the new crop. **Therefore, sustainability is interpreted as retaining the same lifestyle patterns that is supported by the new economic activities (by the groups who directly benefit from those activities).** Further contribution of the village economy to the national economy, the socio-political significance of the village (which is minute in comparison) plays a significant role in allocating external resources that support development.	**Unsustainability issues interpreted in terms of well-being, where well-being is tied to resource availability (an increased sense of well-being)**, the visible positive changes to life style, savings etc. Also it is heavily tied to social harmony, which is maintained by relatively equal access to resources, economic opportunities etc among villagers.	Solutions to unsustainability issues are achieved through, rules and regulations that represent local resource consumption, property division etc traditions, and the property laws exerted by government, however, due to the remoteness of the location, there is more flexibility to consume the forest resource pool (same as in the previous state). . The local property and resource consumption rules are being abandoned.	Solutions to the resource limitation are met through traditional methods and techniques of food production, where new innovations are added as improvements through experience.
Nature Conservation	Sustainability/unsustainability understanding is derived mainly from similar aspects indicated in the temporal state 1; In addition, new knowledge on forest resources (e.g. cardamom) is negatively effecting the forest well-being; from the outside of the system (that represents global and state level institutions) forest sustainability needs to be supported by conserving them against any human threat**.**	Sustainability-linked views towards the forest has not changed from that of the temporal state 1; The group-centric and inclusive view to the relationship with the environment, also remains same, however, **increasingly the environment is considered as a resource pool that has significant economic benefits than ecological and psychological benefit.** Villagers are somewhat aware of the forest boundaries. **The reluctance to oppose unclear yet existing regulations has limited there engagement in cardamom cultivation**	Significant unsustainability issues related to forest eco-system are still not interpreted from the village. **However, excessive forest encroachment for cardamom cultivation and other village-level activities such as grazing, are viewed from the village as defying the law, therefore, the expansion of these activities have been internally regulated.** Globally the conservation of natural forest eco-systems is considered as essential. The local knowledge of the global significance of the forest (where such knowledge could be considered as a resource in forest protection) is limited.	In this stage significant human-stresses on the forest are visible, however the threats from forest to the human-survival are also still reflected in folk-stories, beliefs, rituals etc. **In general the perception of well-being remains tied to the well-being of the forest, (with respect to scenic beauty, positive weather conditions, village identity etc., however they are less emphasized compared to the economic benefits).**	Solutions to unsustainability issues are achieved through local flexible rules, which are based on wisdom traditions and enforced through kinship hierarchy. State set rules however are not effectively disseminated to the local setting.	From the village perspective, environmental sustainability is ensured by sticking to traditional ways of living and interactions with the forest. From the state driven forest conservation perspective, new research methods, evaluation models are engaged to highlight and measure human impact on forest.

Note: Entries with bold letters show the significant changes in the system that drew the system (both positively and negatively) to solidify or alter its sustainability state.

Table 6 : A matrix showing sustainability contexts for temporal state 3 (approximately from late 1985s to about 2000)

Dimensions / Background Layers	Sustainability-linked Knowledge	Sustainability-linked Worldview	Resource limitation/availability	Well-being views	Policies, rules, regulations and governing practices	New innovations, creations and artifacts
Socio-economic development	Sustainability/unsustainability understanding derived from, traditional knowledge (mainly of the paddy-cultivation practices and of forest based resources (e.g., local medicine); new knowledge of cardamom cultivation; knowledge on indicators of socio-economic development.	Sustainability is interpreted as retaining the same lifestyle of the past (when economic benefits from forest was high), visible growth in income, savings, production surplus etc, and obtaining enough welfare facilities. In other words, the sustainability is interpreted with relation to predominantly human-system's sustainability. The state is seen as a provider of needed resources and welfare facilities.	Sustainability is interpreted as the ability to maintain the same pace of past economic growth related to the resources. In this stage the resource pool of the village has significantly decreased due to new forest conservation rules. Sustainability is interpreted as retaining the past lifestyle patterns, which means present time is interpreted as socio-economically unsustainable (especially by groups who directly benefited from those activities).	**Unsustainability issues interpret in terms of well-being, where well-being is tied to resource availability (a decreased sense of well-being), the visible negative changes to life style, savings etc.** Also it is still tied to social harmony and balance in eco-system, supported by the notion of collective economic development.	Solutions to unsustainability issues are achieved through, strict enforcement of rules and regulations, including property laws exerted by government, local rules for property consumption (some of which are perceived as invalid by the state).	Both traditional and new methods and techniques of food production, however the pace of introduction of new techniques are low. New innovations are added as improvements through experience. New tools such as cost-benefit analysis, sustainability indicators etc, to see the sustainability impact of socio-economic development projects.
Nature Conservation	Sustainability/unsustainability understanding is derived from, expert knowledge on the ecological importance of the forest reserve (the increased research activities in the knuckles have been a big source of knowledge for the villagers the ecological value of the forest reserve), stakeholders linked to the environmental issues, local knowledge and wisdom traditions on the forest eco-system. In this state, not efficient ways of identification of all the stakeholders involved in environmental issues (expert projections that are mostly based on other similar locations have not provided accurate estimates of the complexities involved in the forest degradation issue).	**Sustainability is explicitly viewed as the nature well-being, especially from the outside of village (that represents a network of global and state level institutions);** From the village a group-centric and inclusive view to the relationship with the nature, supported by wisdom traditions attached to local medicine culture, religious views etc remains, however, the materialistic view towards resource pool has continued to prevail. **The protection of the forest is seen as a separate (and opposing) entity from socio-economic development.**	Significant unsustainability issues related to forest eco-system are recognized especially from the outside of the village. Generally the environmental stresses have considerably increased, mainly due to resource-related activities such as cardamom cultivation, excessive grazing, and illegal logging (the villagers' contribution for illegal logging is minimum). However, the knowledge on the impacts (especially of the cardamom cultivation and the grazing) is not yet effectively disseminated to the locals. .	**In this stage human-induced stresses on the forest are remarkably visible. They were addressed by organizations such as the forest department and research communities.** The perception of well-being among the villagers is not still significantly tied to the well-being of the forest, although the scenic beauty, positive weather conditions, village identity etc., are appreciated. **The forest is viewed by the village as an entity that has distinctive environmental value that are not necessarily tied to the village-forest relationships.**	**Solutions to unsustainability issues are achieved through strict enforcement of rules and regulations that represent property laws exerted by the state (e.g Knuckles conservation act 1985); local rules for forest resource consumption (including private land-ownership within new reserve boundaries) are perceived as invalid by the state, diminishing value for long-held local knowledge and wisdom traditions.**	New research activities linked to nature protection are practiced by state, evaluation methods for human-impact on the forest reserve. Environmental Impact assessments (EIAs) and the cost-benefit analysis that consider the sustainability impact of forest conservation, replenishment steps.

Note: Entries with bold letters show the significant changes in the system that drew the system (both positively and negatively) to solidify or alter its sustainability state.

Table 7: A matrix showing sustainability contexts for temporal state 4 (from approximately year 2000 onwards)

Background Layers / Dimensions	Sustainability-linked Knowledge	Sustainability-linked Worldview	Resource limitation/availability	Well-being views	Policies, rules, regulations and governing practices	New innovations, creations and artifacts
Socio-economic development	The distinctively significant forms of knowledge in defining socio-economic development related sustainability/unsustainability of the overall human-natural system (that include both the village, the Knuckles forest reserve and the buffer zone where [village's] human system and natural system interact). The development of the village, to some degree, is constrained by the significant environmental and historical values attached to the village and the surrounding. Local knowledge with regards to land use and other development practices.	Sustainability viewed as, **individualized/modernized life style accompanied with continuous economic development; having the standards of living (including social and economic benefits) similar to the rest of the country, while keeping a harmonious life style with collective economic development. Sustainability is interpreted as, development with new income generation methods and less dependency on state welfare and resources; maintaining kin-ship traditions which are threatened due to younger generations' urban sprawling for employment; improved infrastructure and access to national/ regional energy grid are considered as essentials of socio-economic development; maintaining the harmony with the surrounding forest ecosystem, while being able to consume forest resources for non-economic and small-scale economic uses.**	**Sustainability is interpreted as the ability to achieve resource related economic growth.** In this stage the resource pool of the village remains decreased due to new forest conservation rules, **however new domestic crops such as black-pepper to some extent offset the lack of land. For some villagers sustainability is interpreted as retaining the past lifestyle patterns, and for others especially for the younger generation sustainability is being able to have the basic facilities (as energy and education), and further similar socio-economic facilities as to what the city dwellers experience. Present time is interpreted as socio-economically unsustainable, mainly due to lack of income generation opportunities within the village, and social, economic, and cultural stagnation.**	**Wellbeing is tied to resource limitation (resources in this stage have shifted from forest-based resources to energy (alternative forms of energy to traditional fuel food, national grid based electricity and local based electricity generated through small scale solar power dendro power and hydropower generators), local employment and entrepreneurial opportunities, adequate facilities in local schools, the visible change in life style, savings etc.** Also it is still tied to the balance in eco-system, social harmony. A reduced sense of wellbeing with respect to resources.	Sustainability is ensured through strict enforcement of rules and regulations that represent property laws exerted by the state (government), local traditions for property consumption are disregarded by the state. Increasingly the development policies are formed by or being supported by international organizations, such as World Bank and UNIDO. The villagers are considered as significant stakeholders in the process of decision-making (that concerns socio-economic development of the village), however, their sense of dependency on the state and the expert organizations for future development also has increased compared to the past.	Both traditional and new methods and techniques of food production are available, however, the speed of introduction of new techniques are slow. New innovations are added as improvements through experience. New tools such as cost-benefit analysis, sustainability indicators etc, to see the sustainability impact of socio-economic development projects.
Nature Conservation	Sustainability/unsustainability understanding is derived from, expert knowledge same as indicated in state 3; local knowledge and wisdom traditions on the forest eco-system continue to exist (most local knowledge are derived from traditional and indigenous teachings).	**Villager's sustainability views are influenced by views on importance of environment's well-being from outside of village. However the significance of them as protectors of environment is still absent as they regard themselves as non-experts on environment.** The attachment to the environment is mainly reflected through still remaining medicinal practices, appreciation of scenic beauty, identity derived as a forest-dwelling village.	Significant unsustainability issues related to forest eco-system are interpreted from both village and the outside of the village. The villager's tend to regard themselves as active partners of forest protection. However, the sense of entrapment within the forest reserve is strong among many. Villagers highlight the significance of human system (the village) as much as the natural system (the forest reserve).	**Wellbeing is still tied to the well-being of the natural system, however, less when it is perceived as a forest reserve per se, and more when it is perceived as an entity that add scenic beauty, protection and identity to the village.**	Sustainability is ensured through strict enforcement of rules and regulations that represent property laws exerted by government; local forest resources consumption patterns are disregarded in conservation legislations; conflict with long held traditional practices.	New research activities linked to nature protection are practiced by state, evaluation methods for human-impact on the forest reserve. Environmental impact assessments (EIAs) and the cost-benefit analysis (CBAs) that consider the sustainability impact of forest conservation, and replenishment steps.

Note: Entries with bold letters show the significant changes in the system that drew the system (both positively and negatively) to solidify or alter its sustainability state.

Table 8 : **A matrix showing sustainability boundaries**

Dimensions / Background Layers	Sustainability-linked knowledge	Sustainability-linked worldview	Resource limitation/availability	Well-being views	Policies, rules, regulations and governing practices	New innovations, creations and artifacts
Socio-economic development	Boundaries exerted by the limitations of knowledge, of available resources, resource use methods and so on; limited knowledge on efficient economic practices, efficient resource use practices. Nesciences relevant to future economic practices, and trends outside of the village that will influence its own economic development. Thresholds marked by social and economic development indicators.	Boundaries exerted by the views that represent resource practices, self-sufficiency in terms of resources; view that define the ideas of well-being, preferences of life-style, access to nationally provided welfare facilities, education facilities, views that represents collective or individuate attitudes towards well-being, economic development, sustainability etc.	Boundary exerted by limited resources where resources include forest related resources, cultivatable land, monetary savings, available production technologies, infrastructure that supports new development pathways.	Boundaries exerted by the minimum acceptable values of socio-economic development related well-being indicators (related to access to education, energy etc)	Boundaries that are defined by rules and regulations (both traditional and state-induced) that have the effect on resource usage, access to facilities such as energy and infrastructures.	Boundaries exerted by the available amount of technologies (for food production, for other income-generation activities, and energy production)
Nature Conservation	Boundaries exerted by the limitations of knowledge, of forest-ecosystem functions, biological limits, threatened species, critical weather patterns and thresholds connected to them; impact on forest-based resource-extraction practices. Nesciences relevant to eco-system functions, biodiversity, weather-patterns etc, Thresholds marked by environmental indicators, and fear-based beliefs that control the human activities in the forest.	Boundaries that represent minimum acceptable values of environment's well-being indicators that highlight group-centric and inclusive view to the relationship with the environment, views that highlight the physical and psychological dependencies upon the forest.	Boundaries exerted by the threat to the bio-diversity (number of rare species) by the forest resource extraction, illegal logging and other activities, threat to the ecological balance by overexploitation of resources.	Boundaries exerted by the threshold values of natural environment's well-being related indicators such as number of endangered species, forest cover destruction/replenishment rate.	Boundaries that are defined by rules and regulations (both traditional and state-induced) that have the effect on forest-ecosystem preservation and well-being. This may include the amount of forest cover, targeted amount of forest-cover replenishment, saved number of endangered species and so on.	Boundaries exerted by the technologies to ensure economic and social needs of the village to be met, with minimum damage to the forest reserve (e.g. technologies for solar power, hydro-electric generating and maintenance)

In overall, the framework applied in the matrix form allows us to come up with a multiple contexts and boundaries that represent multiple sustainability interpretations and evaluations respectively. With interpretations we try to untangle complexities by addressing some of the fundamental questions around sustainability. With evaluations we aim to provide clarity and a decision basis to those interpretations. They could be compared to the parts and the wholes of the process of sustainability evaluation. Therefore the framework has enabled us to holistically interpret sustainability.

The observation process and some of the key aspects of above detailed interpretations are illustrated in figure 28, 29, 30. In the figures the state in each temporal stable state is described with respect to the focus–system and the combination of the two backgrounds. By the arrows (thick), what represented is the transition of sustainability/unsustainability from one sustainability state to next. By thin arrow direction, what indicated is the negative or positive driving force that is exerted by each dimension. We further call the damping or reinforcing driving forces to next sustainability state. [94]

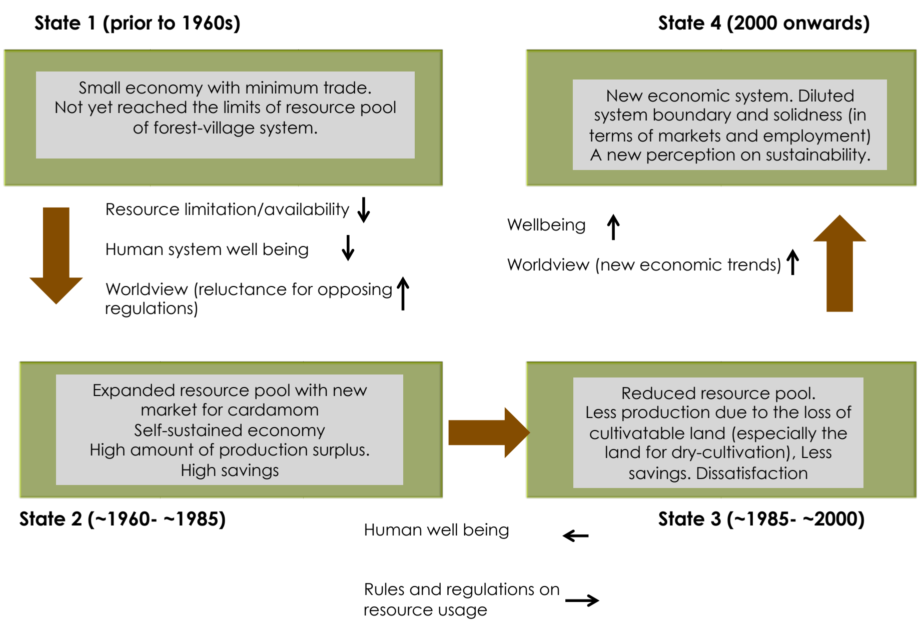

Fig 28. Interpreting sustainability/unsustainability states and their changes related to village socio-economic development

[94] Please note that in this case the temporal states recognized for observation and sustainability states coincide with each other. This is not necessary to be so. There could be situations that significant sustainability states could be recognized only in some of the temporal states.

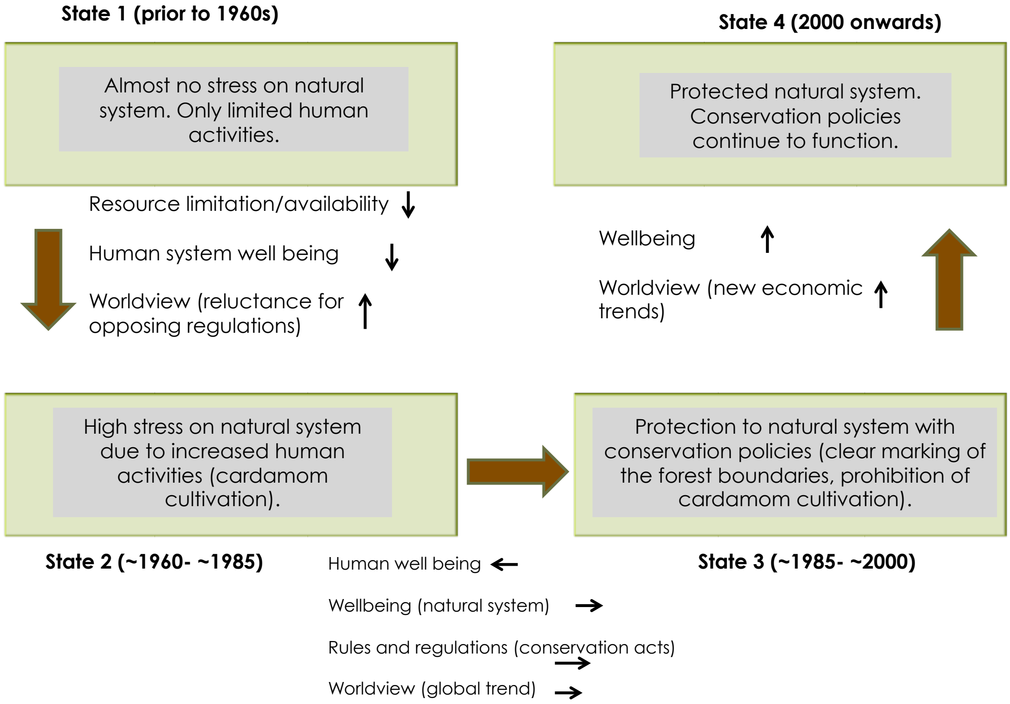

Fig 29. Interpreting sustainability/unsustainability states and their changes related to nature conservation

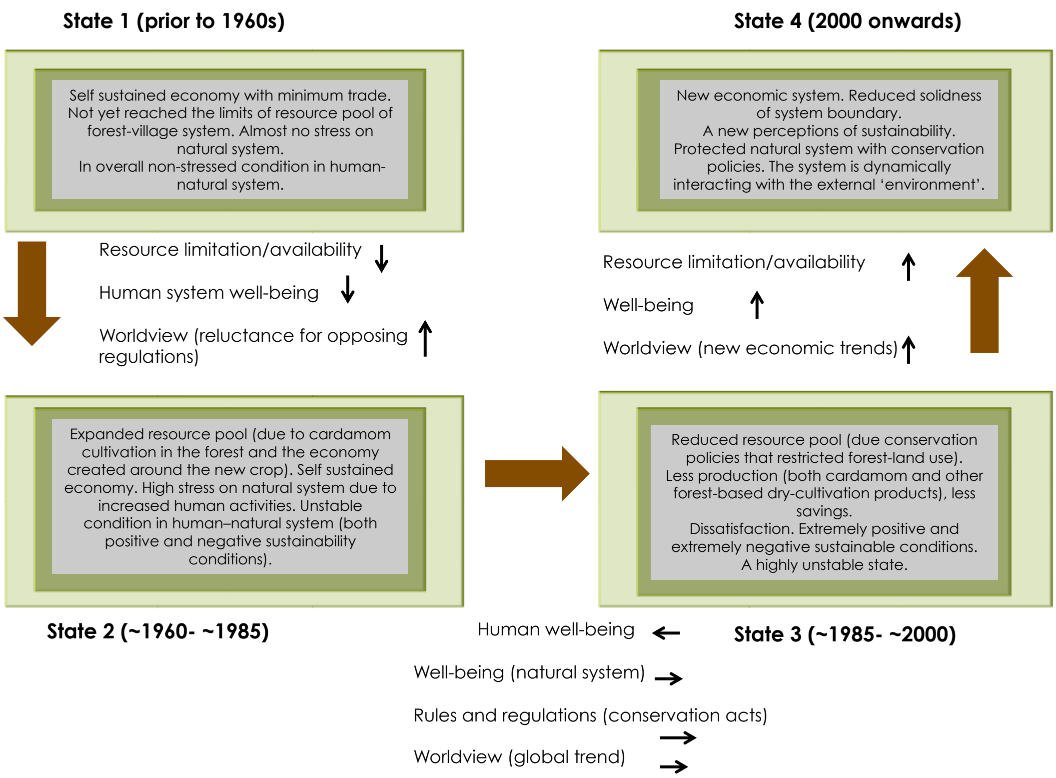

Fig 30. Interpreting sustainability/unsustainability states and their changes in cumulative socio-ecological system

Based on the two backgrounds, the most significant aspect for sustainability for the first state had been that a significant stress on the natural system has not yet occurred. The impact on forest by the settlers stay minimum. In second state's sustainability interpretation, the most visible change had been the expanded resource pool of the village-forest system that had a positive impact on the village economy related sustainability but a significant negative impact for the surrounding forest's well-being related sustainability. This occurred due to the cardamom cultivation in the deep forest (acquiring more forest land than the immediate forest land that the villagers were accustomed to for consumption-based dry-cultivation). The key drivers behind the change to overall human–natural system's functions and accompanied sustainability/unsustainability is the limitations in resources (more precisely land, money, new technologies to improve the productivity of available crops etc), and the perceived increase in human system's well-being (through the increased market to cardamom). One negative driver that controlled especially the excessive forest destruction is the reluctance from the villagers to illegality use forestland. The significant aspect that marks sustainability in the third temporal state is the conserved state of the forest, and the accompanied heavy reduction in cultivatable land for the villagers. The key drivers that solidified this state are the clearness and the inducing power of the policies, and the global views, trends and scholarly debates that supported those policies. The key drivers that negatively influenced sustainability, especially when considering the background of economic development of villagers, were their well-being views, that placed them in victimized and entrapped situation. Finally, the significant aspects that mark sustainability/unsustainability in the forth and current temporal state are the protected forest and the reduction of economic dependency of the villagers on the village-forest system related natural resources, accompanied my new forms of economic activities that are positively influencing the village-economy. Shifting to those economic activities have been supported by the changing worldview—as a result of villagers adaptations for outside views, as well as the influence of their views to the out side institutions, knowledge structures etc. This state also could be identified as an instance the system boundaries are rearranged in a way the that basic views of sustainability is going through significant changes that involve to some degree a balance participation from both inside and out side of the system (e.g. from village side, self-sufficiency is being abandoned to more connected economic and social relations with outside, and further, more economic activities that aim to benefit from their unique setting, culture, and efforts to retain positive human–natural relationships; from outside, more appreciation for locality, tradition, ecological lifestyle etc). This could be seen as a the system and environment relationship shifting from the scenario that system internalizing the environment to the system to generate complex dynamic sustainability or unsustainability changes possibly transforming itself alone, to the scenario that the system and the environment being merged and transformed itself collectively. The key synthesising entity behind this new look of sustainability state could be regarded as the worldview.

4.2.3.3 Discussion

What explained is a step-wise procedure to identify sustainability/unsustainability boundaries for human–natural system. In order to do that, we have visualized a set of temporal stable states that the system goes through. Here, we have made an assumption that the structure and functions of the system (village and its adjoining forest together) is relatively sable in these temporal states. In order to incorporate complex dynamic nature of the system the same two techniques that were elaborated in the framework were utilized, i.e., (i) to differentiate focus–system from its background (ii) to interpret sustainability in the system and background unit we utilized a generally identified set of dimensions of sustainability. Here, we stick to the same general dimensions that were illustrated in the framework. The methodology enabled us to come up with multiple sustainability/unsustainability interpretations for the village. Also it enabled us to see the short-term and long-term system interactions, and their implications on sustainability in a more refined manner than it would have been possible with a lesser systemic method. The analysis shows that the dimensions provided contexts to view sustainability, and also, some of them in this case actually could indicate the positive and negative feedback for the transition process to the new temporal sustainability states in the village. It is also observed that the change in attitude of villagers of the resource dependency and self-sufficiency was closely linked to their sustainability related worldview.

Further, analysing the case in this way directed us towards some significant observations about the system in general. One such observation is that, the two of the unsustainability issues that have governed in this system, i.e., lack of socio-economic development and the degradation of environment, seem to have common driving forces underlying them. Close observations show that the change in the system has always connected to resources—either in the form of natural resources or socio-economic resources—and the resource based relationships with the outside of their physical confinement. Therefore, the resource limitation/availability is a fairly visible common underlying trigger. Another driving force that is slightly less visible is the sustainability-linked worldviews. Views such as the positive regard for self-sufficiency, preferences for harmony in lifestyle seem to have solidified the state 1 and 2, and made the state 3 highly unstable with respect to at the time interpretations of sustainability. In addition the policies, rules regulations and governing practices also have had visible significance in driving changes in this system. In addition, sustainability-linked worldviews (of both external and internal to the system) also have an added value in terms of influencing how the system had interpreted their sustainability, and how it had changed over the years. Apart from these fairly visible triggers, in each stage we have recognized that the entities marked as dimensions have either solidified the current state or actively strengthened system's sustainability changes.

It is noteworthy the sustainability-linked worldview seem to have gained an added significance in the changes that occurred in village-forest system, and their subsequent influence on sustainability. Sustainability-linked worldview has been an entity that had marked the system boundaries. Further, it has reflected its autonomous nature with a strong separate identity yet close interaction with external environment through both internalizing and resisting external worldviews. In addition to worldviews, resource limitation/availability also seem to have had a strong influence in defining the system boundaries. Especially in the past, resource related boundaries had differentiated their system as a viable unit separate from its environment, and also through which the environment influenced the system's sustainability. However, especially in the recent times the way the resource limitation/availability is interpreted ultimately seem to be influenced by their worldviews regarding resource practices, environmental factors, their capacity, and so on. Further worldviews, seems to have influenced the not just the interpretation of the dimension, but also the changes that already triggered by them, resulting a reinforced change process. One example is the reinforcement of the reduction in their perceived level of well-being after loosing cultivatable land for forest by their traditional view of sustainability as being able to be self-sufficient and economically viable (instead of being employed outside of the village). Further, the variations that are visible with respect to other dimensions have their roots in how the villagers perceive their link to sustainability, therefore to their sustainability-linked worldviews. For instance the variations of views of well-being among individuals have their roots embedded in their views of what would enable them to survive individually and as a society as one system, and how their individual and collective survival is linked to each other (such link also extend to larger scales such as how the villagers perceive their individuality as a village and its dependence to the outside environment, how in return such perceptions influence their individual well-being views). The variations across time also seem to reflect changes occurred in their deeper-most worldviews regarding what constitute sustainability for them. Another example is that, just by knowing the biological and ecological importance of the forest have had some effect on how they perceive sustainability of the forest, yet their overall interpretations of sustainability of village-forest system as one interrelated system is heavily influenced by not just their knowledge change but a deeper view change in how they see the influence of forest degradation as threatening the village-forest system's sustainability. These deeper view changes are influenced by their current values, traditional teaching, wisdom practices/teaching that they have referred to when they regard the question of sustainability. Also they seem to be linked to whether they perceive sustainability linked to purely human system, purely natural system, or their system as ecologically interwoven (with depending as well as nourishing roles). For instance in many occasions individual and collective survival—that was in early times based on their food production capacity, spiritual protection etc, and in more recent times on the individual and family economic status, education level, resource governance power etc—had made the social and economic importance of the system standout, and had reduced the perceived importance given to their identity as a forest-village system by themselves (This later tendencies also reflect their dependent and disadvantaged status relative to the surrounding. Because of that mainly the changes to their lifestyle through especially economic practices had been more of an adaptive process to the environment). The knowledge on the biodiversity value, as we discussed, which were attached to policy rules, and expert knowledge structures have altered their view of village. Rather than positively influencing the views with added knowledge however, probably because of the strictness of the rules, and the mismatch of power attached to knowledge dissemination to them, the new knowledge to villagers had not played an immediate effective role as it could have been. Alternatively the policies that clearly highlighted the necessary importance of the natural systems (overpowering human system needs) have significantly altered their views of themselves as a forest-village system and their value as a part of the macro-ecological setting. This shift in identity, sense of place, and relationship to their surrounding, had subsequently reflected in their changing worldviews about sustainability, further influencing how they as a village view their future path. In the same manner, we can see that, sustainability-linked worldviews seem to have been at the root or at the receiving end (to the system) of all the other dimensions and influence their capacity to drive the system's sustainability/unsustainability. Also we can see that worldview seem to have dynamically connected different scales of the system within itself, and the relationships of the system to its environment (the surrounding in other terms) that represent a macro system (region, country) back to the system through individual and collective view changes. Further, as we observed through in final state, worldview also takes on a synthesizing role, by giving a merging influence on the system boundaries, letting not the environmental (outside) factors change the system, but also the system features to change the outside environment.

Another related overall observation is that the two significant backgrounds we have selected could also be interpreted as two significant issues (even though at the outset in selecting the backgrounds, the subsystems of economy, society and nature were considered) that the system is facing, and these issues have their origin in the imbalance occurred in the human–

natural relationships. Especially the stat 2 and 3 indicate time spans where either the human system or the natural system became overly signified than the in the system's future path (Fig 31). In state 2 the economic development have made the importance of nature undervalued, while in state 3, the nature conservation has undervalued the village's need for development and its identity as a distinctive part of the socio-ecological system. This imbalance seems to have made these states unstable in sustainability point of view. Based on this observation, we could predict that in addition to the already recognized triggers, the imbalance in human and natural system's sustainability conditions could trigger further unsustainability conditions in the system.

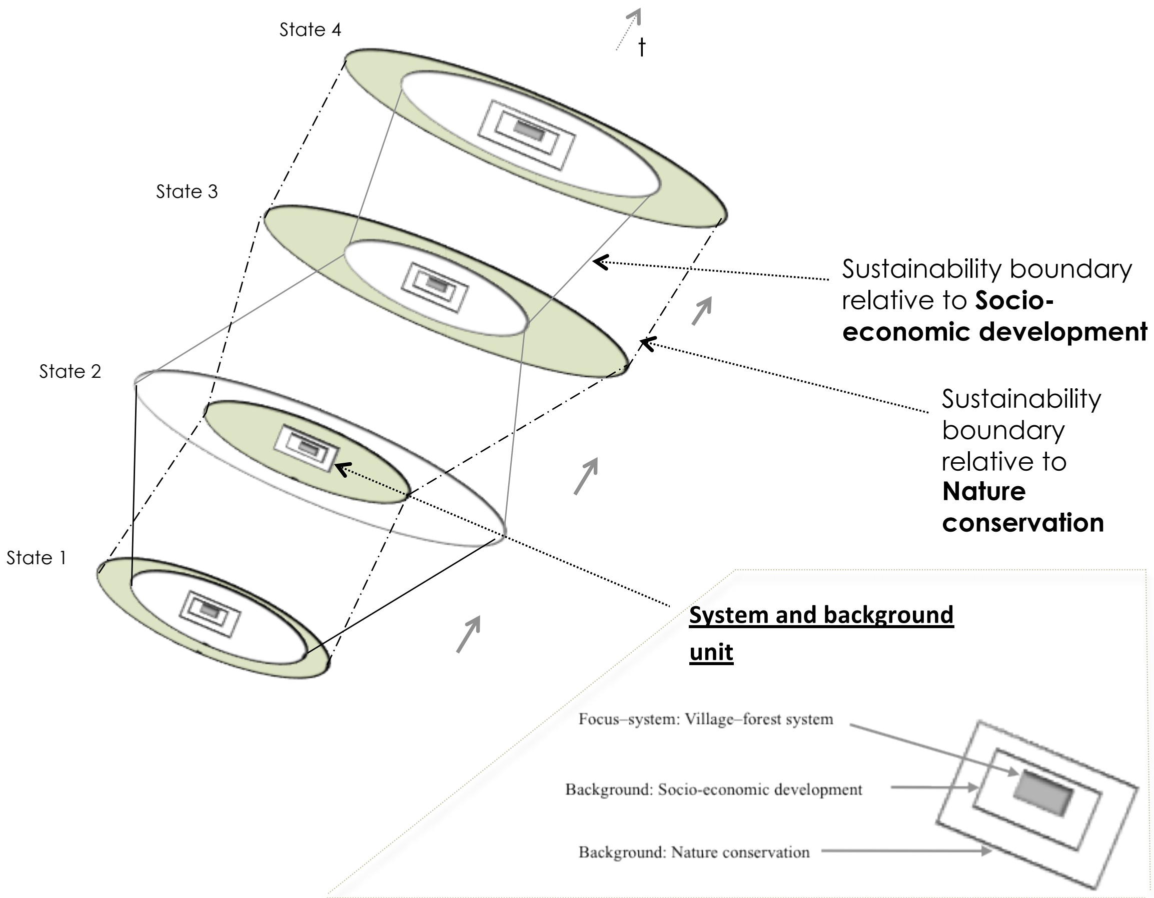

Fig 31. Visual illustration of change in sustainability boundaries with respect to socio-economic development (focus on human system) and nature conservation (focus on natural system)

Note: upward arrows beside boundaries indicate driving forces and triggers that bring the system form one state to another. Some of these drivers collectively have supported to transform the state.

Sustainability conditions of individual human and natural systems could be generated through varieties of ways such as policy initiatives, and new technology based solutions. However contextual interpretations in each state have demonstrated that considering the human–natural system as one integrated system than an isolated unit is a necessity in these initiatives. To recognize this balance, however, it is also important that we do not confine our focus to immediate system boundaries, such as the village as a socio-economic system and the immediate forest as a natural system, but pay attention to the connection of these systems to other systems of different scales. For instance factors such as the global-level, biological and individual-level, psychological significance of the forest, and the significance of socio-economic developmental state of the village upon individual attitudes towards environmental protection, would not adequately be considered if we focus only on the visible territorial boundaries of village-forest system.

4.3 DISCUSSION AT THE END OF EMPIRICAL OBSERVATIONS

4.3.1 Comparison of the two cases

The two case studies were selected in a way that they could effectively illustrate important individual components of the framework, and further its applicability in actual sustainability appraisal. For that, we have aimed to select cases that demonstrate close interactions and conflicts of human and natural systems. Further they were selected to represent different scales of systems, namely a global scale system, and a local scale system, as we wanted to see the applicability of the framework in different scales. The first case study has relied on data from literature. It also is based on an issue whose complexities have already been dealt in the process of finding solutions for the issue. Because of that, to some extent we observe the complex dynamics around this issue in retrospect. Apart from this limitation, the case enabled us to see the significance of observing different contexts around the same issue, and by supporting a reflexive and iterative understanding process, it has also enabled us to see how these contexts themselves have competed and changed in the process of directing the solution trajectories, therefore the direction of countries and globe as a human–natural system. The second case study—of the village-forest socio-ecological system of Meemure—relied on data gathered by direct observations of a system that is faced with varieties of unsustainability issues. In this system as well, in order to make interpretations of sustainability of the present time, we had to explore the historical developments of key events that have had repercussions behind the current state of the system. We have applied the observation methods supported by the framework to analyse theses cases and to make sustainability/unsustainability interpretations and evaluations. In both cases we could recognize the drivers of change that had played a significant role in bringing the systems from one sustainable state to another. Further in the second case, from the outset we have observed that there were key events that had significantly altered the system's path especially relative to the backgrounds that were selected to explore sustainability in the focus–system. These events were placed relatively apart from each other in the time line, which enabled us to see temporal states with relatively stable conditions joining those significant events. Therefore, we have expanded the analysis to engage a set of temporal stable states and applied the methodology of the framework to them separately. This contrast to what we did in the previous case, as to analyse the issue and its solutions as a continuous transition process, from which at the end we recognized significant sustainability and unsustainability states. In both of these cases, what the layers, and dimensions do is to allow us to break apart a complex dynamics phenomenon in to specific parts. They enable us to explore aspects that we intuitively recognize as deeply relevant for sustainability evaluation. By doing so we could understand the phenomena in both detailed and holistic manner. In combination, the framework provided us with a set of contexts, which when explored their close interrelation with other contexts, and their change across time, appear as a set of sustainability narrations. They at the end showed us different sustainability or unsustainability evaluation basis, which we referred to as sustainability boundaries. This process of differentiation of a phenomenon, namely sustainability interpretation of a system, in to parts, analysing the specific implication of the parts, and further to combine the solid understanding derived from those parts to, first separate, and later, a combined understanding of sustainability boundaries reiterate our own initial understanding that sustainability resembles a process and a path than a static state of a system.

Further, it is important to note that the contexts and boundaries were recognized through the dimensions that we have selected to interpret sustainability from the outset of the analysis. Also, to some degree we limit our interpretation of sustainability around the two significant issues that we select as the background layers. In other words, the very process of selection the background layers and dimensions colour the boundaries (i.e. evaluations) that we recognized later. We have to note this point carefully, as it reminds us that the step of selecting these background layers and dimensions should be done with caution. To analyze these cases, the methodology needed to go through minimum modifications. We could demonstrate the manner in which the two observation methods can be integrated, and also the significant roles of the backgrounds and dimensions in indicating sustainability contexts and boundaries. The contexts are shown in a matrix that shows the reflexive and iterative nature of the influence of dimensions in mobilizing collective and integrated change in the systems (that included reinforcing, damping effects to already set changes), and also, of our own understanding process as evaluators. Especially the context-matrix of the first case study demonstrates these collective changes and the reflexivity and iterative understanding that had accompanied (both for the agents of the system and for us as interpreters). Further, exploring individual contexts in a detailed manner had enable us to dive in to less visible aspects of sustainability that led us to acquire in-depth details of cultural implications, individual perspective differences, and so on, that also influence the sustainability interpretation of the system. This process could also be identified as narrowing the path through which the focus–system is to made internalize the information from backgrounds and dimensions to make its sustainability interpretations. As described in the beginning, the dimensions and backgrounds represents aspects that are relevant to both internal and external to the focus–system (e.g. dimensions by definition included both general principles that carry to some extent universal implications as well as their special characteristics that are locally unique to the system). This means that the process of internalizing the environment for sustainability interpretation happened in refined way that could enable emergent understanding.

Further, when we explore the dimensions to see their function as the drivers, we could see that their significance to a system's sustainability change have been in different degrees in different time spans. Even further, their function seems to differ depending whether the system is going through a stabilizing or destabilizing process in terms of its usual functions and the structure. In the second case study we recognized that the mismatch of the significance given to human system and the natural system seem to have been one noteworthy driver behind the instability of the cumulative human–natural system in the perspective of sustainability. Because we have selected the two backgrounds to reflect major functions and importance of each of these systems, we could explore this instability. In addition we also could see that once this instability occurs what seem to influence conscious system changes towards sustainability or unsustainability is the worldviews that informs the sustainability/unsustainability aspects for relevant stakeholders. As we conceptually discussed earlier, these sustainability/unsustainability aspects would differ depending on the system and depending on the point in history. For example, in Meemure, through out the history sustainability has been tied to their survival need as a village, therefore to aspects such as resources, external political structures and so on. This survival need and capacity, which later were integrated to their capacity for development, was influenced by new sustainability-linked knowledge (e.g. global knowledge the added significance of natural system), new policies, and new innovative developments (e.g. rural development policies, social development initiatives, environmental assessment practices and so on) that aimed for human and natural well-being of the system. These drivers in some occasions of change significantly altered system's economic structure, therefore, in socio-economic perspective have brought to the system to a new level of sustainability. In other occasions they have generated changes, but the changes were less significant and often had made the system to solidify its current sustainability state.

4.3.2 Specialty of sustainability-linked worldview

Underlying all these drivers the dimension of worldviews seems to have played somewhat a noteworthy role. There are few reasons why we could say so. If we take the case of Meemure again, the major and rapid changes in the village have occurred due to external factors that were supported by bigger institutional structures, which in turn seem to have reflected global ideologies to some degree. The conservation policies were very much a result of not only to actual threat to the forest by the forest dwellers and other encroachers, but also of the global scholarly debates and policy trends that recognized natural conservation as a timely and prior necessity. In these conservation views, often the forest dwellers were seen as a lesser important nuisance. Also the market based economic policies and implementations that encouraged the younger generation of the village to look for employment outside of the village, significantly altering the family dynamics and village social support structure, had their roots in the country level ideology shift that started in late 1970s. Another less visible example is the government supported social development practices that included effective measures of family planning, which had altered the rural demography in Sri Lanka considerably in the last 50 or so years. Such activities, also have been heavily influenced by global ideologies, and further have strengthened by domestic traditional views and ideologies. These are few visible instances where the worldviews of the outside environment (that reflected through macro-systems such as larger institutions, knowledge structures, governing structures etc with their own negative/positive sustainability direction) had the capacity to influence the change of the sustainability/unsustainability direction of the village. Another reason why it seems to have an added significance is that the villagers' own worldviews related to their sustainability—both directly and indirectly—seem to have in several instances driven the system in an opposite direction from that would have been, if not for their strongly held views regarding their sense of place and identity, which again is a worldview that in some distance is related to sustainability. One example is related to their way of utilizing the natural resources. Earlier we have discussed that villagers have had a restrained attitude towards using forest-based resources. This was seen in their land use practices, especially of the lands whose ownerships were not made clearly visible. If the resources usage was treated equal to any other human system based on our usual understanding of rational actors, the physical seclusion of the village could have driven the system to exploit the natural environment, leading it to a collapsing situation long time back. Further, their current economic state and the economic and social choices that they make (which we discussed earlier) seem to suggest that, not only some of their individual tendency to value harmonious life-stile, but also as a village, similar collective values tied to their identity as a secluded village seem to validate their not purely efficient economic and social choices. That may have been a reason why the urban sprawling that has occurred through out the country seems to have occurred slightly in slower speed in Meemure, and it to this day somehow survive while retained its identity. We cannot however clearly differentiate to what extent the choices of villagers were influenced by the physicality of the constraints that they face, such as the lack of energy and infrastructure, and the mental aspects that connect with those constraints. However, looking at how the village has changed over the years, we could see that the mental aspects, especially the deeply held worldviews, seem to have a strong hold in defining those choices.

Now if we go back and look at the case surrounding the ozone depletion, the significance of worldviews may not be as readily visible as in the previous case. Rather, the sustainability linked knowledge, and the policies, rules, regulations, and governing practices seem to have stronger influence in driving the system changes. However, the context interpretations suggest that the worldviews of institutions, countries, and so on, are subtly visible underlying the facts such as that the two selected backgrounds in reality were in conflict with each other in the process of addressing the issue, and that there were delays in knowledge availability and verification, and policy initiatives which determined how the issue (and the solutions) progressed. The conflict reflects the equal importance of those backgrounds to people in general, and therefore, indirectly to their values on what constitute sustainable/unsustainable for them. Further, this case also aggravate our earlier observations made especially with the second case study, that worldview seem to provide a background to other visible drivers of change as well. For example, the new knowledge of ozone depletion were not adequate to get support for manufacturers, legislatives of individual nations etc, and even after policy enactments, the actual function of those policies were largely slowed down because of the lack of genuine effort from entities such as industries, governing bodies, householders, and so on. And also on the other hand the knowledge of the extent of the harm from ozone depletion (particularly the cancer threat) had significantly shifted people's worldviews about their (and their governments', industries' etc) sense of responsibility for environment (triggered by factors such as their heightened risk perception). Further, the delay in knowledge and policy availability and acceptance goes beyond surprises and nonknowledges to include possibility of negative knowledge, that is knowledge that may have been suppressed of their emergence for political and value laden reasons. In this way we could recognize that worldviews have had a subtle but significant role in sustainability unsustainability changes in the systems. Underlying the more direct and visible drivers, worldviews of individuals, society etc, seem to operate to strengthen or oppose their emergence, functionality, and how successful they could contribute in transforming a negative state to a positive one. In other words, the worldview change supports a *second-order change* in the system.

Earlier, we have explored this dimension's role in the framework, i.e., contributing to indicate sustainability interpretations and evaluations, and other sustainability changes in the system. As for interpretations we mentioned that basis of the interpretations and evaluations were through the two dimensions of (sustainability-linked) worldviews and (sustainability-linked) knowledge. Further under an umbrella of sustainability dynamics we predicated two significant avenues with which the dimension would influence sustainability dynamics of a system; first through enabling the observer to recognize complex dynamics, hence dynamic patterns of the system, and second through influencing the sustainability/unsustainability of the system (without so much observer's involvement). In addition to the aspects that were mentioned, now after the empirical studies, we could also say that changes to sustainability-linked worldviews (and accompanied sustainability-linked knowledge especially when considering an outside observer's role) could be the key transformation agents that bind these two avenues. While all the dimensions have the capacity to form sustainability boundaries as we have seen with the two cases, they also stay as the foundation for all the interpretations and evaluations made, and further, for changes to those interpretations and evaluations with new knowledge and to some extent altered sustainability views. When the evaluator is part of the system, or when his/her evaluation would effect the future changes of the system (as in the first case the evaluations by scientific community, and in the second case evaluation based sustainability understanding of the villagers and that of external organizations such as forest department and the central government), these changes themselves would drive the system towards sustainability or unsustainability. That means in these instances especially sustainability-linked worldviews (along with sustainability-linked knowledge) seem to act as a driver of change (1st order change), to mobilize the changes in other drivers through interpretations and evaluations (2nd order change), and further to support collective transformative changes by alerting the sustainability view of the whole system (possibly a 3rd order change). These are some of the reasons why it seems that sustainability-linked worldview have had specially role in sustainability dynamics.

4.3.3 Revisiting framework

4.3.3.1 Order of selecting framework components

Somewhat related to the framework's capacity to address complex dynamics in an effective manner, we need to highlight several aspects that are related to the order of the steps that we had followed in our analysis. The dimensions as we described could include both general and contextual principles, and the backgrounds could represent significant system relationships or narrations/issues/directions that reflect those relationships. In the examples that were demonstrated, we started sustainability evaluation selecting a particular–focus system. The evaluator's original tendency towards general interpretation or identifying specific issues when s/he first approach a case, may define whether s/he would start recognizing the dimensions or the backgrounds. One with a general understanding of sustainability may immediately start seeing unsustainability issues/concerns in the system based on those preunderstood principles. With further exploration they also may be able to find other specific contextual principles that they could further recognize as dimensions, and based on them may arrive at further context specificities. These context specificities, when they seem to show special significance in defining sustainability of the system, may be visible as its unsustainable issues, or time dependent narrations that could function as alternative background for the focus–system. Alternatively, if the evaluator approaches the analysis with more specific understanding of one or several unsustainability issues in the system, it is more likely that the backgrounds for focus–system become clearer first. Or else if the evaluator already recognizes two conflicting ideologies/directions that may influence the system's sustainability, those ideologies may inform the possible alternative backgrounds for the system. Even in this instance, the next step of selecting a set of dimensions to obtain more general sustainability understanding (in the first case), or more refined sustainability understanding (in the second case), could verify if the selected backgrounds were representative enough of the complexities. In our own case studies, we were somewhat already conditioned in the sense that we had already explored a general set of dimensions, therefore the most significant step in the evaluation became selecting the background layers. However, in the ozone depletion case, while doing the analysis, we have recognized that just as each individual dimension, some dimension combinations could provide us even further sustainability context interpretations, therefore, the selection of those dimension combinations have followed selection of background-layers, and further, the interpretation of some of the sustainability contexts. In this way backgrounds, dimensions, and already interpreted contexts have informed one another to improve the framework application along with the analysis. This interactive process of the observer, the framework, the observing reality, and the interpretations made, have continued to the final steps of reaching multiple sustainability evaluations, and based on them making overall evaluations of sustainability. The interactive process also agrees well with the very essence of observing complex dynamics that we explored in the beginning of this study. In the second case study (case of forest-village system), the selection of backgrounds and dimensions had been slightly different. We have approached the case study without clear recognition of one significant unsustainability issue; rather we have recognized several of issues. Further it was apparent that the close interactions of human and natural systems and their evolutionary patterns seem to have marked the village sustainability or unsustainability. Therefore our starting point had been a complex picture with general sustainability/unsustainability knowledge. Then in order to select the backgrounds we have explored the seemingly conflicting human–natural relationships, and further some of the present day significant issues of the village that represent separate internal system relationships. Further the way we selected the backgrounds also reflects avenues with which the focus–system has closely interacted with the outer environment (i.e., outside of the village-forest [immediate forest] system). Further, for the same reason that we already had pre-understanding of the possible dimensions, here as well, the dimension selection step had been conditioned to some extent. However, especially in this case the understanding of principles allowed us to explore the context specificities further. For instance the resource limitation/availability, sustainability linked-worldviews, well-being views, and policies, rules, regulations, and governing practices had especial relevance and also complexity in this case. This complexity forced us to see sub-dimensions that reflect special contextual characteristics (e.g. with respect to worldviews). Therefore, to some extent, the selection of the dimensions had not been an entirely external adoption, rather a step that enabled us to see the parts of a system (that has relatively autonomous capacity to define the system's sustainability) effectively, and bring back those context specific and partial understanding to guide the subsequent interpretations and evaluations of the whole of the system. Further, the study had a special appeal in terms of time dependent changing patterns. In general, the village seemed to have been stagnant and slow paced, however at the same time there have been sustainability related changes in the past that also have significantly altered their structure and functions and also altered their general sustainability outlook. In a way it seems that both stability and change had co-existed in this village-forest system. Therefore, the selection of backgrounds and dimensions needed added caution for them to adequately represent both stable conditions and time dependent changes. Recognizing these factors we have identified several of relatively stable temporal states that signifies relatively stable conditions and similar narrations with respect to dimensions and backgrounds.

4.3.3.2 Framework's role in connecting system and its 'environment'

In addition, after the two case studies, we could also go back and explore the individual concepts in the conceptual development process. It is worthwhile for instance to explore what the 'environments' that were internalized to our analysis through 'backgrounds' and dimensions constitute in each of these cases and how they differed from each other especially with regards to their capacity to form dynamics in the focused–system. In the first case the environmental factors came from both within the focus–system itself and from the global level. Most of concerns that we summarized in to the two backgrounds came from the global system, where a country in this instance largely resembles a miniature unit of the global system itself. In the second case, we could say that the focus–system and its environment lacked similar resemblance to each other. Because of that there were two somewhat separate environmental factors, ones that originate from the focus–system (the village–forest system) itself, and ones that have roots from the out side of the system. The ones that originate from the outside (such as the legal constitutions from outside) have added value in our analysis, mainly because their influence over the system, and the fact that they have generated conditions that ultimately have driven the system changes suggest that the system (focus–system) had the capacity to internalize these external environmental factors, and create relatively autonomous dynamics based on those factors. The autonomy seems to largely occur through the villagers' or (village's as one unit) views regarding those environmental factors. Aspects such as the feeling of entrapment from the legal boundaries of the forest, and the contrasting feeling of protection from the forest, preference toward merged human-natural zone [that reflects through the home garden practices], by and large reflect how villagers individually and as a collective group see and experience the forest (including forest boundaries). Those views and experiences, and the resulting shared ideas of sustainability/unsustainability become detached from the original intentions and value bases of sustainability/unsustainability of the environment (if and when they were actions that had conscious sustainability/unsustainability direction attached to them, such as the conservation actions to preserve the bio-diversity). Therefore, in a way the background have allowed us to internalize the external environmental factors and see the intrinsic and autonomous dynamics[95] (of the focus–system) that were created by those factors. Understanding such dynamics enable us to contextualize the system more accurately, and also see the reactions, adaptations etc that were made by the system to its environment. Further, it also made our own evaluations more ecologically (and also complexity-wise) sensitive being more conscious to concerns of both inside and outside of the system, along with the synergies, power plays that had occurred in the boundaries. In this light the dimensions role is slightly more distant. Especially for a smaller scale system like in Meemure, the dimensions seem to be enable the observer to internalize (to the focus–system) not necessarily the concerns of the immediate environment, but more of ideological concerns that generally relevant for sustainability/unsustainability changes and evaluations of the focus–system. These ideologies and principles could also be considered as providing environment to the focus–system in the form of meta-structures. We however need to be careful with this later internalizing process as we may start to observe and evaluate the context through meta-structures that are irreverent for the context. For instance we run in to the danger of giving equal weight to the dimensions erroneously thinking that such regard may enable holistic interpretations and evaluations at the end. Therefore, just as it is important to select a representative enough set of dimensions, it is also important that the evaluator be aware that the degree of importance given to them is

[95] 'Autonomous dynamics' also is a term that appears in the cognitive systems theory, where a cognitive system is a continuously active complex adaptive system autonomously exploring and reacting to the environment with the capability to survive', and the autonomous dynamics are via which the system generate out put signals that act back onto the outside world (Gros, 2008). Earlier we conceptualized a similar concept as intrinsic dynamics.

contextually accurate. One supportive self-correcting aspect of the framework was that, we do not explore a system only through dimensions, but as integrated entities with backgrounds, functioning more as integrated angels of observation. The background if selected appropriately as we saw, would have more capacity to reflect the contextual sustainability/unsustainability concerns as they themselves have cause and effect relationships embedded to their description (e.g. economic development of a system of village/country embeds the historical experience of the system's own developmental patterns, actors, issues, and so on), therefore, when the system and background unit is explored through dimensions they provide more refined and specific interpretations that would eliminate over-generalization and misinterpretation. When the distant and external principle based meta-structures were internalized to the system through evaluations, decisions, plans, and so on, if those meta-structures were not representative of the actual reality, or if they contradict with the reality, the resulting evaluations would reflect those deficiencies. This point also gains added importance when we think of the observer/evaluator as an entity who has the power to influence the system's sustainability/unsustainability patterns and direction through both reactions to external means such as externally triggered policy initiative and innovations, but also through internally triggered dynamic forming processes supported by the human system's autonomous dynamic forming capacity. That means the initiatives that precede the evaluations can generate internal changes in the systems. One starting point for such internal changes could be the view changes. If the meta-structures, which shaped the observer/evaluator's views, were further from the reality and contextual uniqueness, then the ultimate resulting dynamics of the system is most likely to introduce new problems to the system. This may have been the case with the evaluation of sustainability (at the time conservation) of the forest system, neglecting important human settlements that ultimately resulted in distanced human–natural relationships than before (in the second case study). It suggests that, in evaluations we need to pay special attention to the intrinsic dynamics of the system that are generated by external triggers. We must also remember that not always, the ideologies and principles would create distanced responses and dynamic patterns that would alienate the system from a lower- and fundamental-level functioning patterns, but may play positive roles, especially if the system or part of the system is already in an unsustainability trajectory. For instance in the same case, when the Knuckles forest conservation policies were introduced in 1970s the forest cover of the country as a whole was rapidly decreasing, therefore in country level it was very much a desirable step to ensure the natural system's well-being. Not only in the country level but also the well-being of global ecology as a whole benefitted positively with the conservations. Therefore, sustainability-linked knowledge, worldviews, and the policies that stemmed from those worldviews and knowledge, have generated positive principles, yet were incomplete for sustainability interpretations at a different level (the local village-level) in the absence of different principles and conditions that highlight other contradicting contextual aspects (such as rural and indigenous development). Likewise, it becomes apparent that the dimensions and background play balancing roles in evaluation by recognizing the actual complexities, avoiding simplification, and synthesising the meta-level and contextual-level sustainability/unsustainability concerns.

4.3.3.3 Room for system transformation

Further in the occasions where the evaluation process could influence the way the system entities perceive their system and its relationships (e.g. the human and natural relationships, the system and the [external] environment relationships), they also seem to have an added capacity to influence the dynamic patterns of the system. However in this regard, one has to be careful to avoid miss-handling change by actions taken at a wrong meta-level (e.g. aim for view changes of the villagers alone, when introducing a policy initiative could be the most suitable immediate response to avoid a system collapse).[96] This could be ensured when the evaluator is well aware of the general principles and their special characteristics in the context-level—in different scales such as country, village etc—and in addition, their likely impact to the problems that may cause irreversible system collapses. The reinforcing and damping capacity of new changes and accompanied stabilizing and destabilizing tendencies of some of the dimensions, add weight to this point. It is well-known that creative destruction could be one of the key mechanisms through which sustainability could be ensured for a system that have long held stabilized negative patterns. In the case of the ozone depletion, the economic networks around harmful ODSs were well stabilized that they had the capacity to regulate even the new knowledge generation. In order to destabilize this structure not only a wide dialogue on ethics but also a whole set of other aspects such as independent knowledge generating mechanisms, political support, and new innovations were necessary. What these aspects collectively could do was to destroy an incentive structure that was attached to the regime around harmful substance. However, the dimensions role in generating positive sustainability dynamics become somewhat tricky when it comes to evaluate the systems with them in the present situation and predict future possible contexts. Utilizing them in retrospective analysis is far easier as we have done in the two cases, where the historical dynamic patterns are already visible with a close examination. Historical patterns could shed light to possible future patterns as we have predicated in the second case study, however they

[96] Miss handling related to a problem has been explored by Watzlawick (1974). Out of three basic ways mishandling the change, in the stage where solution to a problem is already introduced attempting second-order change (e.g. attempting to change views of individuals to ensure better resource handling practices) where first-order change (e.g. through policy initiates that structure and regulate individual behaviours to ensure certain resource usage practices) may have been more appropriate. Please refer to end notes for further information of these steps and his theory of first- and second order change.

would not guaranty to function in the same manner as they did when the system had been actually unfolding in the past. For this point however, we could predict that conflicting background and dimension combinations along with the internalizing step through the evaluator would be able to ensure fundamental and necessary creative destruction steps such as view-changes and view-transformations, even when the sustainable direction is not clearly visible, and would lead to holistic problem interpretations.

4.3.3.4 Assessing framework's strengths and limitations after empirical studies

The application of the framework in the two case studies has shown how to incorporate complex dynamics in to the evaluation process. In this regard the framework especially supported in breaking apart the general understanding of the complexities of the ground to more specific understanding of sustainability, via sustainability contexts. Based on these contexts, when we select sustainability boundaries to represent each of those contexts, we adopt a selection process that to some extent simplify the complex understanding we reached. Further, based on those boundaries we recognize the significant drivers and the significant sustainability states that the system encounter in its path (e.g. selecting the available knowledge of the issue, ODSs and the substitutes for ODSs as a critical boundary that defines the first sustainability state in the example 1), we further generalize the complex understanding back to wholes. This resembles a cumulative process of differentiation to parts and synthesising the whole based on those parts. As we indicated the understanding supported by the framework is a reflexive and iterative process. This is also an instance where especially the dynamics related to understanding is utilized to reach the evaluations. In addition to engage the observer actively in the evaluations, the framework also helped to recognize the dynamic changes on the ground. By focusing on the change process of the systems and its sustainability interpretations, it helped us to see the changes of changes (e.g. emergent and transformative changes supported by the worldview changes) and the key mechanisms behind those changes. Also by closely examining the interaction of two variables we could explore the dynamic changes of the system (e.g. emergence changes generated by the interaction of policy initiatives and sustainability-linked worldviews in example 1). However we must mention that by highlighting the observer dependency and by recognizing different significant variables' role in the change among each different sustainability state, we contrast our analysis from heavily deterministic and mechanistic approaches of recognizing dynamics of a system. While addressing dynamic patterns (e.g. systems going through stable and unstable states) and mechanisms (e.g. driving forces between states, emergent, adaptive, reinforcing, and transformative changes in the systems, and the role of each dimension behind those mechanisms of changes), in these case studies we also have been limited to qualitative interpretations of these patterns and mechanisms. Even though purposefully excluding the mechanistic and deterministic ways of addressing complex dynamics, a case that allows some quantifiable measures of system changes and the dynamics could also strengthen the framework applications. However, it is also noteworthy that there are complex dynamics related to human–natural systems' sustainability changes—such as what we observed through the case studies—which could only be observed and discussed qualitatively.

5. END–DISCUSSION: THE FRAMEWORK'S STRENGTH IN ADDRESSING SUSTAINABILITY DYNAMICS

5.1 ADDRESSING DIFFERENT FORMS OF DYNAMICS

Now at the end of the framework development and examine its applications, it is worth to explore how effective it had been with our first objective, that it is to observe and evaluate sustainability in a complex dynamic context. This study from the beginning was inspired by the dynamic nature of sustainability. In the study we were confronted with the fact that that the dynamics are heavily embedded in complexities of the human–natural systems specially when the systems are complex dynamic systems. Further, we saw the unavoidable distinction of the complex dynamics related to the observation process, which also determines the dynamics of sustainability. With framework we tried to recognize dynamics especially in the form of change in sustainability states that is linked to both evolutionary changes in the human–natural systems and the changes to sustainability interpretations and evaluations of those systems. Such dynamics take different forms, such as change of sustainability conditions, drivers, change to those drivers, adaptation to and internalization of environment, emergence in new sustainability/unsustainability conditions, and drivers etc. They are related to human–natural systems and the understanding process. In the framework development stage we conceptually explained that these dynamics would help to create 'new levels of sustainability reality', which is denoted as new sustainability states. Or else some of these dynamic changes seem able to solidify the existing 'level of sustainability reality', i.e., the previous sustainability state. In this instance outcomes are less strong creating new sustainability/unsustainability conditions, causal 'laws', and new sustainability/unsustainability understanding within a specific level. In other words, the dynamics may take the form of patterns of internal structuring (not significantly changing already mobilized changes; or else having a relatively neutralizing effect among changes, and most probably not having significant impact from the environment [as was the case in Meemure in the early years] to occur any significant adaptive changes) or a whole–system emergence that generates an entirely new epoch or level of reality (significantly changing the system structure and functions; and visible internalizing process of the external environment). In the two cases that we described, we attempted to recognize these states and changes that occur to solidify or transform these states through background and dimension combinations. In the first case, we visualize sustainability/unsustainability boundaries of these levels considering all the background and dimension combinations, and the resulting contexts. In the second case, in addition, we visualize sustainability/unsustainability separately relative to each background, and further recognize that instability relative to the significance given to the human and natural components (hence human system and natural system) may be one significant driver of change in the system. However we must also note that importance of stability only arise where human system appear, and further, would need to rely on natural environment, therefore such a driver of change could be highly context specific. Also this conclusion was influenced and strengthened by our initial selection of backgrounds and dimensions. Therefore, it is important to pay enough attention to select the backgrounds and dimensions to have maximum representative capacity of system relationships, of issues related to those relationships, and also in addition, of impact from environmental factors.

One additional point to note here is that, when we highlight 'observation', we ourselves are already dealing with the value sphere. The fact that evaluations depend on observation process indicates that subjective values of the observer may be attached to those evaluations; therefore evaluations would change with the observer as well. In the process of proposing this methodology, we do acknowledge the possibility of differed value orientations (especially that reflect individual preferences and ideologies of sustainability) affecting the evaluation results, yet do not address any of them explicitly. Instead we propose that in addition to its visible role as an evaluation tool, the methodology also could be utilized to expose value orientations of the stakeholders in the form of normative standpoints, ethical and philosophical orientations, and so on. Sustainability as considered in this study, is a concept that has plurality/plural-viewpoints embedded in to it. Therefore, enabling us to recognize different interpretations of sustainability that would have been influenced by different value orientations could be one significant strength of this framework. In addition as we saw, with framework we may be able to recognize specific value orientations that could drive (and transform) the system by triggering, reinforcing, or dampening changes.

Also, after the empirical studies, it is worthwhile to again explore the framework's role in recognizing dynamics associated with sustainability change in the systems. Change and the closely connected instability are concepts that need persistence and stability for us to understand them. This became quite apparent in the way we utilized the framework. In order to understand dynamic sustainability we had to first freeze our systems in relatively stable states that were similar to small stages in time scale. Some of the indicator approaches that we had for sustainability evaluation such as the AMOEBA approach were to some extent already equipped with sustainability evaluations (with attention to diverse facets of sustainability) in a relatively fixed temporal state. In addition to emphasising that we would have to consider several of these states to make adequate interpretations of sustainability in these systems, as a novel approach, the framework brings variability across time and the changing capacity (that would enable first-order changes) of systems and sustainability interpretations (through co-evolution, transformation etc) in to the evaluation process. Conceptual and issue variability are integrated to the evaluation by regarding several of background layers and several of viewpoints via dimensions. Further, in each example we could identify specific conditions across time with the dimensions that gave further conceptual variability to the interpretations across space and time. In addition, when we recognize the influence of the dimensions on changing the systems structure and functions (e.g. changes in forest based activities of the villagers and the changes to their dependencies on forest, that altered the structural and functional features in forest-village), the dimensions function as drivers of change, and further active change agents for sustainability interpretations (related to dimensions such as physical resource limitation changed sustainability interpretations of villagers [2nd case study], related to new knowledge [in 1st case study] changed sustainability interpretations of system entities [i.e., villagers' and citizens']; interpretations derived with the help of dimensions changed the evaluator's own interpretations). This change in interpretations that is strengthened by change in views could be understood as providing continuously improved sustainability interpretations. As we previously argued it involves a reflexive and iterative understanding process, which was supported by a reflexive observation process. Further such changes to interpretations may reflect not just linear adding up, but also radical leaps in the understanding process (hence subsequent evaluations). In this way the framework internalize the inherent dynamic nature of the systems to sustainability interpretations and evaluations.

5.2 SYNTHESIS OF PARTS THROUGH DYNAMIC MAPPING PROCESS

With the framework, no longer the evolutions appear as static maps of a (complex) dynamic context, but the map itself shows the significance of change and also the close relation of the stability and the change—both in the systems and the interpretations made about those systems. In a sense, this is taking apart the illusion of rigidness and objectivity from sustainability evaluations. Also it makes us recognize the cyclical and interchanging relationship of change and the stability (stability could also be interpreted as the persistence of some of the functions of the system that would support its current sustainability state, therefore could be a dynamic stability as we earlier discussed). This link of change and stability is relevant to not only for system changes but also to the changes in interpretations (of sustainability) of those systems. If we go back to our original intension of this framework, that is to make holistic interpretations and evaluations of sustainability, the process of internalizing complex dynamics in to the evaluation process has exposed the complexities and dynamics linked to sustainability evaluation. In doing so it also strips away the solidity of the interpretations. This especially occurs when the evaluator recognizes the close relationship of the contexts, especially those that were derived observing one system and background unit relative to different dimensions. The close relationship is formed to some extent by the dimensions' capacity to influence one another both in reality through system changes—as we have earlier predicted and also saw in the two cases—and in an interpretative-level through our interpretations of sustainability. In this second instance the value orientations of the evaluator is the one that might go through changes (while for the system, the change could be the change to human systems collective sustainability related-worldviews). This would be especially so, when two seemingly opposite and conflicting backgrounds were selected. While the opposite backgrounds would surface conflicting aspects and bottlenecks of sustainability, they also would force the evaluator to gain new insights of sustainability of the system beyond the general understanding that would have informed her/him to recognize the issues, hence the backgrounds for evaluation. In our case one of such additionally recognized point was that, in the case of analyzing ozone depletion issue, the ecological wellbeing of the planet could not be strictly separate from economic growth/development as they appeared, especially when we consider their long term impacts. However, unless we have done a separate analysis using a background that reflects ecological impact, we could have only focused on apparent health and economic impact of the issue, missing the issues close link to ecological health. The backgrounds and dimensions in this case provided a subsidiary understanding to interpret sustainability of a focused entity supplementing the already gained primary understanding using a different backgrounds and dimension combination. When we closely look at this process, we recognize that what the evaluator is unconsciously made to do is to, first break the complexities in to parts, and then merge those parts with interpretations that ends up being closely related to one another, because they are being informed by a set seemingly separate but interlinked value positions. This process may resemble when a painter draws separate concepts/objects in one canvas but through pattern recognition would make a painting that cohesively stands together as one unit. The same could be seen with a tapestry that we took as an example earlier or with a crotchet pattern. Individual threads would form in to patterns that are informed by various thread colours and positioning. Rather than stopping at different interpretations and evaluations that shows the parts of a picture, the evaluator is made to see the merging areas, and possibly patterns of change that link different system scales, as we could see at the end in the two cases that we explored. This merging takes place with the observer/evaluator's active engagement with the observation/evaluation process. It means that the understanding, interpretations, and the evaluations take place in a separate-level than where what his/her observations take place. We could interpret this process as the observer/evaluator internalizing the seemingly objective reality. In addition, with the help of some of the dimensions—for instance with the dimensions of policies, rules, regulations and governing practices and new creations, innovations and artefacts—not only that we could recognize a system's capacity to change its course, therefore possible future/sustainability states and directions, but also paying specific attention to them could alter our current evaluations by influencing our own perception of system's likely reactions to unsustainability conditions, its capacity to alter its path etc. In other words, the observer/evaluator is placed at a position where s/he could see means and avenues of transformation of system patterns (change of a change, or a second-order change), and be an active agent of transforming the system of evaluation. In this way the observer/evaluator to some degree is absorbed to the reality pushing his/her conventional role as an 'objective-observer' and 'detached-interpreter', to bear a role of active-synthesizer and possibly a change-agent of the system.

5.3 PLACES TO BE CAUTIOUS

However there are several factors of which we need to be careful. We need to remember that just by being aware of parts and wholes (in this context not only the evaluations that recognizing the parts and wholes, but also that represent multiple issues, interpretations, and knowledge basis, preferences, worldviews, stand-points, ethical justifications that colour those interpretations) alone would not ensure to mobilize dynamics such as transformative changes or synthesis. One way the methodology might be able to ensure such dynamics related to observation would be through introducing constraints. One constraint (in other words a limitation) that we could introduce to the framework is to recognize backgrounds and dimensions that are seemingly contradicting with each other, or in reality have made conflicting conditions in the system, especially with its sustainability/unsustainability conditions. The two backgrounds that we have selected for each case resembled such conflicting conditions. Further some of dimensions we have selected were coupled to some extent as opposite angles. One example is the dimensions of the resource limitation and the wellbeing-views. We could see the contrast in them especially in the village-forest system. Therefore, when resources had urged the system to react in shorter time scales (with limitations), well-being views had organized the systems in a way that the changes solidify the perception of sustainability/unsustainability in a more longer time scale (with well-being views). Another example is the dimensions of policies, rules, regulations, and governing practices and new creations, innovations, and artifacts. These two aspects could provide complementary, yet also, alternative means to ensure a system's sustainability. Their contrast was especially visible with the solution trajectories for ozone depletion. With these conflicts and contrasts the evaluator is not only given a reflexive and iterative understanding of the system and its sustainability, but also is forced to face contradictions in sustainability interpretations, which is likely to evoke emergent understanding. As we earlier discussed the emergence is one of the key characteristics of complex dynamics. Emergence in understanding may lead to significant transformations in sustainability/unsustainability views. Therefore, if the framework is properly utilized, the complex dynamics of the system, the observation process, and the subsequent understanding could be successfully merged together to the evaluation process.

Another aspect that we need to be careful is how we interpret sustainability change. The change as we address are in different forms. In this study we started addressing change in the form of spatial, temporal, and organizing-relationship changes. By addressing them we acknowledged complex changes of a system that we observe. Then we further indicated that some of these changes are in the form of mere reactions to the environmental triggers, and some take the form of adaptations/transformations that make significant structural and functional changes to the system itself. Further, the system's tendency to change or to persist (both in this case to ensure its sustainability) would define its sustainability characteristics such as resilience, viability, efficient transformation to new levels, etc. In the second study for example, we recognized that the worldview had supported system's persistence to retain the identity and functionality as a village. In addition, we were exploring ways to adequately integrate the complex dynamics related to the observer's (whether he/she is an entity of the system or an outside evaluator) own understanding and evaluations. The dimensions as we described earlier, and also as we saw with cases, had the capacity to make changes to the system as well as sustainability interpretations of the system. However we have to recognize that the changes that we described are not in the same level. And there are different forms of systems involved. Some of the changes indicated by the dimensions, did not significantly change the sustainability/unsustainability state of a system. When we say sustainability state, what we mean is an interpretation that we have given to describe an outcome of a certain set of habits, functions, as well as characteristics of a group of system, subsystems, system entities, and so on (e.g. interpretation of the current well-being of the village, human society, and individuals). Each of the contexts provided us with different descriptions, and based on them we could think of what could be the most significant limiting factors that define what is sustainable/unsustainable for our system. Collectively they also could give us an overall idea of sustainability/unsustainability enabling us to interpret sustainability/unsustainability states as we did. We should note however that there is some complexity attached to this process. Relative to dimensions and the backgrounds in different time spans we may be able to see significant functional changes in a system. For instance a significant change in knowledge, or resource practices in the system, would change its sustainability, however that particular change may not reflect a significant change to sustainability interpretation of the system. Nor they may indicate special reactions to changes that are already occurring in the system. In the first case study the resources were a driver but availability of it alone did not clearly mark a different sustainability state, but had to accompany changes in some other dimensions as well. In second case study, resource availability/scarcity did create significant system changes and also villagers' own interpretations of sustainability. The knowledge had opposite effect in each of these cases. If we regard changes to resource availability and knowledge as 'changes in sustainability' the changes that occur to sustainability interpretations/evaluations of system entities (villagers) that resulted from those changes would reflect a 'meta-level change in sustainability', because the latter in addition to their system wise changes, had altered the very foundation of sustainability interpretations. And when this process occurs in the minds of system entities (e.g. villagers) this meta-level change would denote a transformation of how other dimensions (and their changes) would be interpreted, and therefore the contexts related to them. And further related to the same aspect, a significant change to sustainability state (which to some degree is a reorientation of the evaluator's point of view, in addition to necessary system changes) would not necessarily coincide with the changes in temporal stable states which would show similar structural and functional features (as described in the second case study); and even further it will not coincide with the system's own evaluations (e.g. sustainability evaluations of the villagers; which may be affected by their worldviews of sustainably such as prioritizing resilience and integrity of the village as one unit in the face of external threats, prioritizing economic development, retaining identity but accepting merged physical village boundaries with the outside etc). The views of individuals or even a group of subsystems would not accurately reflect the actuality of the system (such as whether the system is resilient enough to survive and retain its historical identity), and would go through separate complex dynamic patterns. Therefore, the transformations in individual/group views may occur in a different level than the changes that have supported the transformative change. Simplifying the complexities, if we place focus–system, other subsystems, system entities (along with their changes) in one level, we have to place all the interpretations (and their changes) made as contexts and boundaries along with the dimensions (and also backgrounds) through which we made those interpretations in a slightly upper-level (this could be also interpreted as we already discussed as a meta-structure or a system of thoughts). Further the transformative changes to those interpretations, which were supported by evaluators' reflexive and iterative understanding, enable them to push boundaries of that meta-structure or the system (of thoughts) to new levels. What we interpreted finally as change in sustainability boundaries—especially in the visual form—reflected this final form of change. Therefore it is important to highlight that complex dynamics involved in sustainability occur in deferent levels, and are heavily related to the fact that sustainability is a concept that gains meaning by we as humans interpreting it. It also blurs the distinction that we initially made as sustainability changes in systems and the changes that occur related the observation process. And also it leads us back to the dimension of worldviews.

Worldviews appear in most of the selections that we do as framework components, and the subsequent interpretations. Further, after breaking the complexities in to parts, analysing each part in detail interpretations, and drawing specific evaluations based on those detailed interpretations, especially the final step of reaching overall evaluations that reflect a synthesis process, could not be done without some value judgment, at least in the form of selection among important sustainability/unsustainability interpretations. This fact does not limit to the application of this framework, rather it is there behind all the evaluations that we do regarding sustainability. The easiest example we could give by thinking unsustainability issues. What are recognized as issues as we earlier discussed go to the basis of mindsets/reference frames of human system. As earlier mentioned, what the framework had done especially regarding worldviews is that, it had functioned as a tool to surface different worldviews relevant for sustainability interpretation of a system or an unsustainability issue. But this process does not free us from the necessity for value judgements/selections etc at some point of the evaluation.

5.4 MECHANISMS OF SUSTAINABILITY DYNAMICS

Finally, based on all the discussions that were made so far, it seems that the ***complexity, change, sustainability-linked worldviews***, and ***limitations*** could be at the basis of sustainability dynamics. Let's explore them briefly one by one.

Complexity, we have described in detail in the first sections. As we saw, complexity resonates two meanings, that is the general idea of complexity that denotes a characteristic linked to high amount of components/attributes, that become generally relevant for sustainability interpretations of a systems. They could represent diversities of components/attributes in general sense. A more specified meaning of complexity, which we referred to as complex complexity, also have a special relevance for sustainability in these systems. Such meanings go one step back to bring in complex dynamics patterns to the system interrelations and their sustainability interpretations. These patterns have their own organizing mechanisms such as emergence and self-organization, which as we saw become integrated to sustainability/unsustainability changes in human–natural systems. Collectively complexity tends to transmit dynamic characteristics to sustainability via system relationships and interpretations, and also tends to obscure these characteristics if we did not adopt a method of observation that acknowledges their presence and surfaces them.

Change in the context of dynamics is seemingly independent and self-apparent concept. As we saw, both change related to the human–natural systems and the change related to interpretations become equally significant to describe sustainability change. Sustainability being a concept that fluctuates among different issues-, possibilities-, value basis- etc that are interconnected and would influence one another across diverse dimensions, change in itself seems to be a part of sustainability. Change takes different forms (e.g. adaptive changes, transformative changes) and could occur in different orders (e.g. first-order change, second-order change). It can be visualized across space/time, or organization relationships, and also across principles/value bases as we have observed earlier. Not only that, the complex dynamics necessarily generate changes in systems and our interpretations of their sustainability. Also change, as we discussed earlier, and also recognized in the systems that we explored, is closely connected to its opposites, i.e., persistence and stability (e.g. via exerting dynamic stabilities). These aspects of systems and the system interpretations have the capacity to change sustainability in a complex way even within a small time duration, so that static interpretations of sustainability lose their meaning. Therefore we could say that change in different forms, and along different axis, is in the heart of sustainability dynamics.

Sustainability-linked worldviews also was explored and described in detail. As we already saw, worldviews form the basis of sustainability interpretations, and further they have the capacity to change a system from one sustainability state to another. These aspects we explored both through theoretical explanations and through the empirical case observations. Especially with empirical studies we could see that the worldview has a significant role in internalizing the external environmental factors to a human–natural system, that would enable the system to effectively change on its own by generating viable dynamic patterns of its own. This could extend to system and the environments actively interact to transform the unit synergistically. Further we saw that worldview has the capacity to synthesise the influence of other drivers of sustainability change in a system to form stable sustainability states. Further especially for second-order changes that involve fundamental changes to human component of human–natural systems, change in worldview could be an essential component. Further, we could also argue that all the other dimensions that we specified, and which any one else may adopt in a similar study, may be considered representing forms of worldviews of sustainability in their ontological foundation. Because of these aspects, for a further analysis of the dynamics related to those dimensions, we could extract out sustainability-linked worldviews from the others. We also may be able to argue that this dimension of worldview would generate, strengthen, or even dampen the changes reflected by those other dimensions. It also stands out because of it being at the foundation of human observations, interpretations, understanding etc related to sustainability dynamics.

The final aspect to highlight along these others is the limitation.

Limitations here do not confine to resources as in the early descriptions, but would show any form of constraint. The role of the limitation for sustainability dynamics is less visible. We could see its importance in our own interpretations. It was apparent that examining paradoxical or conflicting facets of sustainability, either in the form of issues, or in the form of conflicting evaluations could support a system through generating new ideas, solutions etc. In the face of conflict, one automatically become constrained, and because of this may be forced to come up with creative solutions that will change the sustainability direction of a system. Of course this is an aspect we need to explore further, however at this level we may be able to say that the limitation itself could mobilize sustainability dynamics.

These are concepts that are seemingly distant from each other, even though we also saw their interrelatedness for sustainability. And also these are only a few significant ones that especially became apparent through this study. For example in the first case study sustainability-linked knowledge played a substantial role in mobilizing dynamics related to sustainability. And in the second case for a long time resource limitation/availability had driven the system's sustainability generating new changing sustainability patterns in the system. Therefore, we must mention again that the context would carry tremendous implications on what really drives sustainability changes in a system. The ones that are mentioned wouldn't mean that they are the only important aspects of sustainability dynamics for a certain human–natural system, at the same time they may be considered as giving a form of a direction that could lead to more refined idea of sustainability dynamics. Because of that, they may be recognized as some of meta-level dimensions of sustainability dynamics. However, at this point we must differentiate them from the previous dimensions that we explained in the framework. As we saw, those dimensions gave the basis for us to recognize sustainability boundaries and their changes. In other words, as a first most role, they help to see the change of evaluations that to some extent appear as indicators of sustainability (if we recognized sustainability boundaries as a form of sustainability indicators). In order to reach those boundaries, we examined the complex changes in systems and sustainability/unsustainability interpretations of those systems. As earlier pointed out, those dimensions could internalize the complex dynamics to the evaluation, and further the dimensions had the capacity to change sustainability/unsustainability of a system. And especially with some of the dimensions such as the sustainability-linked worldviews, we could go one step further to explore the mechanisms behind those changes, and to examine changes of interpretations. This is precisely where the meta-level aspects we mentioned would start to differ. They, with the help of those previous dimensions, could trigger and drive change of change in sustainability. In this way collectively they seem to function as mechanisms of sustainability dynamics[97]. It addition, it is also noteworthy that each of the meta-level mechanisms could be further explored to identify individual patterns and mechanisms of their changes as well, however this study has note gone up to the level of examining dynamic processes related to these individual mechanisms. What the new understandings of these meta-level aspects of sustainability dynamics would especially bring out for evaluations would be that, gaining understanding of them, in reverse, could support the evaluations through improvements/right-use of the framework and its individual features, in a way that would further assist in internalizing the dynamic understanding of sustainability.

At this point it is also necessary to remind that, the framework along with the explained dynamic patterns and mechanisms that would support the evaluation, does not resemble a deterministic dynamic model, such as that we use to model engineered systems (which also occasionally found being adopted to model human–natural systems). Fundamentally this study does not regard a human–natural system as a deterministic system for its evaluations of sustainability and sustainability changes. The thesis has repeatedly emphasised the impact of

[97] Note that mechanisms may have two meanings. One is that mechanism represents system of parts working together in a machine, and the process through which some thing is brought about.

the human observations and interpretation on the final evaluations of sustainability in these systems. Also the type of cases that we explored shows the necessary randomness attached to the disturbance that occur within and from outside of the system. The framework in overall resembles a reflexive way of looking at a system to understand its sustainability dynamics in a reflexive and iterative manner, and to make evaluations of the system along with that dynamic understanding (that is argued as subjected to change along the way), giving ample room for the plurality and the changes to sustainability interpretations. Therefore, how the framework addresses the future of the system acknowledge the uncertainty attached to the future predictions based on the past evaluations. However, as described with the case studies, the recognition of patterns and mechanisms of sustainability change, and the change of those sustainability changes, and the patterns and mechanisms behind them, would be able to shed light on some form of prediction of the future path of theses systems. One remarkable aspect of the framework is that, these meta-level sustainability dynamic mechanisms, which were derived through development and the application of the framework, well reflect the integration of the observer to the sustainability change and transformation process in the system. For that reason also the methodology supported by the framework essentially differs from the highly mechanistic outlook of dynamics and strict deterministic approaches of explaining dynamic processes in systems.

Finally with the preceding discussion we could say that the development process of the framework and its application in case studies seem to have expanded and also verified our first idea that sustainability is a concept that would lose meaning without human interpretations, and need to be regarded as a dynamic process and a path than a state of a system.

6. CONCLUSION

The focus of this thesis was drawn mainly from three significant observations related to complex dynamics and sustainability in human–natural systems.

First observation is that, recent discussions on sustainability often tend to carry an underlying implication of static past, present, or future state. Whether it is for planning or problem solving, a strong need exists for understand the change and continuation in those systems. These extend to the domain of complex dynamics, making sustainability a concept that has a dynamic nature in its basis, however could not be adequately apprehended without referring to the complex dynamics linked to the concept. The second observation is that the sustainability understanding faces the challenge of incorporating both generalized and context-specific understanding of the systems we observe, which also have their roots in complex dynamic nature of systems and the complex dynamics linked to observing the systems. It is important for us to gain holistic enough understanding of a system, to interpret sustainability of it correctly. The third observation, which became apparent from exploring the first two observations, is that sustainability understanding, and the subsequent interpretations and evaluations, are very much tied to the processes of observing complex dynamics.

Often there are either specific but not representative enough interpretations of sustainability, or on the other end, too much simplified or too generalized interpretations. These limitations are also visible in the methodologies that we as researchers and practitioners incorporate in evaluating sustainability. Most of the methodologies, methods, and techniques that we use allow us to deeply analyse the parts, specific processes, or on the other end, allow us to have generalized overview ideas that reduce the complexities. This study recognizes that to deal with complex dynamics linked to sustainability, it is very much necessary to have middle ground methodologies, methods, and techniques in dealing with complex dynamics. One way of addressing these challenges could be through a methodology-based sustainability-evaluation framework built on techniques to internalize the ideas in complex dynamics to its evaluation methodology. A systemic way of observing sustainability in a complex dynamic context could be such a technique. However, at the same time, because of the very nature of complex dynamics, it appeared that such a framework should not be a totalizing or truth promising one, but a supportive one that can guide the process of observing, understanding, and evaluating the system in a reflexive manner. This also demands the framework to be flexible, and have a balanced amount of generality and specificity.

Considering these factors, the thesis proposed a framework to observe and evaluate sustainability in a complex dynamic context. The framework's development process, along with its key sections was explained in detail. In first section, by adapting systemic view, the concept of boundaries of sustainability—which is introduced to provide a metaphorical basis to sustainability evaluations—was elaborated. In the second section, the layer view-based observation method that enables us to reflexively observe sustainability boundaries was introduced and described. The mechanisms behind the observation process were discussed and compared with some of the key ideas behind complexity and complex systems. This observation process is argued as to engage multiple systems of awareness making interpreting sustainability in human–natural systems in itself a complex dynamic process. In the third section of the framework, a complementary step to the layer view-based method, namely the dimensional view-based method was proposed. By exploring sustainability context with relation to both backgrounds and dimensions, the idea of dynamic sustainability boundaries was further discussed. Finally the two observation methods were combined in the framework to observe and evaluate sustainability. In order to demonstrate the framework's applicability we have utilized it for local-level and global-level sustainability evaluation via two case studies. Applying the framework to make interpretations and evaluations of sustainability of the human–natural systems that each case dealt with, enabled us to conceptually perceive the possible complex dynamic changing patterns and mechanisms. In addition, it helped us to be aware of complexities involved in our observations, interpretations, and evaluations. By selecting different background layers and dimensions enabled us to examine the conflicting facets of sustainability, and further, to place the system in a complex dynamic context (instead of regarding the systems in isolated forms, by focusing on multiple issues, system relationships, and sustainability principles that connect systems to its subsystems and to external environment, could place them in a complex dynamic context). This had eliminated the risk of reduction in our interpretations. Also this methodology helped us to recognize the specific contextual factors. Dimensions, especially the ones that we have proposed, provided more general contexts to the observation—abiding with general principles of sustainability—that one would easily miss out in a specific and focused analysis. Also they could direct our attention to context specific characteristics and the mechanisms of change through the eye of general principles. In addition, the selecting the dimensions and observing systems with respect to them, enabled us to consciously address changes in sustainability interpretations of these systems as narrations. As a result, the identified contexts are not confined to static interpretations, but with dimensions they implicitly carry information of temporal and organizational variability. Also these changes as explained could represent changes between relatively stable states and changes within such states.

The underlying structure of the framework with respect to its role in both (stable and changing situation) can be summarized in steps as follows. First step is to differentiate general idea of context in to parts. This includes identifying focus–system, identify backgrounds that support sustainability interpretation of the focus–system, and identifying a set of general and contextual sustainability dimensions to observe system and background unit. Second step is to observe the interrelationships between parts. This includes observing the focus–system with relation to its background, and interpreting the whole unit with relation to sustainability dimensions. Third, is to observe the systems with purposefully interchanging the parts to obtain the understanding of whole. These parts and wholes were reflected in interpretations and evolutions made as sustainability contexts and boundaries. These steps can be regarded as representing an integrated differentiating, analysis, and synthesis process respectively. Utilizing them, the methodology allows us to address multiple contexts of sustainability in a systemic manner. It further guides the researcher in a reflexive and iterative understanding process across divers contexts and boundaries. Reflexivity and iteration could be considered as two of the key mechanisms involved in observing the complexity in a stringent manner. Therefore, in overall the observation methods supported by the framework increase the observer/researcher's capacity to reflect the complexities and to consciously engage in dealing with them. Further, the framework has enabled us to address sustainability dynamics in our evaluation process.

In overall sustainability dynamics could be understood as the complex dynamics linked to sustainability or unsustainability changes of human–natural systems, and in the process of observing and evaluating sustainability and sustainability changes in those systems. The framework was developed to address sustainability dynamics by utilizing observation metastructures that lead to holistic interpretations and evaluations of sustainability and sustainability change. The development process of the framework and its application in case studies helped us to explore the patterns and mechanisms of sustainability dynamics. Further they have expanded and also verified our first ideas that sustainability is a concept that would lose meaning without human interpretations, and that it need to be regarded as a dynamic process and a path than a static state.

ANNEX

I. GLOSSARY

(i) Adaptation

Adaptation is the evolutionary process whereby an organism becomes better able to live in its habitat or habitats (Dobzhansky, 1968).

(ii) Boundary

In the simplest sense boundary mark something from what it is not. These 'something' could be visible attribute, property, a pattern, organization and so on. In the thesis the boundary encompasses such different features.

(iii) Complexity

Complexity has both general and very specific meaning. Depending on the field of study general term also is widely accepted in academic domain. According to Oxford dictionary the general meaning of complexity is 'The state or quality of being intricate or complicated'. Or in a slightly different interpretation, it also can mean what one find when one find a tangle of actions, interactions, and feedbacks (Morin, 2008; 1992, 2002, 2005). However in complexity studies where complex acquire a special meaning, first most it is differentiated from the term 'complicated'. When complexity is understood as a characteristic of a system, in the first glance it is a quantitative phenomenon with extreme number of interactions of units. However the meaning of complexity also encompasses the uncertainty, indetermination, and randomness (Morin, 2008, 2005, Taylor, 2001, Scott, 2013). When complexity is understood as a measure, it could be understood as the degree to which some thing can differentiate as parts and get integrated as wholes. At the same time as a measure complexity coincides with the part of uncertainty that arises with the limit of our ability to comprehend, or the part off uncertainty inscribed in the phenomena itself (Morin, 2008). This aspect of complexity is addressed in the 'butterfly effect' phenomenon. In the thesis both for general and specific meaning the term has been used with explanation, and indicated which meaning where necessary. There are several subtopics of complexity being discussed under literature review. In addition the following topics also are relevant.

Ecological complexity

Ecological complexity poses challenges to conventional scientific ways of knowing. Ecology is not like thermodynamics, in which complexity can be simplified through statistical averaging or large numbers of identically behaving components. Moreover, whereas progress in the physical science depends greatly on controlled experiments in which systems are isolated from their context, this strategy is not clearly appropriate for understanding organisms in a context of interactions with a multiplicity of hazards and resources distributed in various ways across space and time. At the same time analysis and observations from nonexperimental situations is best by circularity- ecologists need to know a lot in advance about causal factors before they can design methods of multivariate data analysis capable of revealing the effects of those factors (Taylor, 2001, pg 1)

Relationships of stability and complexity

There are two prominent ideas that describe this relationship

1. The diversity and complexity of interrelations among organisms ensure harmony or stability in the order of nature (Ergerton, 1973, adopted from Taylor, 2001)

2. Complexity does not necessarily promote stability (Goodman, 1975)
While it is observed that the question of the form of the relationship continued in the ecology discourse (Taylor, 2001, Pimm 1994), it is also became more accepted that the change is the normal state of ecology.

Note: these are just a few factors to note in complexity, for a detailed review and discussion, please refer to the explanatory section of the literature review.

(iv) Complex complexity
'Complex complexity' is the term given in this work to distinguish the strict complex system based meaning of complexity from the general complexities observable due to interactive relationships and the unorganized and numerous information in systems (Manson, 2001).

(v) Complex dynamics
The term 'complex dynamics' is one of the key words used throughout this study. Complex dynamics is used to denote a characteristic observed in the systems that reflect their complex nature (both in strict sense and general sense) and their changing and evolving nature (both especially relevant to complex systems and the general changing patterns). Within this interpretation we address complex dynamics both in the domain of strictly complexity studies, and the domain of general interpretation. Complexity and dynamics are often tied together in patterns and mechanisms, while in other occasions they may not have any such interlink. The interlinked domain is the focus of this study. Also the framework reflects complex dynamics, and complexity and dynamics as separate concepts. This is important to note as in this thesis the term were used alternatively at different places. Our initial target had been to see sustainability a concept that has change embedded to it, which in the beginning we interpreted with an umbrella term sustainability dynamics. This study acknowledges the strong relation of complexity to the sustainability related dynamic patterns in the system. Further it acknowledges that the observer has a significant role in the interpretation of complex dynamics, therefore, in the interpretations of sustainability in human–natural systems. The framework is developed in away that it can reflect both general complex and dynamic changes and complex dynamic changes that are specifically relevant for complex systems. For ease of explanation some times the complexities and dynamics are explored and explained separately, but their interlink is considered thought out the study.

(For a detailed explanation on complex dynamics in systems and complex dynamics linked to observation please refer to the sections of literature review and the framework (section II and III))

(vi) Complex thinking
Complex thinking denotes thinking that engage observation and understanding that involves complex systems, where high amount of interactions over space, time and organization relationships are found. Complex thinking does not itself known to resolve problems, yet it reminds us of the interdependent, changing and uncertain nature of reality and our interpretations of reality.

(vii) Context
The two descriptions given for the meaning of context in Oxford dictionary are;

1. The circumstances that form the setting for an event, statement, or idea, and in terms of which it can be fully understood and assessed (e.g. *the decision was taken within the context of planned cuts in spending).*

2. The parts of something written or spoken that immediately precede and follow a word or passage and clarify its meaning (e.g. *word processing is affected by the context in which words appear).*

In relation to sustainability—that is how the word is being used in this study—both of these meanings are attached to the term. We talk of sustainability in the context of issues, of physical and political regions, networks, systems and so on. Also we talk of 'context specific' features that need to be considered in sustainability evaluations, such as local practices and knowledge base. Both these ways are regarded as general interpretations of context.

In addition to this general interpretation, aligning with the dictionary definition, context can also be seen as a connected stream of information that helps to ground a certain idea or an observation. This is the basic idea behind, when the term 'sustainability context' is being used in an explicit way giving a weighted meaning, especially in the development part of the framework.

(viii) Emergence

The term emergence, just as the term complexity has both general and specific meanings, and being used here as well for both meanings. In general usage, emergence can mean when a new attribute, a characteristic a pattern etc, grow out and takeoff from entity which support to generate such that attribute, characteristic or pattern. For specific meaning of emergence, there are several definitions that can be found in complexity studies. One definition is, emergence is the process by which relatively simple rules lead to complex pattern formation (Holand, 1998). Further emergence has been identified to have correlation not only t complexity but also to limitation. Where there is constraint it is possible to expect emergence (Scott, 2013).

(ix) Environment

The term environment is used to reflect both general and specific meaning. The general meaning would indicate the environment regard of the surrounding to include especially the natural systems in it. With specific meaning, the environment denotes the out side of the system boundary that would have complex dynamic relationship with the system.

(x) Human–natural systems

Using the term human–natural systems we intend to highlighting that the systems that are considered in sustainability have both human and natural components. Even though sustainability is very much an anthropocentric concept, the dependency and influence of human system on the natural resource base is the key justification given to consider them collectively. Similar to human–natural systems, another term being used in sustainability literature is human–environment systems. In this view environment can mean both natural environment as well as other environments as human, technological and so on. We want to highlight the distinctive significance of both human and natural systems in sustainability discourse. Therefore in this work the key system of observation is selected as a human–natural system, while the significance of seeing its relation to various types of 'environments' was emphasized elsewhere.

(xi) Interdisciplinarity

Contrasting to transdisciplinarity, the term multidisciplinarity is used to represent the interactive platform of disciplinary knowledge, where one discipline can inform and support others, without going through complex interactions that lead to new knowledge types as in transdisciplinary platforms (Lang et al, 2012: max-Neef, 2005; Beaney M, 2012).

(xii) Iteration

Iteration in understanding is when the previous understanding adds up to the next understanding. To a certain extent iteration embeds the reflexive characteristic of the observation, as in order to previous understanding to add up to the next understanding, it has the new understanding has to bend back to encompass the previous understanding.

Further, iteration has strong research implications. According to Basset (2010) "Iterative refers to a systematic, repetitive, and recursive process in qualitative data analysis. An iterative approach involves a sequence of tasks carried out in exactly the same manner each time and executed multiple times. Meaning is provided to this repeatable formulation in qualitative research by calling upon a prior, recognized authorized usage. The interplay between elements of the research, such as that between design and discovery, or among data collection, preliminary analysis, and further data collection, are examples of an iterative approach in qualitative research. The philosophy behind an iterative approach to research is that of flexibility and ongoing change that meets the needs of the research design, data requirements, and analysis methods in response to new information as it is collected. Loops of iterative cycles occur that may begin as small loops and then move into larger cycles" (Basset, 2010).

(xiii) Knowledge, data, and information

Technically the meaning behind data, information and knowledge seem to be used interchangeably. However they have distinctive meaning. Knowledge is what we know. It can be regarded as a map of the world. The term data is used to denote the facts of the world. Data are arranged in to information so that they carry a message, which leads to expanding knowledge. So when we use the terms especially information and knowledge in the same place, above is the distinction that we make among them.

(xiv) Meta–structure

While meta-structure is a term found in studies of ontology, Beckers (2012) introduces the concept of meta-structures to analyze these clusters in detail. He defines a meta-structure as a historically evolved structure composed of four elements—(i) basic assumptions, (ii) basic evaluations, (iii) driving forces, and (iv) institutionalizations—that substantially affect societal and individual thoughts, actions, and relationships. The author explores the implications of meta–structures in formation of ethical understanding of sustainability. A meta–structure related to the observation can be further identified as a system of thoughts (Jenks 2004).

(xv) Methodology

Methodology is the systematic, theoretical analysis of the methods applied to a field of study, or the theoretical analysis of the body of methods and principles associated with a branch of knowledge. It, typically, encompasses concepts such as paradigm, theoretical model, phases and quantitative or qualitative techniques (Berg, 2009). A method in this case may involve a series of steps that need to be taken to reach certain knowledge. A technique, according to oxford dictionary is a way of carrying out a particular task, especially the execution or performance of an artistic work or a scientific procedure. Therefore technique in this case can be regarded as specifics that support in carrying out a particular method or a methodology.

(xvi) Multidisciplinarity

In multidisciplinary platforms the disciplines are considered to interact, yet do not leave their domain in utilizing newly acquired knowledge and tools.

(xvii) Observation

According to oxford dictionary the 'observe' is 'Notice or perceive (something) and register it as being significant'. In this study the term 'observing' is being used to denote the process of perceiving and registering something. Therefore, 'observing sustainability in a system' means perceiving and registering the features that are sustainable/unsustainable of that system. This process of perceiving and registering can be aided by a set of predetermines of sustainable/unsustainable principles, or the process may involve an entirely new streams of perceive to register steps, that could be considered as a simultaneous process of understanding that eventually lead to an evaluatory decision of sustainability/unsustainability. It means the observation in the process of perceive to register may involve a series of subtle decisions within the observer's mind.

(xviii) Paradigm

Paradigm is made up of a certain kind of extremely strong logical relation between master notions, key notions, key principles, these relations and principles commands a set of propositions that obey them (Morin, 2008). Paradigms are closely linked to the principles, and mental frames. (Further the author interpret paradigm of simplicity as putting order in the universe chasing out disorder. Order is often reduced to one law, one principle. Simplicity can see either one or many, but it cant see that 'One' is perhaps at the same time 'Many'. The paradigm of simplicity either separates that which is linked (disjunction), or unifies that which is diverse (reduction).

(xix) Reflexivity

In Social theory *Reflexivity* refers to circular relationships between cause and effect. A reflexive relationship is known to be bidirectional, where both the cause and the effect affecting one another. Reflexivity therefore comes to mean an action that has the self-reference characteristic where an action, inquiry (or an observation) bends back on to itself. As the term being used in this study reflexive means when the observer is aware of the observation process, or when the observation process has implication on what is being observed. Reflexive observations would leads to reflective understanding (Morin, 2008; Speaks, 2014)

(xx) Self-organization

Self-organization is often known as the process where some form of global order is achieved through local interactions of an initially disordered system. However the concept along with emergence also has been debated over the years and has acquired slightly different and specific interpretations from different fields of studies. In philosophy, Morin (2008) defines self organization as ensemble of processes involving order, disorder and interactions in a complex dynamic system (where organization is defined as interaction of order, disorder and organized in a circular or a spiraling relation, or what he refer as "tetralogical loop" in which no one particularly force acts independently of the others. At the heart of organization is the self-organization and in complex dynamic systems he further believes that all organization is involved in self-organization (Morin, 2008 adopted from Wells, 2012, p 136). One characteristic of a self–organizing system for instance, is that, it seems to be detaching itself from its environment and distinguishes itself by its autonomy and individuality, yet it also seems to link itself more to the environment by increasing its openness and the exchange. (Morin, 2008, p 19) Some parts of this view also been shared by several other philosophers of complexity. Further in his work Morin gives the term self-eco-organization to describe this process, characterizing a self-eco-organizing system as more autonomous and less isolated and play a internalizing its environment play a co-organizing role.

(xxi) Sustainability Boundary

The term sustainability boundary is used in the simplest sense to mark sustainability from unsustainability. Here it is expanded beyond this simple interpretation to include the link between sustainability/unsustainability conditions in systems, their observation and understanding, and the evaluation basis of sustainability.

(xxii) Sustainability Context

As indicated under ‘context’, the dictionary definition of context can also be seen as a connected stream of information that helps to ground a certain idea or an observation. This is the basic idea behind, when the term context is being used in an explicit way giving a weighted meaning, especially with sustainability as ‘sustainability context’. In the thesis sustainability is encouraged to visualize as a path that have both spatial and temporal significance. Also it is explained that interpretation of sustainability involves handling information that are of general and context specific principles and selection of a focus (in terms a focused system) that automatically generate a background to it. Therefore in this work sustainability context is regarded as a stream of understanding of sustainability (understanding that derived from information from multiple facets across time and space and from a certain way of observation of those information). With relation to the proposing framework, in practical terms, sustainability contexts are observed by handling information of different focus–systems, background issues and systems, and principles of sustainability in a systemic way.

(xxiii) Sustainability Dynamics

The complex dynamics linked to the process of observing and evaluating sustainability in human–natural systems are referred to as ‘sustainability dynamics’ in this thesis.

(xxiv) Sustainability Evaluation

The term ‘sustainability evaluation’ is employed to represent the decision between what is sustainable and what is not and the degree of sustainability or unsustainability in a concise manner.

(xxv) System

The term system is used to describe a group of entities that have common characteristics and specifically cohesive organization pattern. Further in the later part of the thesis the role of observation in recognizing and highlighting these patterns also is discussed under systems view.

(xxvi) System boundary

The region that differentiates the common organizing pattern from its environment is referred to as the system boundary.

(xxvii) Transdisciplinarity

The term transdisciplinarity is used to indicate the platform of interactions of disciplinary, expert, stakeholder knowledge, interests and ideas in the sustainability decision-making process. These interactions are considered here as complex interactions and involve decision that have novel features and have grown well out of their initial collaborating domains. In addition to that this thesis work recognizes the commonality in the process of individual understanding of a complex phenomena and the collective efforts to address it (in terms evaluating, solving, designing, decision making etc) and that both of them are significant aspects in transdisciplinarity (For a more elaborated account please refer to the literature review section).

(xxviii) Transformation

Related to systems thinking, transformation processes can be described as an intended change in behaviour that will reflect structural and functional change of a system to alter the desired outcome. Individuals can go through a transformation process that deals with their intellect, worldviews and personality. Organizations can also go through transformation processes.

II.

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MARKET ECONOMY AND SUSTAINABILITY MAPPING: ROOM FOR MUTUAL LEARNING[1]

Abstract

Often sustainability is considered to be most challenging in the face of market realities. All countries in the world either directly or indirectly linked with global market. Within the field of sustainability there is a debate on whether market is the correct instrument to be highly relied upon, mainly due to disparities it creates in terms of wealth division and the challenge it induces upon global ecological sustainability. Among these discussions there are two distinct views, namely; (i) Market based capitalistic economic system has to be replaced in order to live within the capacity of ecosystem; (ii) Sustainability could be achieved still with capitalism and market, focusing on new directions such as ecological modernization. Considering these two views along with the hypothesis that sustainability rather than a static end state carries a strong implication of dynamics, the existing correlation between dimensions of market dynamics, and sustainability is explored with the aid of qualitative scenario analysis. Extending those observations to a further stage of metaphorical conceptual model building, how market triggered positive dynamics can intrinsically steer a society within an identified sustainability sphere is argued and illustrated in detail. Finally, additional implications for the process of characterizing Sustainability Dynamics (SD) are discussed at length.

Key words

sustainability mapping, sustainability sphere, market economy, dynamics, metaphors

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1. 1 Background

Within the emerging field of sustainability, there is ongoing debate on whether market is an instrument to be highly relied upon leaving it to form intrinsic societal movements. The resistance emerges not only due to market's widely talked disparities creating in terms of wealth division, but also for the challenges it induces to achieve long term global ecological sustainability. (Costanza and Daly, 1992; O' Connor, 1993; Hawkins, et al., 1993, 1999; Pepper, 1998; Balakrishnan, et al., 2003)

A market is a social system based on division of labor, where the prices of goods and services are determined in a free price system set by supply and demand. This is often contrasted with a planned economy, in which a central government determines price of goods and services using a fixed price system. In the real world, market economies are regulated by society (Alvater, 1993). While no country has ever had within its border an economy in which all markets were absolutely free, many states which said to have a market economy have a high level of market freedom. Thus, almost all economies in the world today are either mixed economies with varying degrees of free market or planned economy traits. (Alvater, 1993)

Even though the term free-market is sometimes used synonymously with market economy, in literature there are mainly four systems explicated; namely, capitalism, laissez -faire, anarcho-capitalism, and market socialism. Both laissez-faire and anarcho-capitalism are being referred to strictly free markets which are free of government interventions and regulations besides the minimal function of maintaining the legal system and protecting property rights. (Clerk and Cynithia, 2003) The book that is considered as the most influential in economic history, 'The Wealth of Nations' by Adam Smith which expounded the idea of government leaving market to itself, has popularize the concept of laissez-faire (Smith, 1776). Market socialism refers to various economic systems in which the government owns the economic institutions or major industries but operates them according to the rules of supply and demand. Finally capitalism generally refers to an economic system in which the means of production are all or mostly privately owned and operated for profit, and in which investments, distribution, income, production and pricing of goods and services are determined through the system itself.

Within this paper, more emphasis was given for those economies in which the concept of capitalism is functioning to the highest extent.

1.2. Introduction: *Sustainability and Market;* the famous paradox

"Although overall sustainability requires a long term view, our particular money creation system is like a pair of spectacles which give short term economic issues such prominence that they obscure our vision of the future."

(Douthwaite and Siochrú, 2006)

Historically, man has continuously been in war with nature considering it as a basic resource pool and a waste sink; although there are records of some indigenous cultures who had kept on nurturing more harmonious relationships (Diamond 1997, 2005). Three major distinct stages of human history have paved the road for the current capitalistic market economy. First the agricultural revolution which took place about 10,000 years ago, then the industrial revolution, triggered by trade between different parts of the world which ultimately led to sharing and advancement of new ideas and technologies. Starting from some parts of England in around 1500 AD, the development of market based capitalistic epoch unfolds a long story of, permanent technological revolution, sudden enrichment in material life, population explosions and growth of cities, change in nature of family units, threats to ecosystem, changed role of governments, etc, which expands in to present day complex globalization. (Bowels, et al., 2005) In the face of this rapid change, neither market nor capitalism has been free from continuous debate, dialogue and criticisms. Initially the biggest concern has been to identify the coupled system's functionality and to justify or challenge its suitability to serve the basic purposes of what it stands for. Many different views from Adam Smith, Karl Marx, Joseph Schumpeter, Thomas Malthus, John Keynes, Amartya Sen and many other economists and social scientists to answer this fundamental basis, have formed most of the theoretical concepts we know today about this complex system.

On the other hand starting from the 'Sustainable Development', which first introduced in famous Limits to Growth (Meadows, et al., 1972), and then often quoted from Our Common Future (WCED, 1987), today the concept 'Sustainability' has become a key global concern which spreads right across many scattered disciplines. However, when it comes to addressing the economic circle of the famous three pillars which most would in a glance identify as the visual description of sustainability (yet in our view would not necessarily be an adequate interpretation), there are two fundamentally dissimilar opinions yet being expressed in similar terminology. For instance, when a particular firm, corporation or an economy talks of sustainability, often it is about the entity's own long term survival, in other words, more or less about sustaining itself. Some others, though not many, would pay more attention on ways to maneuver their system's functions to ensure an improved state for the surrounding as well. These efforts have come in forms of many criticisms as Limits to Growth (Meadows, et al., 1972), Tragedy of Commons, ethical de-coupling (Vranceanu, 2005) as well as radical viewpoints such as ecological economics (Daly and Farley 2004) and ecological modernization (Hajer, 1995; Huber, 2000) etc. With ecological economics, Herman Daly has asserted that continuous growth in economy in its physical dimensions is limited by the fact that the economy is a subsystem of a finite, non-growing, materially closed ecological system (Daly, 1990; Daly and Farley, 2004). On the other hand, rejecting the fundamental opposition between economy and ecology, ecological modernization theory stresses the increasing importance of economic and market dynamics in ecological reform and the role of innovation, entrepreneurs and other economic agents and social carriers of ecological restructuring (Mol, 1997). In addition, there are some other views which support market's capacity to level down terrains of human interactions to overcome wealth disparities (Friedman, 2005), although such standpoints are strongly challenged in the face of one of the fundamental basis of unsustainability, the natural limitations induced by earth's physical carrying capacity (cf. Wackernagel and Rees, 1996). Likewise in the face of negative factors such as uncontrollable competition, excess consumption patterns, undesirable negative externalities on environment, difficulty in taking timely corrective actions so on and so forth, numerous opinions are being raised either to introduce improvements or to suggest for a paradigm shift from capitalistic economy based market model. (Common and Pierce, 1973; Daly, 1990; Jacobs, 1994; Petrella, 1994; Jacobs, 1996; Foster, 2002; Daly and Farley, 2004) However it is important to note that, all these views equally identify not only the dependency many human transactions and relationships have grown upon the market model, but also the fact that, the vigor and resilience the whole system has shown in its long term evolution is incomparable to any other known economic movement.

On the other hand, the concept sustainability too is still on its evolution. Different disciplines may constantly use the same term sustainability, where, while their implications often manage to fall in to a common domain, do not necessarily converge to a common focal point. For example, when a natural scientist may think of ecological replenishment or carrying capacity, an engineer may think of a particular clean technology, and an economist probably of corporate social responsibilities or green investments. One of the positive aspects of this lack of commonality would be that, instead of producing hasty, incomplete and biased sketches, the uncertainty (Dovers, 1992) and complexity entwined with a dynamic learning process would enable to create a more colorful and profound masterpiece. Clerk and Dickson (2003) has addressed sustainability challenge as the multiple movements to harness science and technology focusing on the dynamic interactions between nature and society, while giving equal attention to how social change shapes the environment and how environmental change shapes society. Yet nowadays the multiplying views about sustainability tend to bring forward a common underlying assumption of a rather static ultimate state, than treating it as a path or navigation route itself (that is closer to the process of selecting colors and patterns to draw a picture), which as a result leads to interpreting sustainability of not only an economic system but of any other relevant system as an incomplete, fuzzy state. Therefore we reemphasize that, more than an isolated static state, or as fuzzy concept lying above or ahead of us, sustainability can be identified as a sub system of rest of our surrounding systems, and it necessarily involves continuous changes, deviations and dynamic behaviors of those system's intrinsic components, characters as well as the peripheral environmental forces and triggers they subjected to. In this article taking the capitalistic economy based market model as an example, the above hypothesis is observed and qualitatively analyzed. In addition, a metaphorical approach of mapping a sustainability path within a defined sustainability sphere is illustrated and discussed in detail.

2.1 From Dynamics to Sustainability Sphere: A Metaphorical approach

Approximately fifty years ago, economist Joseph Alios Schumpeter introduced the term creative destruction in economies where he has insisted that disequilibrium was the driving force behind capitalism (Schumpeter, 1934). Following him some other scholars have described the underlying force of a capitalistic structure identifying their interactions and interrelationships (Petrella, 1996; Fligstein, 2001). Fligstein (2001) has summarized most of his observations on how the dynamical forces govern the market taking the viewpoint of sociology. Another remarkable recent attempt has been by Bowel, et al. (2005) where he has taken a dimensional approach to interpret capitalism. In order to base the foundation for our conceptual model, we have selected the same dimensions he has used in order to describe dynamical behavior of any economic system. The dimensions are command, competition and change. Command stands for those aspects of economic relationships which involve power, coercion, hierarchy, subordination, or authority and it has a strong link with choice. Competition refers to the aspect of the system in which exchanges plays the most important role, and an analysis on how competition work is essential to any attempt in understanding an economy. The third dimension, change, is concerned with the passage of time and the way in which, over time, the operations of an economic system will change the system itself. (Bowels, et al., 2005) The most significant fact is that the interactions of these three dimensions lay the basis to observe the behavior of an economy through modern complexities in different viewpoints of politics, economics, psychology and other social sciences.

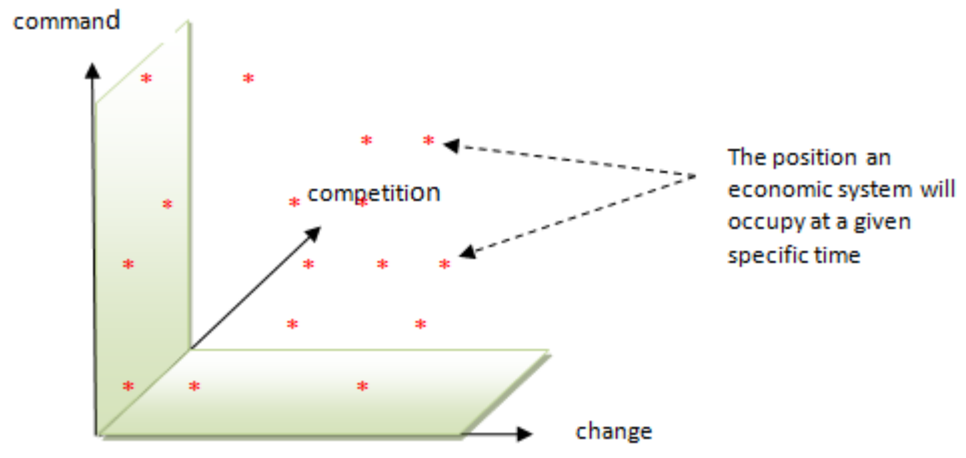


Fig 1: The dimensions of economic system in terms of dynamical behavior

Fig 1 could be regarded as a snap shot of a cluster of economic systems. That is, a random point marked relative to shown three axes may represent a position a particular economic system will occupy at a given specific time. It could be a company, a firm, a strictly locally bound economy or even a complex global market. Each of these systems would vary depending on its physical properties as, size, boundaries, etc or external factors such as interactions with other economies and places they secure within some other broader domains etc. However relative to time, they all would be moving within a larger three dimensional system space. This random movement, we would interpret as dynamics of an economic system towards the end of this paper.

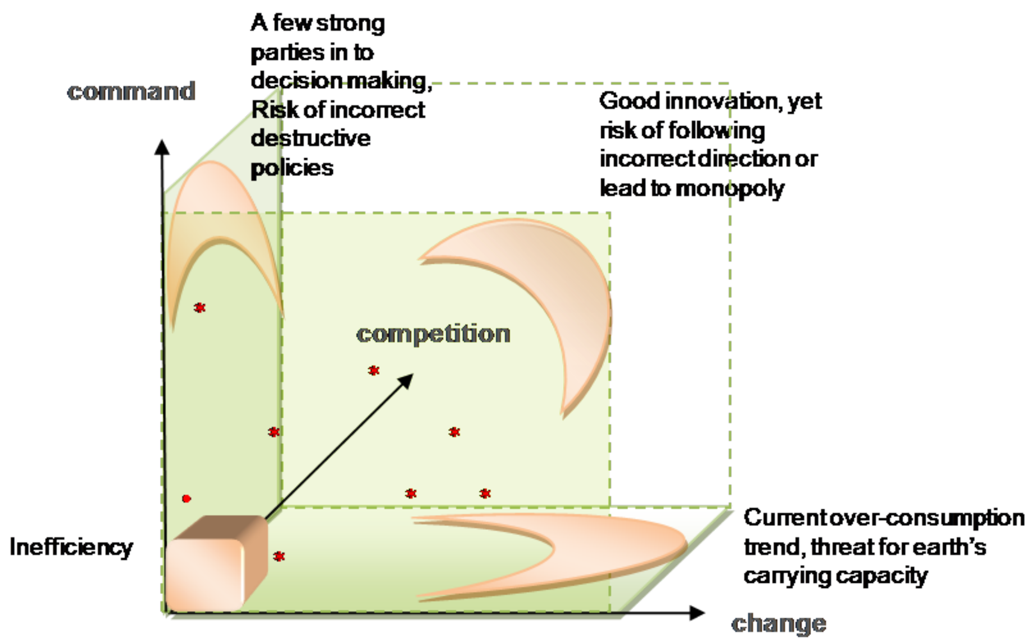


Fig 2: Sustainability problem space

Assume one of the moving points represents a particular country's market economy, whose boundaries, intrinsic behaviors, external relationships are well understood. One might prefer to keep this market closer to command axis to make sure his control over the system is high. Such behavior could be state interventions or even the power one would gain through being a lone successful player. Another might like to 'let loose' and let the intrinsic forces to compete within. Such would be a highly volatile environment which theoretically would let only the best or the fittest win. The final one who would rather stay closer to change axis may keep on innovating so his market would never age. These are three extreme choices. In reality, at a given time any market will have a specific point within this space, and relative to time, the point will move both due to external or internal drives.

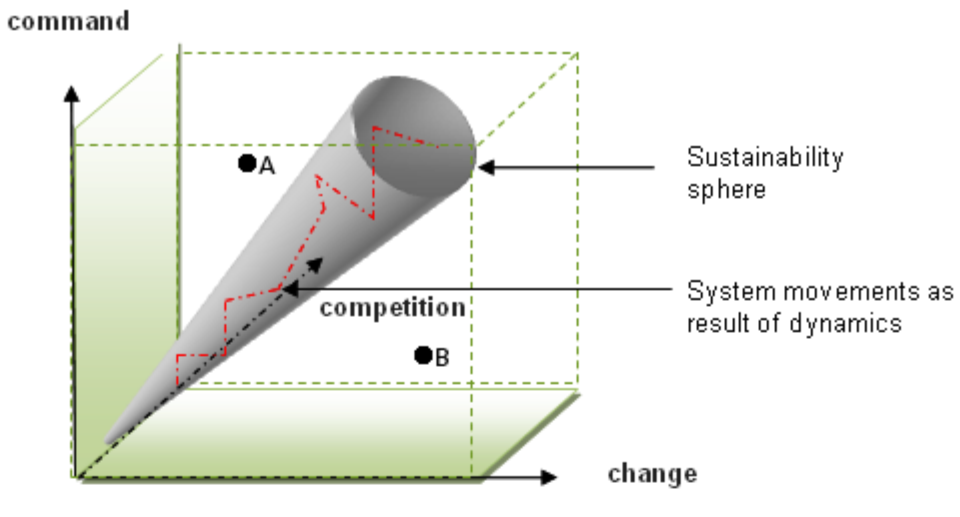
Now the question comes can we identify sustainable or unsustainable domains/sub-spaces within this defined space, if so where? Assuming the market's behavior will reflect at least two of these dimensional attributes, while sticking to our earlier position on what sustainability is, we identify three possible long term unsustainable extremes, which are illustrated in Figure 2. Those extremes reflect direct consequences of biased behaviors relative to only two of the dimensions, neglecting the other. For example, when in the system, there are highly competing strong entrepreneurs and their capacity to innovate is very high, the two factors coupled together can lead to increase material production, hence in long run, extreme consumption habits within societal boundaries it operates. Many different arguments have risen in literature on market's position in sustainability, where these three unsustainbility extremes are extensively talked about. For instance, Petrella (1996) describes globalization and internationalization of recent times as a new 'competitive era' emerged in the last twenty years, especially in connection with the globalization of economic process. He emphasize that competition no longer describes a model of functioning of a particular market configuration such as a competitive market as distinct from oligopolistic and monopolistic markets. To be competitive has ceased to be a means. Competition has acquired the status of a universal credo, an ideology. For industries and bankers, competitiveness has become the short- and middle-term primary goal, whilst profitability remains the long-term goal and the *raison d'être* of the firm. For government, the competitiveness of the nation is now the primary concern, with a view to attract and retaining capital within its territory, in order to secure a maximum level of employment, access for local capital to global technology, and revenue needed to maintain a minimum social peace (Ricardo, 1996). His interpretation is embedded with two interesting observations. First it clearly reflects the obsession and biasness the behavior of market have started to show upon the competition axis. Secondly, it reflects the fact, even though a market or a capitalistic economic system may regard as a separate entity, it is inseparably linked with many other important geopolitical and ecological systems.

Thomas Friedman in his two books World is Flat (Friedman, 2005) and The Lexus and the Olive Tree (Friedman, 1999), repeatedly mentions that today, the virtual distance between different regions has shrunken making the new globalized world to operate in a flatter platform than ever before. He bases most his arguments on his observation that, world is losing many of its internally set traditional boundaries. He pictures how the command of globalized market being taken over by players themselves and how their open competition results in levelling the terrain of world. However, with his counterargument to this in "Bad Samaritans: The myth of free trade and the secret history of capitalism" (Chang, 2007) Ha-joon Chang is totally against the view that free trade is usually beneficial to the development of poor countries. In the process he brings forward very interesting two points, one, that almost all capitalist economies including countries as United States, Japan, South Korea, England have relied on protectionist policies and government "intervention" to achieve development, while engaging themselves in "free trade" which is in line with many other similar view points. In Friedman's perception, though it is not directly stated in terms of dynamics or sustainability, strong emphasis given for the intrinsic command which is created among the players themselves, one question could be how far this intrinsically formed command is willing to think of sustainability. One of critical drivers to form intrinsic commands which are sustainable as well would be the incentive structure within the system. In the counter argument on the other hand, much less trust is given for intrinsic commands, but more on governmental interventions, protectionism, and strategic investments.

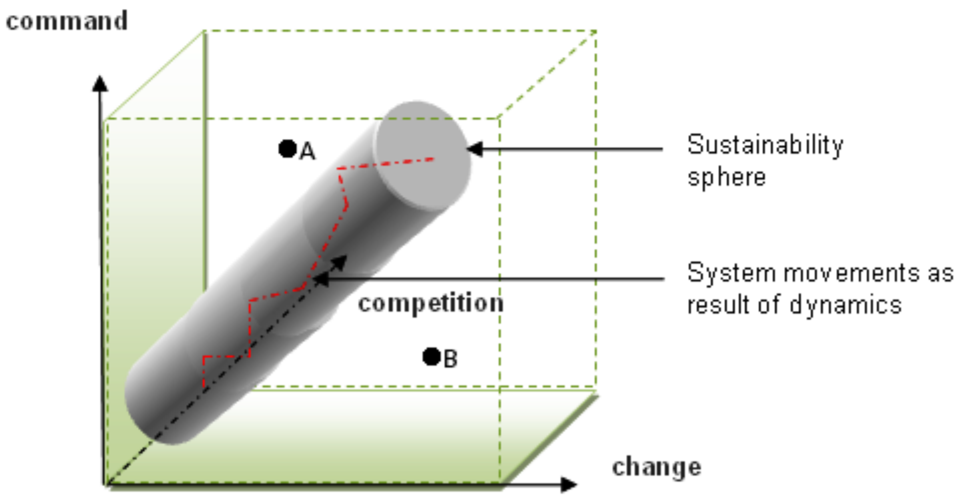
2.2 Sustainability Sphere

Once the key dynamic triggering forces and their positive and negative effects are identified as above, most fractions of the problems encountered with existing systems are coupled with what creates the dynamics within the system. Fig 3 shows a possible movement of one of the points in a way that the economic entity represented stays within sustainability boundaries. The path is selected in such a way that attractions from each of peripheral dimension are balanced. The metaphorical sphere which encloses the space where this random movement occurs, we may call, sustainability sphere. However this interpretation is strictly relevant to a system's intrinsic dynamics, in other words, most of the other relevant parameters of sustainability, (for example the amount of environmental degradation a country where the economic system is based on has already undergone), are kept external. Even though explaining their role is outside the scope, these external factors indispensably play a significant role in defining the size and shape of the sustainability sphere. However these factors have to be dealt in each and every case separately. For instance two sustainability spheres for equal economic systems in two different geographical locations may look very different from each other. What shown in Fig 3(a),(b) are conceptual approximations of boundaries which enclose a controlled path. In addition, it is important to take in to account that suggesting this type of a boundary is influenced by several key underlying assumptions;

(i) Relative to time, all the dimensions describing dynamics of the observed system are equally important and have equally strong influence over the system's path.
(ii) The dimensions taken as together have the capacity to induce a balancing but not neutralizing effect on its path relative to time, rather all three dimensions have a common positive vector component which will ensure the system's future advancements.
(iii) The imbalanced forces induced by the dimensions over the system make it move within this dynamical space.
(iv) The time taken to for the dimensional force to have the impact on the system is roughly similar for all three dimensions.



(a)



(b)

Fig 3 Sustainability Solution Sphere

(Fig 3.4)

A sustainability sphere for a market based economic system could take different forms. Figure 3(a) would suggest when dynamic forces are high; the movable area of the system is high, still being within sustainability constraints. One reason could be a situation closer to when high competition for more sustainable focused innovative products supported by correct strong policies taken by entrepreneurs and other influencing commanding bodies. However it has an underlying assumption that the geographical base within whose boundaries the concerned system operates is infinitely away from reaching its carrying capacity limits, there can be scenarios where such limits has already reached, that increased system's dynamical triggers could no longer provide a basis to extend the limit, rather might lead to reach sooner, hence the sphere could be of an inverted shape. Fig 3(b) would suggest an ideal situation where the three dimensions alone can continuously keep the system balanced; in other words, the dynamics within the system themselves are arranged in such a way not to have any negative effect on recognized sustainability thresholds. Likewise the position of a time span the system secure and the influencing external sustainability parameters relevant for that specific time will determine the shape, size and position of the sustainability sphere. However the forces which manure the system within, to determine its path needs to be the internal dynamics (competition, command and change in example here) and intrinsic forces, triggers they help to generate. Such forces can both be negative and positive in the face of sustainability and they course path deviations to ensure any component of the system to stay within those identified boundaries at any given specific time, for instance. To prevent diverting to point A or B, would need thorough understanding of not only of boundaries it would be constrained to (sustainability sphere) but also the system's capacity to induce and balance these forces.

3. Discussion and Conclusion

While this type of macro level conceptualization would be helpful to stop catastrophically failures (by roughly identifying the boundaries of sustainability sphere), it is equally important to zoom in this holistic macro picture to reach down for more micro details, for instance such as the path within. Only such a process would allow to identify where changes in directions need to be made, and more importantly within which time scale. In the transition theory it is emphasized that fundamental changes of assumptions to introduce new rules and practices are necessary to reach from one equilibrium to next, through stability and inertia. (Rotman, et al., 2001). To make such changes, one needs to be able to identify where the error is. In order to utilize such inertial forces to transit through temporal stabilities, the knowledge on what courses these forces and where these forces are needed etc are equally essential.

In response to above conceptual illustration, one important counter argument would be, why trying to super impose a sustainability scenario on few random dimensions. The three dimensions taken for this example, command, competition and change, may well interpret dynamic behavior of an economic system, but often sustainability will be recognized with many other different dimensions. The basis of selecting these three dimensions instead of expanding them to include some others to increase the comprehensiveness of the model in sustainability perspective is partly with the objective of achieving the optimal point between interpretative capacity and complexity, as a mapping process which includes all such possible dimensions would need numerous other parameters such as, environmental limitations and priorities, social factors, ethical factors, technological limitations etc to be taken in to account. However there won't be universal parameters representing sustainability which can adjust to any given situation, hence no handy kit of dimensions to fix in to a random dynamic model. Here we come back to our earlier argument that, sustainability rather than an end point or a system itself could be regarded as cumulative set of paths of some other existing systems. Therefore instead of measuring a system's behavior in the point of view of a common sustainability view alone, we suggest a process of identifying sustainability or unsustainability within the dynamical process of a concerned external system. This in a way is place a foundation to expand the current discussion on sustainability to a further level to include dynamic component which we would call as Sustainability Dynamics (SD). One strong point to conclude from this conceptualization could be that, just as making a system more sustainable needs expanded knowledge on the system's dynamics, to understand sustainability dynamics, the same relationship might be able to provide a sound basis.

In addition, this form of metaphorical conceptualizing could be a first step to allow fractured and highly specified different knowledge domains to come in terms with sustainability much easier than imagining the whole concept as a partly relevant yet mostly irreverent, complex but attractive piece of art. Especially at points where systems are expected to take rapid actions, such an approach becomes highly advantageous. Even though what's being described may sound highly conceptual and overly simplified, they can be strengthened with case studies and empirical justifications. The methodologies such as Environmental Impact Assessment (EIA), Integrated Sustainability Assessment (ISA), to a certain extent have succeeded in coupling environmental and social aspects in to development project decisions. One interesting and novel fact in the approach suggested here might be that, instead of static reference base-line data, the concept emphasizes the strong need to map those external interactions within dynamics of the concerned system. That way in addition to prevention and control, throughout the ongoing process, one might be able to even trigger catalysts for constant positive outcomes. This is in a way helps to detach certain negative aspects from your system while making room for novel insights gained through an eye of holism to facilitate a mutual learning process. It brings us to Sterman (2002) interestingly states, "*all decisions are based on models, and all models are wrong*", which indirectly carries the message that at no matter how far we think we understand, at any given instance we should be prepared to question our assumptions.

While watching Flatland (Flatland, 2007), we feel A^2's frustration when he tried to make his fellow landers see that the third dimension is nowhere to left or right but to up and down, something which had not crossed their plane of perception ever before. What finally made A^2 himself to accept that there are higher dimensions than just the two he knew was to detach himself out of his own world to a higher dimensional space, and then look back down, with a completely new and different insight.

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