

DETERMINANTS OF STUNTING IN EASTERN RWANDA

A Thesis

by

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DETERMINANTS OF STUNTING IN EASTERN RWANDA

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ABSTRACT

During the Copenhagen World Summit for Social Development, the United Nations Commission for Social Development committed itself to eradicate hunger and malnutrition and promote the rights of children by providing them with adequate nutrition. The heads of State and Government defined more concrete targets in the Millennium Declaration by pledging to combat hunger by halving the proportion of hungry people by the year 2015. They also aimed to reduce under-five child mortality rate by two thirds by the same date. A well-nourished population has now been recognized as a pre-condition for sustainable development and strategies to combat malnutrition are being increasingly integrated into development programs and policies.

Africa suffers from the highest incidence of stunting, which stood at 40% of all children younger than 5 years old in 2005. Stunting is a main indicator of malnutrition. Height for age z-score (HAZ) is the indicator for measuring stunting. It is determined by calculating the difference of the under 5 years old child's current height from a median universal standard of growth path calculated by the World Health Organization. The child is stunted if HAZ falls below two standard deviations of the mean reference. Stunting causes higher child mortality and morbidity in the short-term and lowers intellectual ability, economic productivity and reproductive ability in the long-term. In Rwanda, despite remarkable economic growth after the 1994 genocide, the prevalence of stunting stood at 44% in 2010 for children younger than 5 years old and was responsible for 9.9% of child deaths in 2008. The prevalence of stunting remains especially high in rural areas compared to urban areas, and is a major social and health challenge for rural communities.

The purpose of this study is to determine the factors behind stunting in the Eastern province of Rwanda. Prevalence of stunting in the Eastern province stood at 43% in 2010, which is close to the national average. The Eastern province however suffers from considerable food shortages during the dry season and prices of food rise significantly. It also has a historical proneness for droughts and famines.

The approach to assess the factors behind the variations in HAZ follows two measures. The first measure is geographical accessibility to healthcare. Given Rwanda's hilly nature and the dearth of studies focusing on travel time to health centers in Sub-Saharan Africa, this study comes as an initial attempt to clarify the relationship between travel time to healthcare service delivery points and stunting in Rwanda. The second measure is the effect of the mother's role in intra-household allocation of resources. Recent studies on child health have been increasingly shedding light on additional determinants of stunting in Sub-Saharan Africa, other than traditional variables such as distance from health service delivery points and cost of consultation. The study will constitute an initial exploration of the relationship between a mother's role in allocating nutritional resources in the household and stunting in Rwanda.

The dataset for the study consisted of data extracted from the Demographic Health Survey (DHS) database and field surveys. The DHS sample consisted of 974 children younger than 5 years old in the Eastern province with information about HAZ, household's wealth index and GPS location, mother's education, sex, preceding birth interval, birth order, and mother and father's involvement in agriculture. Travel time from GPS locations of households to health centers was calculated using ArcGIS software and AccessMod, an add-on tool developed by WHO for the purpose of

simulating traveling scenarios to health centers. Land cover and population data and health center GPS locations were obtained from the Center for Geographic Information Systems and Remote Sensing of the National University of Rwanda and the Rwanda Natural Resources Authority. Field data obtained through a wide survey that targeted 600 households divided equally between the sectors of Rukara and Mwiri in the Eastern province complemented the data from DHS by additionally inquiring about waiting time and travel safety. The questionnaire inquired about general health behavior, food security and socio-economical background. Measurements of children's height were also taken. The sample size of children extracted from the field survey consisted of 260. A smaller nutritional survey targeted 32 households in Rukara and Mwiri and inquired about the household members' daily food intake. It was used to complement the DHS based study on intra-household allocation.

Due to the lack of a theoretical basis for a model/equation of healthcare access, the time to health center variable was used in a step-by-step multiple regression analyses with HAZ as a dependent variable. Variables of wealth index, mother's education, sex, preceding birth interval and birth order were added respectively. A similar regression analysis with HAZ as dependent variable was undertaken with waiting time and perception of travel safety's effect by caregivers as independent variables. An equation of a simple model of intra-household allocation was estimated with DHS HAZ as a dependent variable, the involvement of the father and the mother in agricultural activities and the mother's primary and secondary education levels as independent dummy variables. The estimation was complemented with the results of the nutritional survey. The HAZ of 17 children was used as a dependent variable in a series of bivariate regressions against a variety of foods.

Both time to health center and mother's education proved to be highly significant factors of HAZ variation for travel time values below 120 minutes. The presence of a 120 minutes time "barrier" after which the relationship flattens out might mean that households have become way too far for there to be any significance for travel time. Waiting time at health center and travel safety were also significant factors in explaining HAZ variations. Mother's involvement in agriculture and her completion of a secondary degree had a positive effect on the distribution of HAZ. The nutritional survey showed that differences in HAZ were significantly correlated with differences in meat and milk intake, which are high protein foods and therefore point to the possible role of the mother in better allocating nutritional resources.

Given the strong positive impact of mother's involvement in agriculture and her secondary education on stunting, its alleviation is therefore not a simple matter of improving accessibility. Further studies are required to investigate the effect of the mother's status in intra-household dynamics on the children's HAZ. A higher status of the mother can affect different aspects of her life, such as time management, nutritional allocation and employment. The effects are expected not to be straightforward, since higher status women can become employed, and devote less time on their children's health. Also, more accurate studies of travel time to the health center are recommended, such as researchers undertaking the actual journey to the health center with the caregivers while measuring travel time.

Key words: Malnutrition, Stunting, Intra-household allocation, Geographical accessibility, Mother's education

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I. Introduction

1.1 Poverty and malnutrition

The United Nations' Millennium Declaration aims to reduce child and infant mortality rates by two thirds in 2015 as compared to 2000 in developing countries mainly (United Nations Millennium Declaration 2000). Malnutrition is a main driver of infant and child mortality rates. Norman et al. (2008) define malnutrition as

the imbalance between intake and requirement which results in altered metabolism, impaired function and loss of body mass or as a state of nutrition in which a deficiency or imbalance of energy, protein, and other nutrients causes measurable adverse effects on tissue and/or body form. (Norman et al. 2008:p. 6-7)

In 2011, malnutrition was linked to the deaths of more than one third of children aged under 5 years old (WHO 2012). 171 million children under 5 years of age were stunted in 2010 and 104 million were underweight (WHO 2012). Malnutrition has a synergetic relationship with infectious diseases (Scrimshaw & SanGiovanni 1997). This relationship is characterized by a two-way feedback in which malnutrition makes a child more prone to infectious diseases by essentially weakening his/her immune system, and infectious diseases in their turn raise the body's demand for food and energy and cause other harmful symptoms (such as mal-absorption), thereby making a child at a higher risk of malnutrition (Deaton 2007; Riley 2001). The two most common ailments associated with malnutrition are diarrhea and respiratory infections (especially pneumonia) (UNICEF n.d.; Riley 2001). In addition, malnourished children suffer from a higher frequency of stronger illness episodes (Riley 2001). Diarrhea and pneumonia are the leading causes of death for children under 5 years old, causing the death of 700,000 and 1.3million children respectively in 2011 (Walker et al. 2013). Undernutrition was identified as a main risk factor (Walker et al.

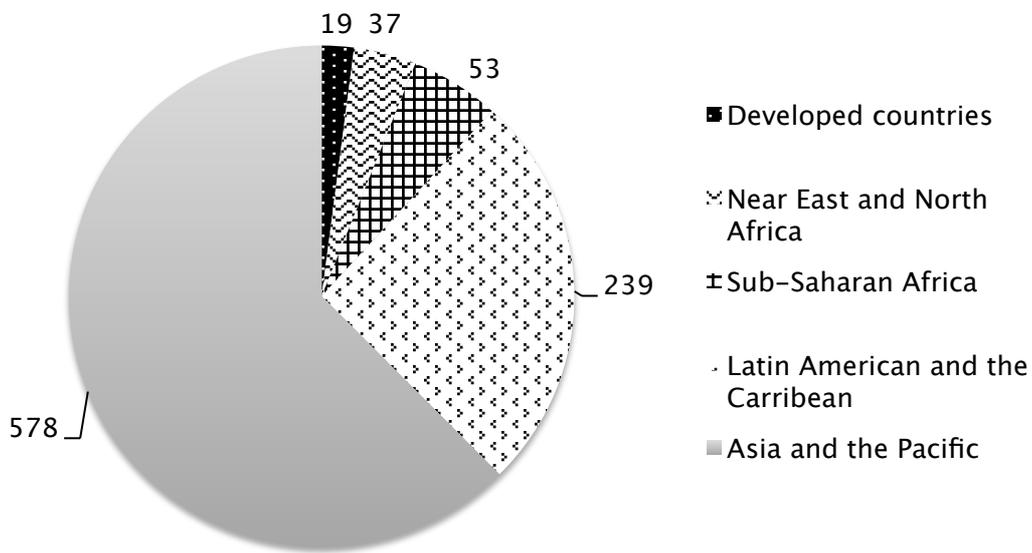


Figure 1: Total number of undernourished people per region in millions

Source: FAO 2010; WFP 2010

2013). Undernutrition is a form of malnutrition that occurs when ‘caloric intake is below the minimum dietary energy requirement (MDER)’ (FAO & WFP 2010:8). Figure 1 shows the distribution of the total number of 925 million undernourished people in 2010 in different regions of the world.

While at first sight Asia and the Pacific looks like the region that is affected by undernourishment the most, percentages relative to total population numbers show that it is actually Sub-Saharan African that carries the heaviest burden of undernourishment (Figure 2).

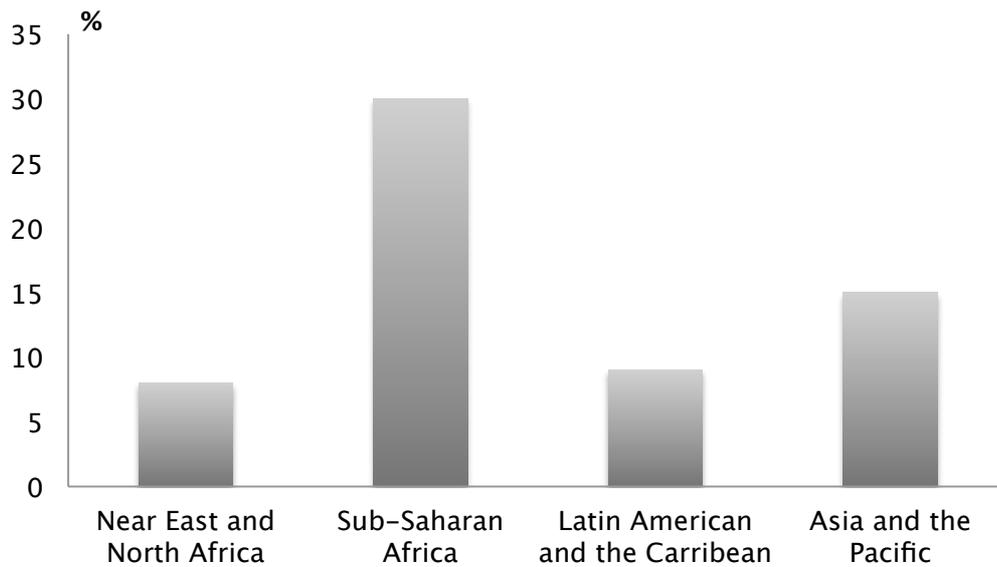


Figure 2: Percentage of undernourished people per region
 Source: FAO 2010; WFP 2010

Although it is obvious from the distribution of undernourishment that poorer regions are more afflicted by undernourishment, and that malnutrition has ultimate causes in poverty, it is not however necessarily related to food scarcity per se (food scarcity should not be confounded with food security), agricultural potential nor income (Deaton & Dreze 2009; Jaspars & Young 1995; Reutlinger 1977). In India for example, despite increases in incomes and wages, the country still has one of the worst anthropometric indicators. Improvements in these indicators have been very slow at best, and rates of malnutrition in India remain worse than many Sub-Saharan countries, despite the latter being poorer (Deaton & Dreze 2009). Surprisingly, even in wealthy Indian families abnormal rates of child and infant malnutrition were detected alongside dietary practices diverging from recommended norms, thereby pointing to social determinants as potential culprits (Deaton & Dreze 2009). Additionally, in Darfur, during times of food insecurity or acute malnutrition, nutritional status of whole communities worsened independent of wealth status (Jaspars & Young 1995). Sources of income, diversification of income sources and

traditional factors were found to be more important than absolute income (Jaspars & Young 1995). The fact remains that health generally is a consequence of multiple factors whose weights can vary in space and time (Riley 2001). Consequently, studies of causes of malnutrition should always be contextualized (Jaspars & Young 1995).

UNICEF has developed a conceptual model of the causes of malnutrition characterized by three levels of causes (UNICEF 1990). The model, reproduced in Figure 3 identifies inadequate dietary intake and disease as immediate causes. The level below the immediate causes identifies three underlying causes of household food insecurity, inadequate health services and health environment and inappropriate child and maternal care (UNICEF 1990). The lowest level, representing basic causes, reflects the technological, political, ideological and economic structures of the society that result in an unequal distribution of potential resources (UNICEF 1990).

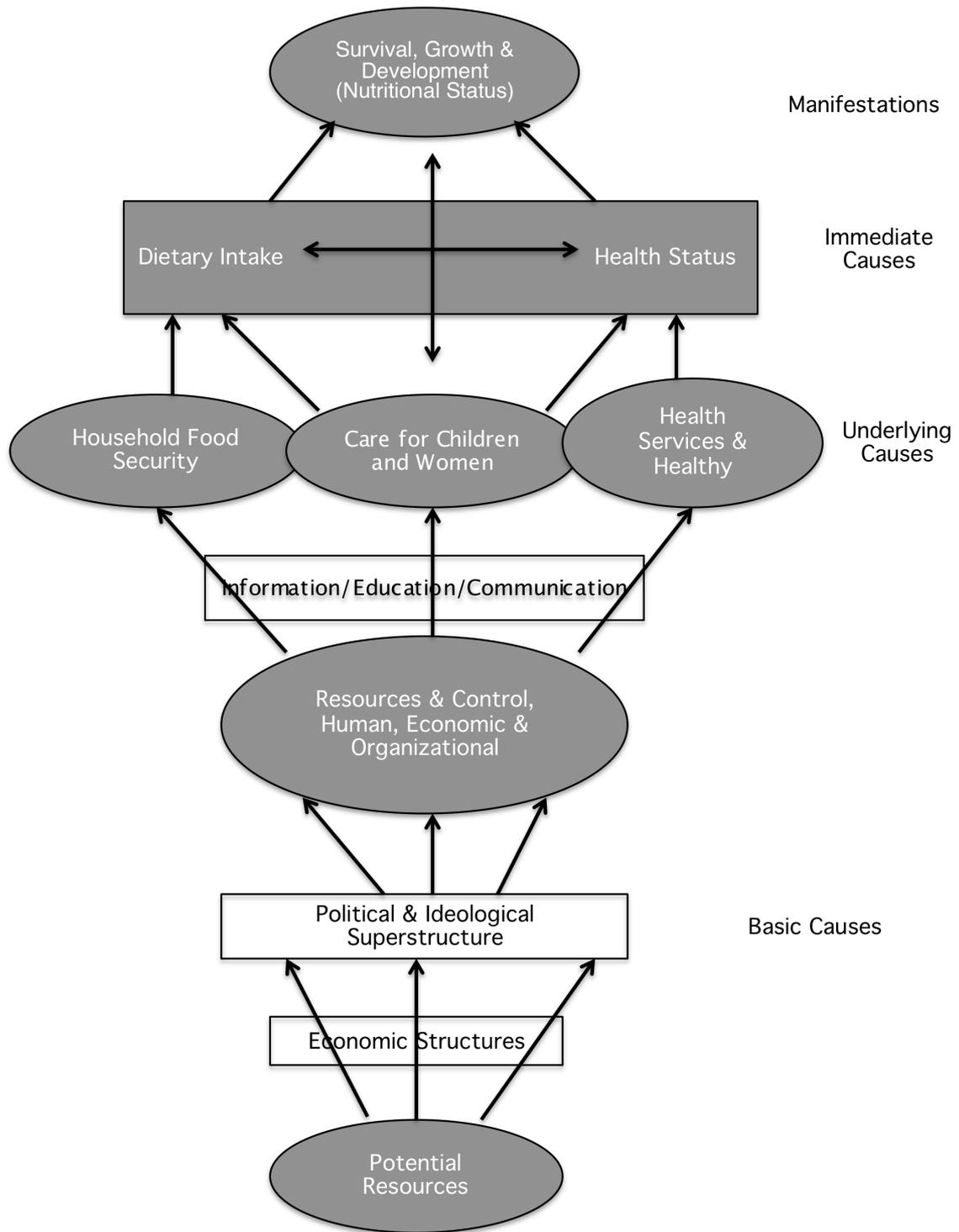


Figure 3: UNICEF conceptual model

Source: UNICEF 1990

Worldwide, high (dietary) energy availability, female literacy, immunization rates and GDP were the main factors associated with low levels of wasting and stunting, the typical symptoms of undernutrition (Frongillo, de Onis & Hanson 1997). Other factors such as public health expenditures differed depending on the region and countries (Frongillo, de Onis & Hanson 1997).

1.2 Stunting

Stunting is the ‘chronic restriction of a child’s potential growth’ (Young & Jaspars, 2009:24). It reflects long-term effects of inadequate nutrition and a nefarious disease environment at an early age of life. It is the most prevalent form of undernutrition for children in the developing world, with a tendency for women to be more affected than men (World Bank 1993). In 2005, the prevalence of stunting stood at 32% for children younger than 5 years old in developing countries (Black et al. 2008). South Asia suffers from the highest absolute numbers of stunted children (Black et al. 2008). Stunting happens mostly in children aged between 0 and 24 months, especially during weaning periods (Black et al. 2008). Growth faltering is also heavily influenced by the early infectious disease environment (Black et al. 2008). Its incidence increases progressively from birth and stabilizes after two years of life. Prevalence is therefore higher for older children as compared to younger ones (Young & Jaspars 2009). Due to its dependence on past disease environments and nutritional conditions, height is widely used as a proxy measure of poverty and socio-economic conditions at a certain point in time (Deaton 2007; Riley 2001). This correlation is not universal however, as children of wealthier families have been shown to be less well nourished than poorer children in an Indian village. Similarly in Darfur, wealth status was not a determinant of nutritional status (Jaspars & Young 1995). Regardless of what causes stunting at an

early stage of life, stunted people tend to perform worse in education, work and health than their taller counterparts in later stages of life (Deaton 2007). Evidence from the United States and Brazil shows the log function of wages to be positively correlated with height for men, even when controlling for education (Strauss & Thomas 1998). The relationship is stronger when labor relies on manual strength, which is the case in many developing countries (Strauss & Thomas 1998). Stunting is also correlated with earlier death and higher morbidity in later life (Young & Jaspars 2009). Stunting's relationship with child mortality is not straightforward. For children between 0 and 3 years age, it strongly predicts mortality (Young & Jaspars 2009). A study of 1343 children that followed children from birth until two years of age in Bangladesh found a significant negative relationship between stunting and food security, making height for age a potential candidate as an index for food security (Saha et al. 2009). More specifically, a study of cohorts from Brazil, South Africa, Guatemala, India and the Philippines found that height at age 2 is the best predictor of future human capital (Victora et al. 2008).

1.3 Geographical accessibility to healthcare

Access to healthcare is 'the timely use of services according to need' (Peters et al. 2008). Ronald M. Andersen has developed the main theoretical model of behavioral access to healthcare during the 1960s to guide policy makers in assessing and ensuring equitable access (Andersen 1995). Although the model has witnessed different updates throughout the years, its main core are three functions that define people's access to and use of healthcare. Those are predisposing characteristics of a certain individual (and also population), enabling resources and needs (Andersen 1995). Figure 4 shows the original behavioral model developed in the 1960s.

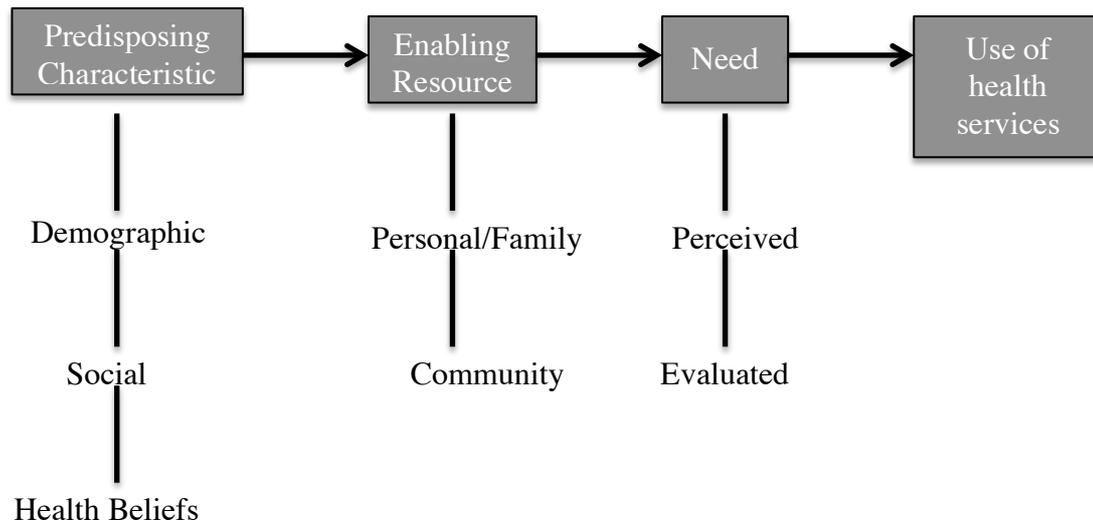


Figure 4: Behavioral model of healthcare access

Source: Andersen 1995

Demographic characteristics represent biological factors (Andersen 1995). Social structure factors are represented by variables related to the status of a certain individual within his/her own society. Education, occupation and literacy are traditional measures of such factors (Andersen 1995). Strength of social networks and caregiver's autonomy are increasingly seen as relevant predisposing factors (Rutherford 2010). Health beliefs characterize the people's perception of different diseases, their perceived need for healthcare and remediation for that disease, and the services used (Andersen 1995).

Enabling resources represent the individual and/or family's enabling powers, as well as the presence of healthcare infrastructure and personnel, which are the community's enabling resources that facilitate access and use (Andersen 1995). Travel and waiting times, income and health insurance are relevant variables (Andersen 1995). Time and travel distance become vital determinants of healthcare demand when health services are offered at reduced prices or for free, which is the case in many developing countries (Acton 1975; Johan & Strauss 1998). Here again, social networks can work as enabling resources (Andersen 1995).

Two factors define the needs dimension. Perceived needs are people's assessments of their own health status and whether this health status requires intervention (Andersen 1995). Perceived needs are defined by the social structure of the society (Andersen 1995). They are contrasted to evaluated needs that are evaluated by a health professional based on the current state of medicine (Andersen 1995).

As mentioned earlier, the purpose of this model is to make access more equitable. Andersen defined equitable access when demographic characteristics and need drive the use of healthcare services, and inequitable access when social structure, health beliefs and enabling resources are the main factors (Andersen 1995).

Peters et al. (2008) define four dimensions of health care: geographic accessibility, which is represented by the distance and/or travel time to the health facility, availability, which is characterized by the presence at the point of service delivery of the appropriate health services (both personnel and technologies, drugs etc..) as well as convenient operating and waiting times, financial accessibility, which is characterized by the cost of service accrued to the users, their ability and desire to pay as well as the users' protection from potential harmful opportunity costs of paying the cost of service, and finally acceptability which is similar to the needs and health beliefs of Andersen's model with the addition that the health services offered should be compatible to those beliefs and perceived needs (Peters et al. 2008).

Those four dimensions have quality as a fifth dimension at their center, since it constitutes a part of each dimension (Peters et al. 2008). The model also defines deeper determinants of health care access such as the policy environment and the individual and household characteristics (Peters et al. 2008). Figure 5 illustrates the model. It is important to note in concluding this paragraph that similar to malnutrition and health, there are no universal laws of access to healthcare. The importance and

dimension of all factors and dimensions determining access to healthcare vary depending on the context. It is therefore important to contextualize the understanding of the drivers of malnutrition, ill health and access to healthcare every time a study is undertaken in a particular region at a given time (Riley 2001; Peters et al. 2008).

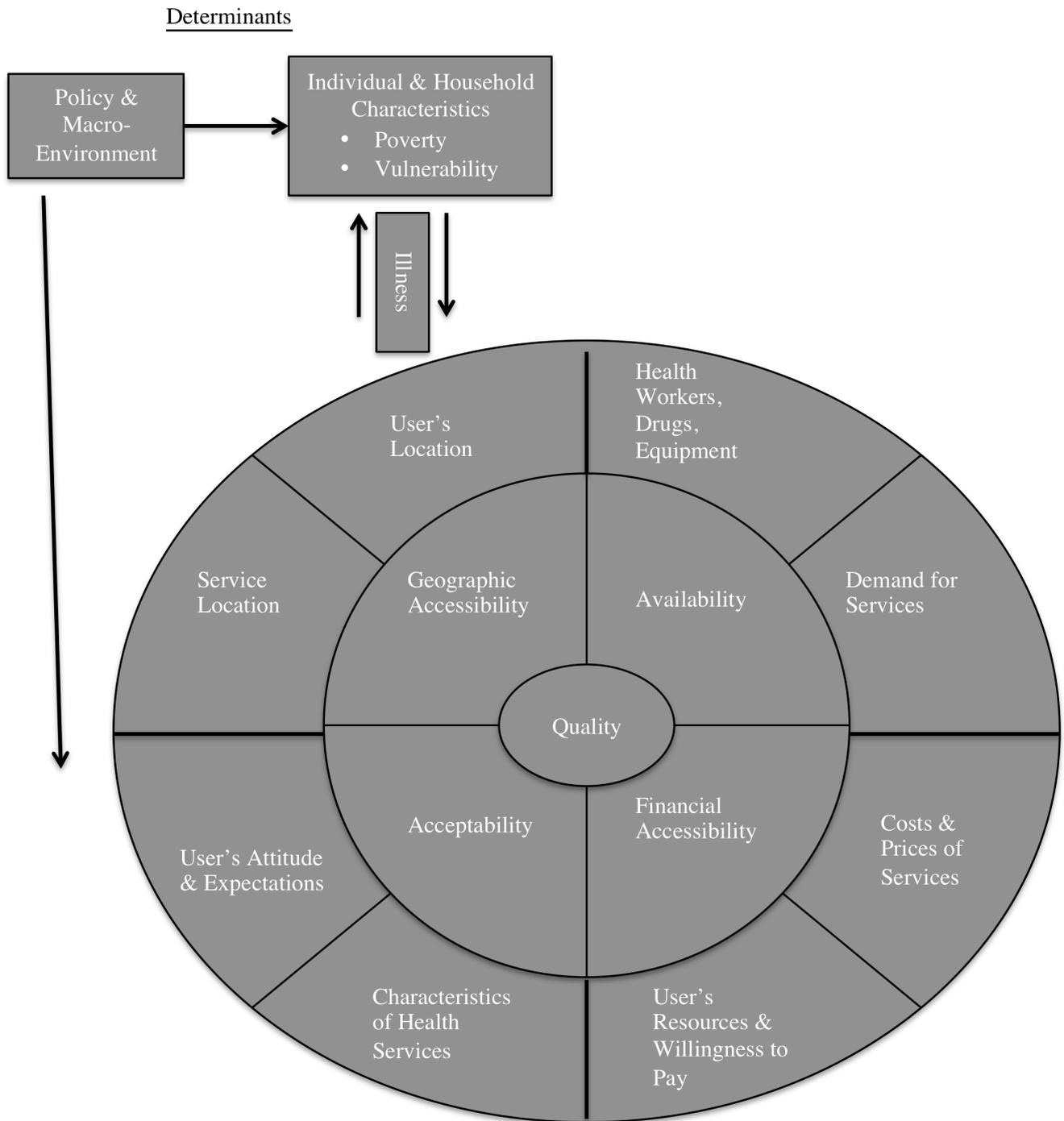


Figure 5: Framework of access to health care

Source: Peters et al. 2008

Since the thesis is primarily concerned with actual accessibility to healthcare and its relationship with stunting prevalence, the following paragraph will mostly describe the concepts relevant to geographical accessibility in figure 5 and enabling resources in figure 4. The next section will also present a brief literature review of mother's power and status effect on stunting because, as will be explained later, not only is this an important factor in stunting, but also a relevant issue to address through policy-making.

Distance to health centers has been found in numerous studies to correlate intimately with health care access and use. The phenomenon was named "distance-decay effect" (Feikin et al. 2009). In the rural Ahafo-Ano South district of Ghana, a study administering questionnaires and interviews to a random sample of 400 households showed that distance was the prime factor affecting utilization and had a strong negative relationship with utilization (Buor 2003). Although travel time also correlated negatively with utilization and positively with distance, distance still had the major impact (Buor 2003). Other factors of importance were mostly service cost and income (Buor 2003). An additional result of important significance in the study was the more pronounced effect distance had on the utilization of elder people, ill people and females (Buor 2003). This result proves that the effect of distance is mutable by other factors. Other studies have also confirmed both the effect of distance and its mutability. In a rural area of Kano State in Nigeria, per capita healthcare utilization was shown to decrease exponentially with distance (Stock 1983). Similarly to the Ghanaian study, the rate of decay varied depending on the type of facility, the particular illness and the community's perception of it, the spatial location of the village and factors such as age and sex (Stock 1983). A study of 60 cases of perinatal deaths and 120 controls conducted in the West Nile region of Uganda has shown that

mothers who had travelled distances longer than 5Km had a higher likelihood of experiencing a perinatal death than those who didn't (Akello et al. 2008). In rural Burkina Faso, a study of survival of children born between 1992 and 1999 also found that distance to the nearest health center was a risk factor associated with increased mortality (Becker et al. 2004). In rural Niger also, a study compared the use of health services and mortality rates of under 5 years old children in three types of villages. A health dispensary serviced one group of villages, village health teams supported others and the last group did not have access to any form of modern healthcare (Magnani et al. 1996). Children living in villages served by health dispensaries were less likely (32%) to die than children without access to modern healthcare services during the study period (Magnani et al. 1996). In Zaire (current Democratic Republic of Congo) a study of 776 children aged between 0 and 3 months found that distance to a health center greater than 5Km was a main maternal factor associated with excess mortality of children (Van Den Broeck, Eeckels & Massa 1996). A more recent study in rural Western Kenya measuring the rate of clinic visits by children younger than 5 years old found that the rate decreased in a linear manner as distance increased from the center for households located between 0 and 4Km (Feikin et al. 2009). The rate stabilized beyond 4Km (Feikin et al. 2009). The rate of decay varied depending on the severity of the illness and the type of facility (Feikin et al. 2009). In Tanzania, a survey administered to 21600 households determined that households located beyond 5Km from a health facility had higher infant mortality rates than those living within the 5Km area (Armstrong Schellenberg et al. 2008). Studies outside of Sub-Saharan African have validated a decay effect, and have also shown it to be mutable based on other factors (Muller et al. 1998; Taiar et al. 2010). While this might lead to a premature conclusion that distance is always a significant factor of healthcare access

and use, numerous studies in Sub-Saharan Africa point to the lack of statistical significance of Euclidean distance as an explanatory factor for the access and use of healthcare facilities and services. A case study in Gambia of 140 children who died before the age of 5 showed that distance, although significantly associated with child mortality in a univariate regression, lost its significance when a multivariate analysis was performed that controlled for possible confounding variables (Rutherford et al. 2009). The location of the place of residence (rural or urban) was the only traditional variable of importance, in addition to other variables reflecting social networking and social capital (Rutherford et al. 2009). Similar results were obtained in another study in Ethiopia that followed a 1987 birth cohort until their 18th birthday in 2005 (Byass et al. 2008). While living beyond 5Km from a healthcare service point was significantly associated with mortality in a univariate analysis, its significance faded in a multivariate analysis (Byass et al. 2008). In northwestern Burkina Faso, demographic surveillance data of around 30,000 people was used to calculate the geographical distribution of childhood mortality (Sankoh et al. 2001). Distance to next health center failed to account for the calculated geographical distribution (Sankoh et al. 2001). Also, a study in Kenya has shown that the importance of distance in explaining childhood mortality fades with the increase in density of health facilities (this argument could be used as well to validate the importance of distance) (Moisi et al. 2010). Outside of Sub-Saharan Africa, in Pakistan, a study exploring the use of public health services by 691 children less than 5 years old suffering from diarrhea, upper respiratory infections and fever has shown that distance is not a determinant of use of government services (Noorali, Luby & Rahbar 1999). Although many studies mentioned above measured mortality instead of other measures such as attendance rates, it is implicitly assumed that the mortality is happening due to the lack of use of

health services, which is in turn related to lack of access. It should be clarified though that actual use also depends on the perception of individuals regarding the need to treat and/or take preventive measures for a particular disease. Therefore, accessibility is not the only determinant of use (Mburu, Smith & Sharp 1978).

The survey of the literature above shows that the relationship between distance, health use and health outcome is contextual. A main reason for the incongruence of results other than context might be that direct Euclidean distance between the household and the point of service delivery not only does not represent the real distance traveled, but also does not represent travel time (Rutherford et al. 2010). A main issue with the use of Euclidean distance is its disregard of natural obstacles (rivers, lakes, forests etc...), land cover that impose walking speed differentials, road networks that enable the use of bicycles and public transportation and the elevation of the terrain which can considerably impede walking speed (Munoz & Kallestal 2012; Muller et al. 1998). Therefore, Euclidean distance is safer to use in very specific cases where the terrain is flat, walking is the only option and distances are relatively small (less than 5Km) with a high concentration of footpaths that allow for a more or less direct travel from the household to the health facility (Muller et al. 1998; Taiar et al. 2010). Travel time to the health center has been recommended as a more realistic and better indicator of costs associated with reaching a health facility (Rosero-Bixby 2004). In fact, WHO does recommend the use of travel time as a measure of accessibility coverage over distance because of the same geographical and infrastructural reasons mentioned above (WHO 2001). Travel time to the health center might conflict with other household chores that are hard to postpone (Muller et al. 1998; Rutherford et al. 2010). Thus it carries with it both a distance cost (long travel time and cost of travel) and an opportunity cost (caregiver becomes unproductive while seeking healthcare)

(Ensor & Cooper 2004). The different values people ascribe to the opportunity cost of time puts limits to its use as a standardized comparative indicator (WHO 2001).

Thaddeus & Maine (1994) developed a conceptual framework identifying three types of delay in seeking healthcare. The first delay is in *deciding* to seek healthcare, the second delay lies in the time of travel to the healthcare facility and the third type of delay is in the time spent waiting to receive care at the facility (Thaddeus & Maine 1994). Although their study focused on obstetric complications on which time delays have much more serious consequences, the framework is still relevant to most cases of diseases and health complications.

Very few studies in Sub-Saharan Africa have assessed travel time and healthcare access and utilization (Rutherford et al. 2010). A study in Kenya modeling access and use to health services in four districts compared two models of access using ArcGis. One model calculated travel time based on Euclidean distance and the other on a transport network also accounting for constraints such as topography and land cover showed that the transport network model predicted travel time better than the Euclidean model (Noor et al. 2006). On the other hand, the Euclidean model overestimated the proportion of people within 1h of walking time from a health facility (Noor et al. 2006). Outside of Sub-Saharan Africa, in the Philippines, the likelihood of using a health facility for prenatal care by women was reduced as travel time to the facility increased (Wong et al. 1987). In Ghana and Yemen, physical distance had a stronger association with utilization than travel time, although the latter did correlate well with distance (Al-Taiar 2010; Buor 2003). With this scarcity of analytical studies about travel time and health care access, there is definitely a need for more studies assessing the relationship between traveling time (which can include

waiting time in health centers) to health centers and health service utilization as well as health outcomes.

1.4 Mother's status

Two concepts influencing child mortality and morbidity are strength of social networks and caregiver autonomy and status (Rutherford 2010; Riley 2001). This is particularly relevant in the case of Rwanda where the 1994 genocide and other civil wars in the early 1990s lead to a weakening and breakdown of social networks and general mistrust between members of the same and different communities as well as the death and illness of caregivers (although violence in Rwanda was mainly committed by Hutus against Tutsis, inter-communal violence took place). Those consequences of violence have reflected negatively on child security and health (Betancourt et al. 2012). It is therefore also important to explore other factors that build on or can rebuild the original intrinsic networks weaving a society's interactions. People who are better connected within a society can seek information and acquire relevant skills through community events regarding different aspects of health and nutrition better than more isolated individuals. At the same time, higher educational and power status of the mother also leads to improved skill acquisition, resources being more efficiently spent on children's health and decreases gender differentials in health and nutritional status of the children (Rutherford 2010, Riley 2010). In Nepal and Papua New Guinea, children of households whose mothers are members of community-based organizations have significantly better nutritional status as measured through weight and height for age (Eklund et al. 2003; Imai & Eklund 2006). Closer to Rwanda, in Gambia measures of distance were not statistically significant in explaining under 5 child mortality, as opposed to indicators

of social support and caregiver autonomy and financial status (Rutherford et al. 2009). In Ethiopia, under 5 years old children whose mothers scored low on decision making ability and on social capital also had a higher mortality rate (Fantahun et al. 2007). Also in Ethiopia, a World Bank study found that enhancing a community's (mainly mothers) ability to discriminate between stunted and non-stunted children by 25% through skills acquired outside of formal schools could decrease rates of child malnutrition by as much as 43% (Alderman & Christiaensen 2001). Finally, the mother's degree of control over plot management in rural households and over income transfer expenditures intra-household have also been proven to positively affect child health (Kurosaki & Ueyama 2001). In most of Sub-Saharan Africa, agricultural production is sex-segregated and women usually are responsible for subsistence crops from production to marketing and disposal, whereas fathers are responsible for the production of cash crops also from production to marketing and disposal stages (Kurosaki & Ueyama 2001).

1.5 Objective

The study aims as a first step to measure the significance of travel time in explaining the variation in height for age z-scores in the Eastern province of Rwanda, and as a second step to determine how significant mother's involvement in agricultural production and disposal as well as her level of education are as factors of stunting. Travel time, defined as walking time to health center, and waiting time in the health center are expected to be significant determinants of stunting in Eastern Rwanda, as well as mother's educational attainment and her involvement in agriculture. The conceptual model (figure 6) of the study is based on a combination of the WHO and

UNICEF models of stunting and malnutrition, and the literature review above
(Stewart et al. 2013).

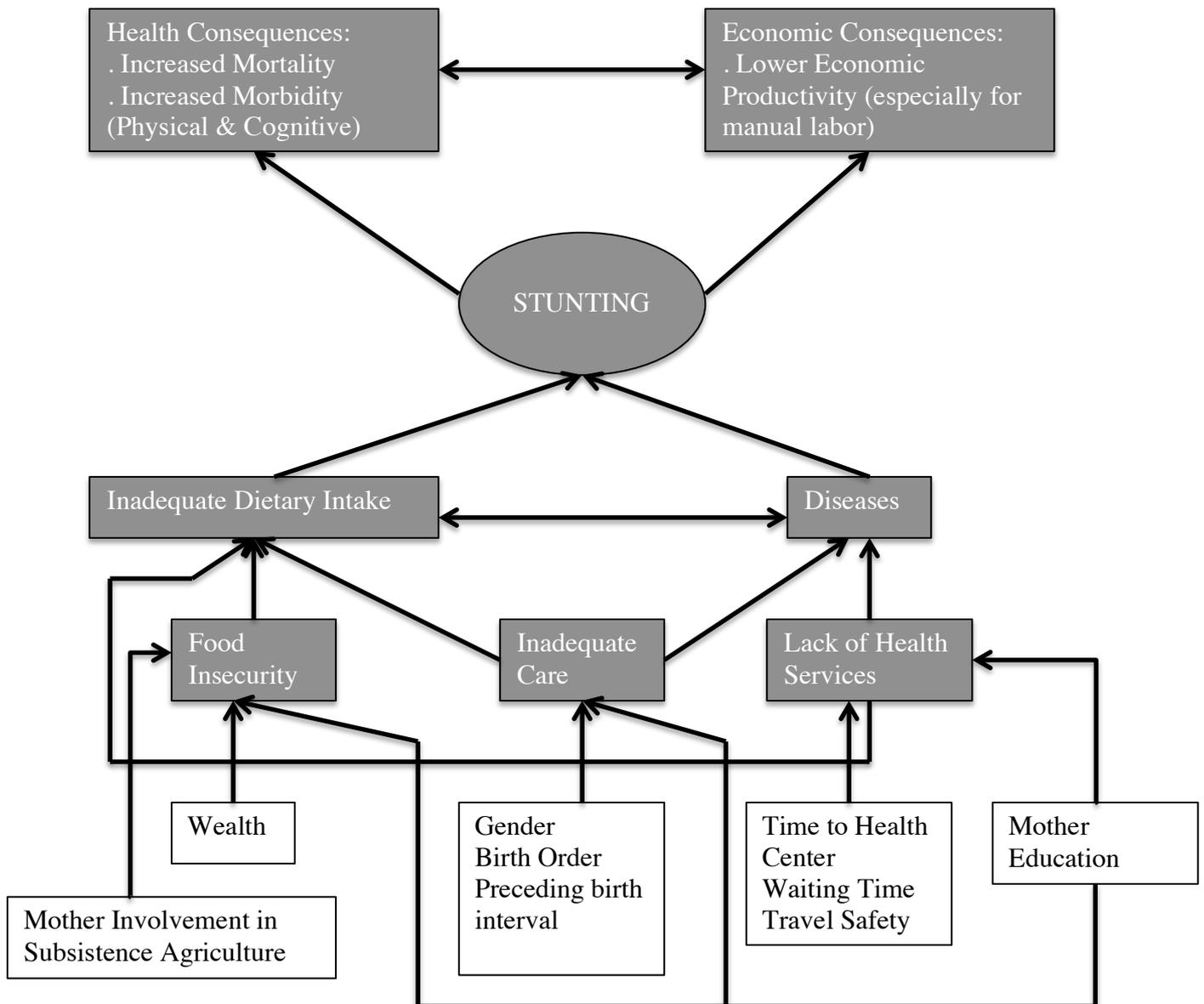


Figure 6: Conceptual Model of Study

The health and economic consequences of stunting, stunting itself, diseases and inadequate dietary intake, and food insecurity, inadequate healthcare practices and the lack of health services' place in the conceptual model have been explained in earlier sections. The following paragraph will explain the choice of the variables representing the lowest level in the conceptual model. In order to do so however, definitions of food insecurity, inadequate care and lack of health services have to be provided as relevant to the context of the study.

Food insecurity is defined as the availability and accessibility of food to households in sufficient quantities and appropriate quality (United Nations Children's Fund n.d.). Food being available in the market is not enough, as households need to have the capability of buying the necessary food. The household's wealth was chosen as a representative of the food security dimension due to its importance in enabling households to buy food as well as to access food markets. Mother's education is also perceived as a determinant of household food security, because a better educated mother is more knowledgeable and well informed about the appropriate food that is to be bought and fed to the infants and children. It therefore mainly affects the quality part of food insecurity.

Adequate care is the adequate feeding and remedying and health practices offered by the caregiver (the mother in the case of Rwanda) to the child or infant. Gender, preceding birth interval (proxy for mother status and her power of regulating her fertility) and birth order were selected in order to account for the effect of culture and society on intra-household allocation of food and potential selective preferential treatment by the caregiver towards certain children (Howard 1994). Mother education is also a representative variable of adequate care because better education of the caregiver is expected to lead to more equitable and rational care among children.

Health services in the case of the study are the medical and nutritional services offered by health centers to children and caregivers (services include educational input to the caregiver about appropriate feeding practices). Since the concern in this study is the actual use of those services, access variables such as travel time to the health center, waiting time and safety of travel were chosen as representative variables.

II. Overview of stunting and healthcare access in Rwanda

2.1 Rwanda

Rwanda is a small landlocked country in East Africa with a total area of 26,338Km² (Prunier 2010). The landscape is mountainous and hilly, which is why the country has been called “The Land of the Thousand Hills”. Rwanda’s elevation is above 1000m, with a mild and humid climate (Prunier 2010). The country experiences a long dry season from June to September, followed by an intermediary period composed of short rainy and dry seasons from October to January, and the cycle ends with a long rainy season from February to May (Vansina 2012). The average yearly temperature is 18°C and rainfall ranges from 900mm to 1600mm depending on the altitude (Prunier 2010). The unique geographical setting of the country blessed it with protection from malarial infections and attacks from foreign tribes and slave traders. Moreover, its favorable climate was a boon for farmers and pastoralists alike (Prunier 2010; Vansina 2012). A consequence is the particularly high demographic densities in Rwanda (Prunier 2010; Vansina 2012). The high population densities and small available lands lead to increased social interactions between the country’s occupants and historical competition between pastoralists and agriculturalists for land (Prunier 2010; Vansina 2012). These unique and arguably extreme circumstances laid the ground for the emergence of political regimes with high degrees of centralization, coercion and control especially over land allocation and tenure (Prunier 2010; Vansina 2012). High population densities, proximity and land scarcity combined with other political and economic factors were also main factors driving and escalating the social strife and the civil hostilities that culminated in the notorious 1994 genocide during which between 600,000 and 800,000 people were killed (Andre & Platteau 1998; Prunier 2012; Verpoorten 2012).

The population of Rwanda stood at 11.46 million in 2012 with a GDP of 7.103 billion US dollars in the same year (World Bank 2013). The three ethnic groups constituting the population are Hutu, Tutsi and Twa. The government of Rwanda has annulled any reference to ethnicity in official and public documentations. Life expectancy at birth stood at 55 and the poverty headcount compared at the national poverty line at 44.9% in 2011 (World Bank 2013).

2.2 Stunting in Rwanda

In Rwanda, the prevalence of stunting stood at 44% of all children aged less than 5 years in 2010 (NISR et al. 2012). It can therefore be inferred that around half of Rwandan children less than 5 years of age are at risk of suffering from the consequences of stunting mentioned earlier. During the past decade, the prevalence of stunting had actually increased in Rwanda, despite the attested improvement in the general health status of the population. This increase was possibly caused by the reduction in the mortality of under 5 years old children (U5MR), who, although are surviving now, grow to be stunted (MINECOFIN 2007).

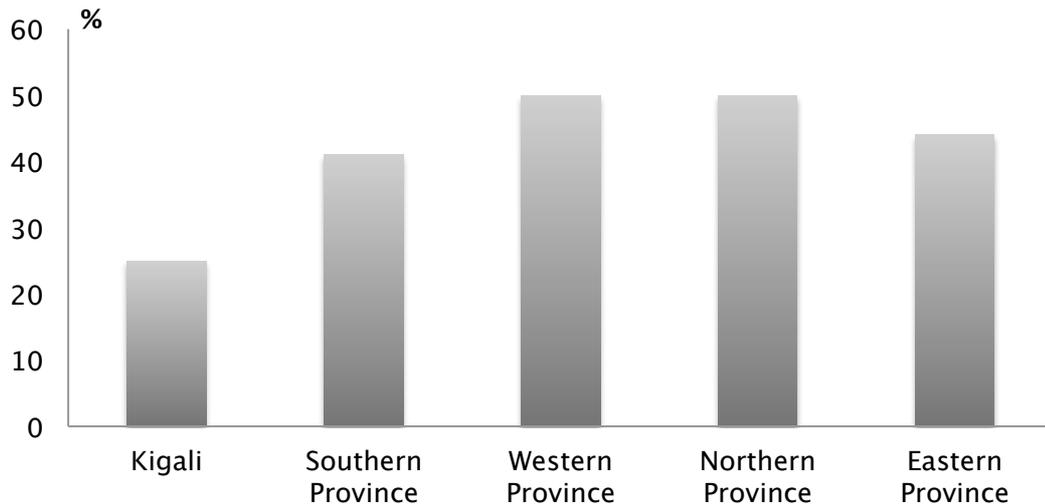


Figure 7: Prevalence of stunting for less than 5 years old children
Source: Demographic and Health Survey 2010

An estimation of the prevalence of stunting for children younger than 5 years old in the provinces based on demographic health survey (DHS) data in 2010 is shown in figure 7.

The Northern and Western Provinces have the highest prevalence (50%), followed by the Eastern Province (43%), the Southern Province (41%) and Kigali (24%). Kigali's lower prevalence (albeit still high in absolute terms) compared to other provinces comes as no surprise since stunting is more prevalent in rural than in urban areas (MINECOFIN 2007). Boys tend to be more stunted than girls (WFP 2012). Stunted children are mostly in rural households located far away from health facilities (WFP 2012). Particularly, child-feeding practices between 12 and 23 months are strong predictors of later stunting in life (WFP 2012).

Stunting is one of the major health challenges on which the government of Rwanda is failing to achieve significant progress (MINECOFIN 2007; MoH 2009). Figure 8 shows the leading drivers of mortality amongst younger than 5 years old children. Malnutrition was still responsible for 9.9% of deaths in 2008, and, knowing its

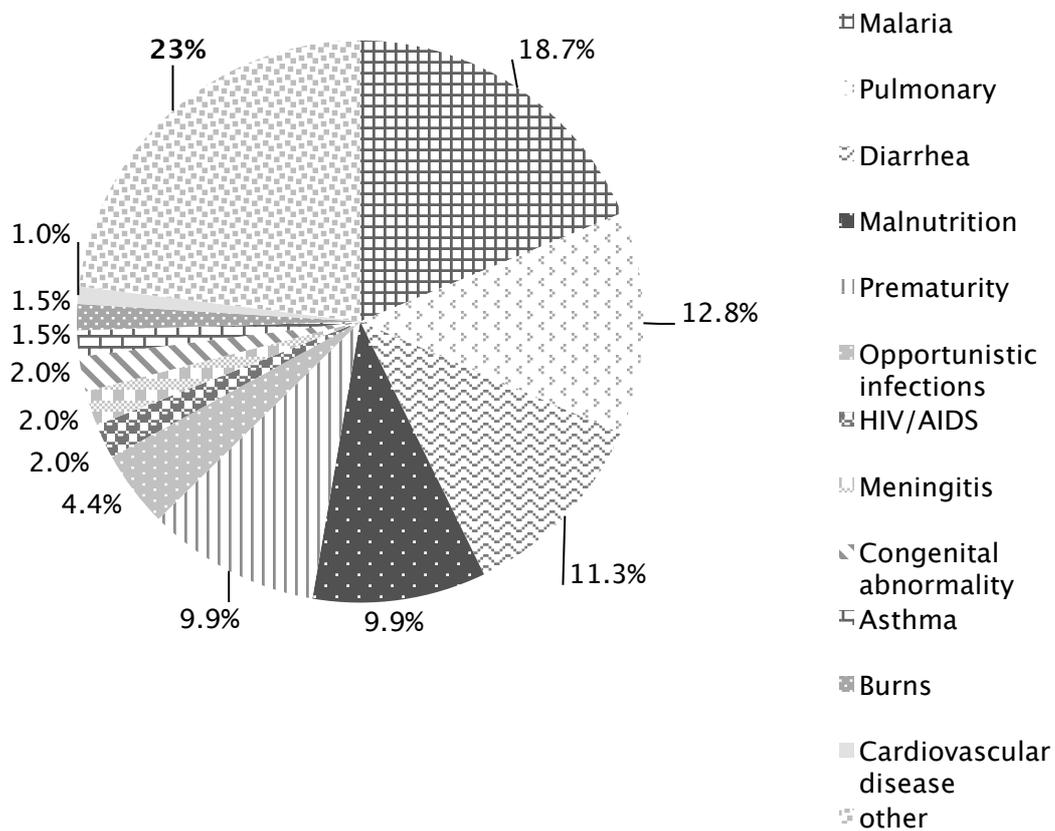


Figure 8: Leading causes of hospital mortality in under fives in 2008

Source: MoH 2009

intricate relationship with infectious diseases, it can be also asserted that it does play a role in making other leading causes of death such as pulmonary infections and diarrhea more lethal (Riley 2001).

2.3 Health sector in Rwanda

The MoH heads the health sector, although other ministries also intervene in health policies. Both private and public actors and NGOs operate health facilities in Rwanda. These facilities and actors in the health system permeate the different levels of administrative zones in Rwanda (Rwanda is divided top down into provinces, districts, sectors and cells). In 2011, the country possessed 4 National Referral Hospitals, at the apex of the health system. At the district level, the country had 40 district hospitals. At both district and sectorial levels, there are health centers, and dispensaries and health posts at the cell level (in addition to those facilities, there are special Police/Military Hospitals too) (MoH 2012). The numbers stated before exclude private health facilities. Government policy requires the presence of at least one district hospital in each district, at least one health center per sector and one health post as a minimum for each cell. Finally, within sectors, networks of community health workers must be active (MoH 2009). In a private correspondence with World Vision Rwanda (WVR), personnel affiliated to the NGO stated that the government mandates the presence of community health workers. They are elected by local bodies such as village councils and are unremunerated volunteers.

The decentralization policy followed by the Government of Rwanda places the base for health care services at the district level. The public health sector in Rwanda operates through three levels. The central level is located in the capital and is mainly concerned with policies. The second level consists of the 30 administrative districts of the government of Rwanda whose district offices include the Health, Family Promotion, and Protection of Children's Rights Unit. The district hospitals mentioned before are located at this second level. The third level consists of the health centers, health posts and dispensaries corresponding to the sector and cell administrative units.

Each level of the health sector provides a set of services called package of health services that differ depending on the level. At the peripheral levels (health center, dispensary and health post), services related to nutrition include growth monitoring, nutritional activities and nutritional rehabilitation (dispensaries and health posts have a more restricted set of activities than health centers but still provide growth monitoring). The district and national referral hospitals provide more comprehensive services than the peripheral health facilities, while sometimes also delivering the full minimum package of activities of the peripheries (note that not all hospitals provide services such as immunization for children etc...) (MINECOFIN et al 2008). Despite the presence of dispensaries and health posts in addition to health centers at the tertiary level, the latter are still considered the main locus of the peripheral level, as well as the first step in the system of referrals to hospitals located higher in the ladder (MINECOFIN et al 2008). The health centers are expected to provide the minimum package of activities at a minimum frequency, with 24-hour delivery services and with at least one qualified staff. The Eastern Province is the worst in Rwanda, with only 31% of public, private and government assisted health centers satisfying this requirement (MINECOFIN et al. 2008). It is also quite surprising that growth monitoring is the service that is least offered at the health center level, and is not well performed even if offered, given Rwanda's high stunting prevalence. Only 41% and 72% of health centers and polyclinics have infant and child weighing scales respectively (MINECOFIN et al. 2008). Compounding this issue is the virtual absence of in-service training (including nutrition and micro-nutrient deficiencies) provided to child health providers throughout the country (though supportive supervision is near universal) (MINECOFIN et al. 2008). In the Eastern Province, only 8 professional nutritionists operated in 2010. The number is comparable to the Northern Province (7)

and Kigali (5) but much less than the Western and Eastern Provinces (33 and 27 respectively) (AHWO 2009).

The EDPRS document promulgated in 2007 set as objective:

to maximize preventative health measures and build the capacity to have high quality and accessible health care services for the entire population in order to reduce malnutrition, infant and child mortality, and fertility, as well as control communicable diseases.

(MINECOFIN 2007:x).

A special emphasis to achieve these goals is placed on increasing geographical accessibility and building human resource capacity to ensure decent healthcare accessibility to the population (MINECOFIN 2007). The latter are specific goals of the core 2004 Health Policy by the government of Rwanda (MoH 2009). The MoH's norm is that health centers should be within 1h walking distance of potential users, though it is estimated that around 40% are still outside this time boundary (MoH 2009). This proportion of underserved potential users might be an underestimate (Munoz & Kallestal 2012).

III. Methodology

3.1 Study area

Rwanda's Eastern province (figure 9) has a smoother topography than the rest of the country. The lands are lower and have a gentler slope (Prunier 2012). It contains large marshes (Prunier 2012). The Eastern Province is drier than the rest of the country due to the monsoon wind's direction flowing from the Southeast to the Northwest, which consequently experiences more rain (Vansina 2012). Rain deficits occur in cycles of 4 to 5 years (WFP 2012). Risks of famine have always been present historically in Rwanda and famines did occur, hitting farmers more than pastoralists (Vansina 2012). Due to the wind and rain regime, the Eastern region is thus at a higher risk of droughts and famines (Vansina 2012). Currently, its population stands at 2,264,904 people according to data obtained from the Center for Geographic Information Systems and Remote Sensing of the National University of Rwanda. The prevalence of stunting in the Eastern Province of Rwanda stood at 43% in 2010. Although around the national average, the Eastern Province is expected to be at higher risks of food insecurity in the future due to its historical proneness for droughts and famines and the exacerbations of drought frequency due to climate change. It also suffers from the highest levels of anemia in the country. Last but not least, the Eastern province witnessed one of the highest levels of violence during the genocide (Verpoorten M 2012).

Two sectors in the Eastern province were the subject of special focus: the sectors of Rukara and Mwiri (figure 10). Rukara has been the target of a child nutrition project area development program by World Vision because of its high malnutrition and poverty rates, lack of sanitation, as well the heavy reliance of its population on

agriculture with limited alternative sources of income (World Vision 2013). Rukara is located in a hilly area, between 1400 and 1600 meters of altitude (World Vision 2013). The weather is hot and humid (between 18 and 26 degrees Celsius), with average annual rainfall between 1000mm and 1200mm (World Vision 2013). The area of Rukara sector is 64Km² approximately. As of 2013, there are 6335 households and 28422 people living in Rukara according to the data provided by the GIS center in the National University of Rwanda. Around 90% of the population was dependent on subsistence agriculture in 2009 (World Vision 2009). Banana is the major crop in the sector. Bananas, beans, groundnuts, sorghum, cassavas, potatoes and maize are the staple foods in the region (World Vision 2009). The sector suffers from considerable food shortages during the dry season and prices of food rise significantly (World Vision 2009). The control sector is Mwiri, also highlighted in figure 10. Unfortunately, detailed information about Mwiri is not available. It is also located in Kayonza district and is much larger than Rukara, with an area of 540Km², although a big chunk of the surface is occupied by Akagera National Park. Mwiri's population stood at 19090 and the number of households at 4162 in 2013, which is lower than in Rukara. The sector is located at a lower altitude than Rukara and is less sloppy.

Figure 9 is a sketch of the study area showing the districts, water bodies, health centers and a national park. Akagera National Park is shown on purpose to underline the fact that it will be excluded from the simulation area (details later). Figure 10 shows a similar map to the one depicted in figure 9, with the exception that it displays sectors, with Rukara and Mwiri being highlighted.

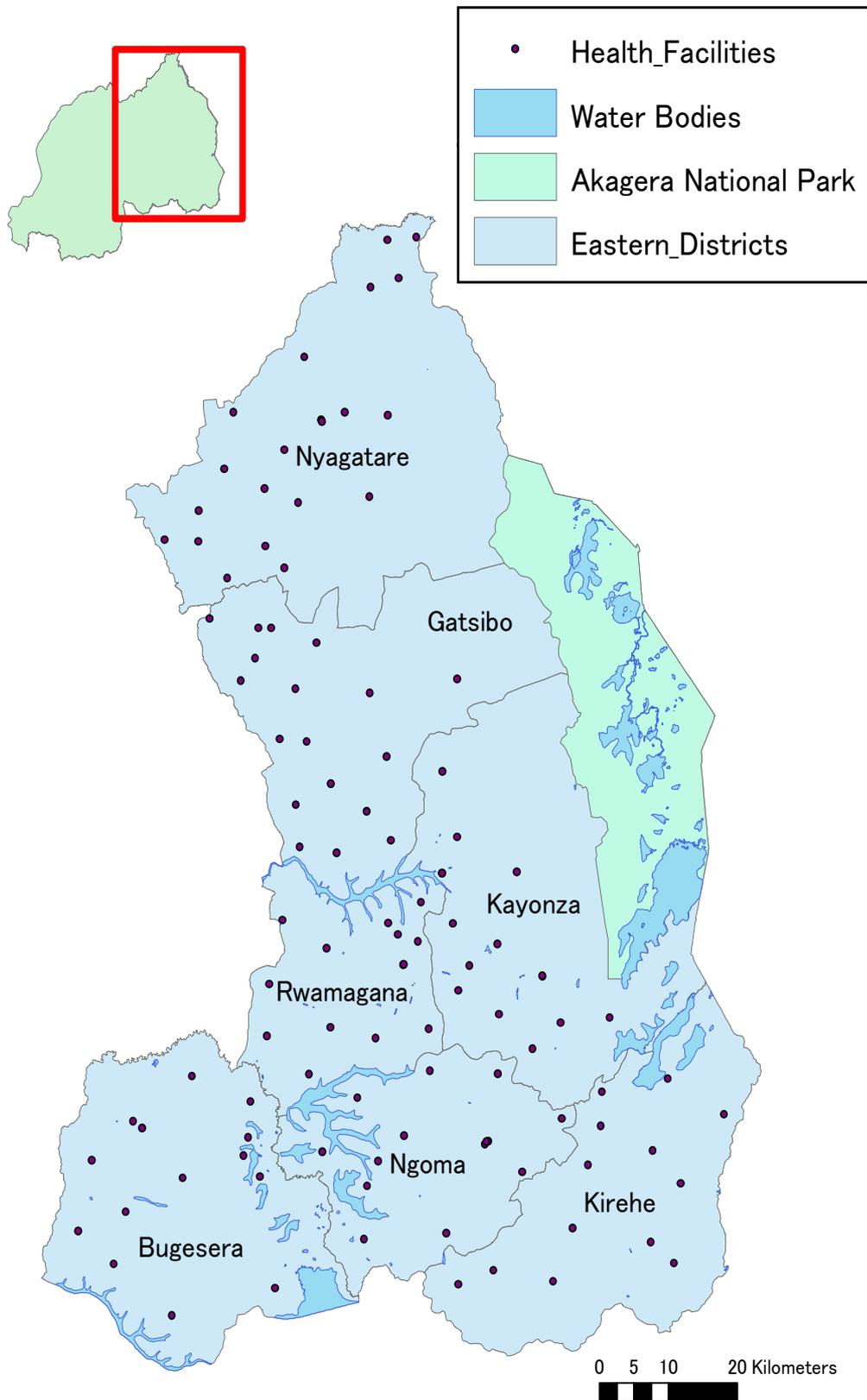


Figure 9: Eastern Province Rwanda

Source: GIS Data from The Geographic Information Systems and Remote Sensing Research and Training Center National University of Rwanda 2013

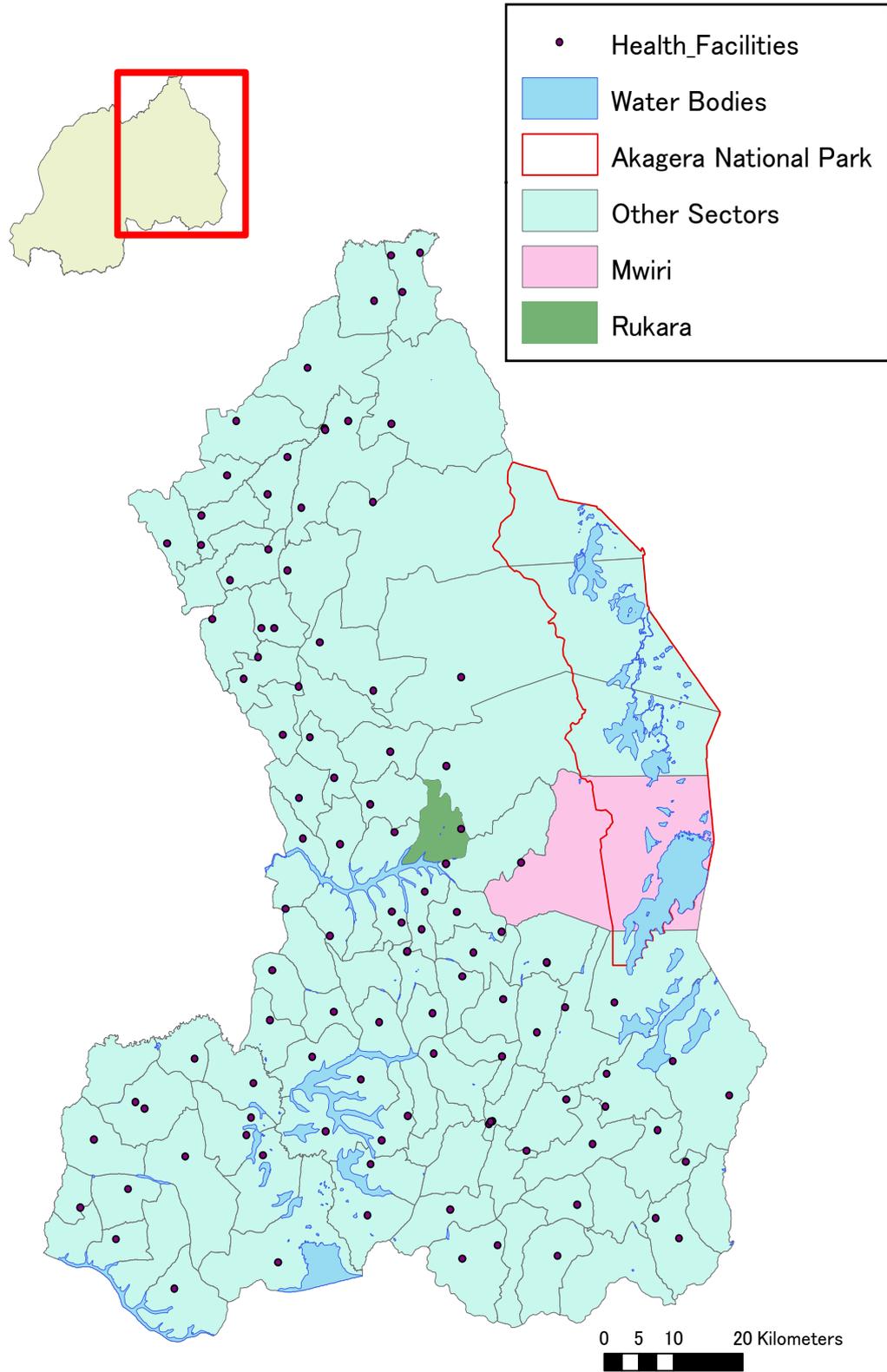


Figure 10: Eastern Province with Mwiri and Rukara highlighted
 Source: GIS Data from The Geographic Information Systems and Remote Sensing Research and Training Center National University of Rwanda 2013

3.2 Subjects and fieldwork

The study is composed of two main parts. The first section is based on Demographic Health Survey (DHS) data of Rwanda collected in 2010 (www.measuredhs.com). Since the DHS database does not include any variable or indication about travel time to health centers, travel time was simulated using the Geographical Information System (GIS) software ArcGis. The study focused on a sample of 974 younger than 5 years old children whose anthropometric data was available.

The second part of the study was based on a field survey conducted in Rwanda targeting 600 households divided equally between Rukara and Mwiri. The administered questionnaire collected a variety of information about health behavior, food security, socio-economical behavior and anthropometric measurements of family members in March 2013. After cleaning the data, a sample of 260 children was kept for statistical analyses. The survey was complemented by data from a nutrition survey by a team from Ochanomizu University targeting 32 households in Rukara and Mwiri (22 and 10 respectively) that was completed in two stages during the months of March and September 2013. 22 out of the 32 surveyed households were common between the large and small surveys.

3.3 Travel time to health center simulation

An add-on to ArcGIS called AccessMod, a software tool developed for WHO to simulate travel time and coverage of health centers based on land cover, infrastructural, digital elevation models (DEM) and population density data (WHO 2013) was used for the simulation. GIS and demographic data were requested from the Rwanda Natural Resources Authority and the Center for Geographic Information Systems and Remote Sensing (CGIS) at the National University of Rwanda (NUR).

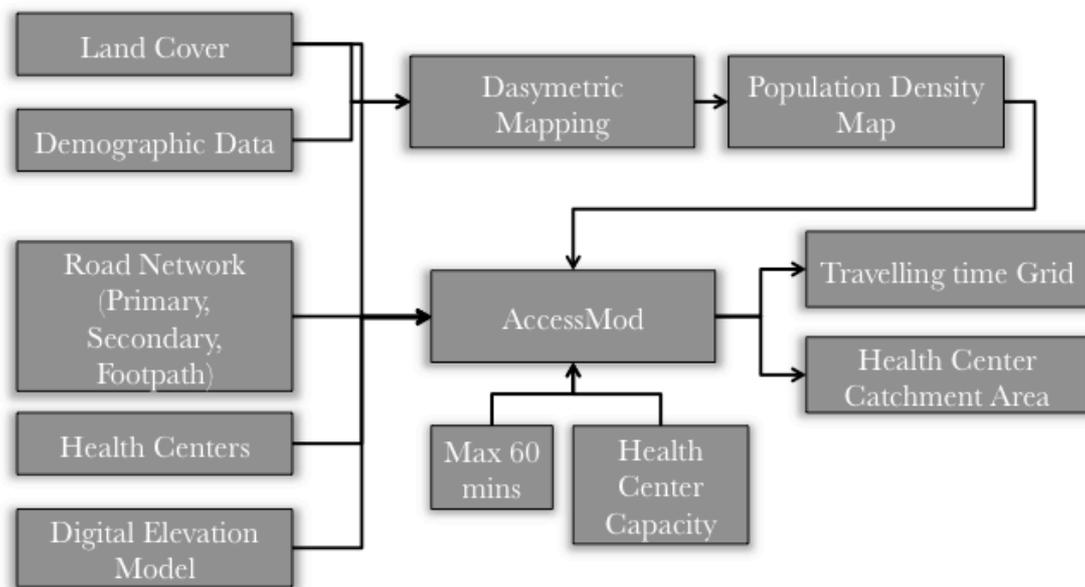


Figure 11: Simulation Model

The GIS data comprised information about the social and physical infrastructure of Rwanda, administrative boundaries of the Eastern province and a land cover map of the Eastern province. The DEM data was extracted from the Shuttle Radar Topography Mission (SRTM) database. The model shown in figure 11 captures the logical flow behind the ArcGis simulation.

AccessMod takes a road network raster, health centers distribution point shapefile, a digital elevation model grid and the population density map raster as inputs. The demographic data was not spatial but contained the total population number of each cell in the Eastern province. Calculating population density per cell by dividing the total population number by the area of the administrative cell will not deliver realistic results since such a kind of uniform and homogeneous spatial mapping does not take into account the differences in population density imposed by different land covers. The case of water bodies is a basic and obvious example of the shortcomings of such a kind of spatial mapping. Since people in Rwanda do not live in towns situated on

water bodies, the population will tend to be concentrated exclusively on land. However, even on land, differing land cover types such as forests or agricultural lands are usually populated by different concentrations of people. Emulating the study conducted in the Western province of Rwanda (Munoz & Kallestal 2012), a dasymetric mapping method was opted for (Mennis 2003; Sleeter 2004). Since AccessMod requires a rasterized population density map, the dasymetric method distributes the population of each administrative cell to grid cells of 90m resolution based on the difference in population densities per land cover type and the percentage area occupied by the land cover within each administrative cell (Mennis 2003; Munoz & Kallestal 2012). The resolution was set to 90m in order to match the SRTM DEM resolution. The population density per land cover type is calculated by sampling all administrative cells that are fully contained within a certain land cover type (Mennis 2003). The population density for those cells was calculated based on the population value and area, and the different density values per land cover type were averaged to obtain a single but representative population density value per land cover type (Mennis 2003). Then, a population density fraction was assigned to each land cover type to determine the number of people to be allocated to that same land cover type within each administrative cell (Mennis 2003). However, since the land cover type area in each administrative cell varies, the population density fraction was adjusted by an area factor equivalent to the ratio of the percentage area that a particular land cover type occupies within an administrative cell to the percentage area occupied by that land cover type if the administrative cell's area was evenly spatially partitioned by the different types of land cover constituting it (Mennis 2003). In addition to this, an exclusion area was defined for water bodies and roads since they are not expected to have people living on them (Munoz & Kallestal 2012; Sleeter 2004). It is important to

note that the land cover types obtained by the GIS center of NUR were reclassified according to the GLC2000 global classes (Bartholome & Belward 2007), the reason behind the reclassification being that travel speeds have been calculated and assigned to each global class of land cover by the European Commission Joint Research Center (European Commission Joint Research Center 2010; Munoz & Kallestal 2012).

All layers were rasterized and set to the same resolution as the DEM (90m), except the health center layer, which is a point shapefile. As mentioned earlier, the government of Rwanda intends to cover households in rural areas especially within a 60 minutes walking time area around the health center. The 60 minutes limit has been set as a boundary for the generation of the coverage area using AccessMod. However, a health center's operation is also limited by its population catchment maximum capacity. Therefore, the maximum capacity of a health center has also been set as a boundary to delimit a coverage area. The actual limit will be the intersection between the 60 minutes coverage and the catchment capacity. If the number of people within the 60 minutes boundary is less than the capacity of a health center, then the coverage area is equivalent to the 60 minutes travel time layer around the health center. If the capacity based on the population density data is reached prior to the 60 minutes boundary, then the spatial distribution of this population density will be equivalent to the coverage area of the health center.

The inputs having been prepared, the travelling time distribution grid can now be calculated. This grid calculates how long it takes for all the population within the eastern province to reach the health center by foot. Travel by foot was chosen as a travel scenario because it reflects the reality of travel of rural dwellers in Eastern Rwanda best. Table 1 shows the travelling speeds per land cover type extracted from

Table 1: Travel speed per land cover class

Land Cover Class	Travel speed (Km/h)
Cropland/other natural vegetation	1.67
Shrub cover	1.67
Regularly flooded shrub	1.00
Cultivated and managed areas	1.67
Sparse	2.50
Tree cover broadleaved deciduous open	1.25
Tree cover broadleaved deciduous close	1.00
Urban and associated areas	5.00
Tree cover broadleaved evergreen	1.00
Herbaceous cover	1.67
Rural feeder road	5.00
National road	5.00
District road	5.00

Source: European Commission Joint Research Center 2010

the European Commission Joint Research Center (European Commission Joint Research Center 2010).

AccessMod contains four modules that perform different sets of operations related to travel simulation and health center coverage calculations. Module 2 calculates the traveling time distribution grid. Prior to that however, Module 1 has to be run in order to combine the land cover and roads layers. This combined layer is input into Module 2 along with the health facilities layer, the traveling scenario file (equivalent to Table 1 along with the specification that people only walk on the different land cover types) and the digital elevation model from SRTM in order to perform an anisotropic cost analysis that corrects for travel speed depending on the slope of the terrain and the direction of travel.

After the distribution grid has been generated, the GPS location of household clusters (20-25 households) in DHS can be superimposed on the traveling time distribution and travel times from the cluster to the health center can be easily extracted with GIS.

However, due to confidentiality imperatives, cluster GPS coordinates in rural areas are displaced between 0 and 5Km for 99% of the clusters in the sample with the remaining 1% displaced between 0 and 10Km (Perez-Heydrich 2013). This obviously creates errors in the subsequent analysis and simulations. In areas with low densities of health facilities, such as rural areas, the mean square errors (MSE) and subsequent bias in the distance to the health facilities between the real and shifted locations of clusters decreases (Perez-Heydrich 2013). Since travel time is proportional to distance, the same will be true for the error in measuring travel time to the health centers. However, in order to ensure an even lower error, an attempt was made to shift back the location of the cluster to an area where there is a high likelihood that its original GPS position actually existed. By extracting the DHS data of the altitude of clusters and using the DEM, points of similar altitude to the GPS cluster location within a circle area of 0 to 5Km for 99% of the points and 0 and 10Km for the remaining 1% were visually located using GIS. Then, their centroid was located and the cluster position was shifted to that location, since it is the location that reflects where similar altitude points are highly clustered. The traveling time values were subsequently extracted for each newly shifted GPS cluster location. The next and final step in the GIS analysis was to determine whether the shifted cluster location is located within the coverage area of the health facility or not. Module 3 of AccessMod was run, and based on the additional data for the capacity of health centers and the limiting condition of 60min travel time to health centers the simulation tool determined the coverage area of each facility.

3.4 Anthropometry

Measurements of children and infant's height were performed following the standard methods (Cogill 2003). For children (generally between 2 and 5 years of age) an Eiken caliper was used. For children younger than 2 years old and infants a SECA 231/232 measuring rod was used. Height for age is the indicator used to measure stunting prevalence on the community level and to also diagnose an individual case of malnourishment (Young & Jaspars 2009). The WHO issued in 2006 new growth standards for children from birth to 60 months of age (de Onis et al. 2006). The standards were developed based on data collected from the Multicenter Growth Reference Study, also conducted by WHO. The study followed the growth of 8500 children from Oman, Norway, Brazil, Ghana, India and the United States between birth and 24 months of age under what were considered optimum infant care and feeding practices (Duggan 2010). An additional feature of the study was a set of cross-sectional measurements of children aged between 18 and 71 months from four of the six countries (de Onis et al. 2006; Duggan 2010). These standards are considered to be norms of growth that children growing under the right childcare practices will achieve, as opposed to the earlier NCHS references that served the purpose of comparison benchmarks (Duggan 2010). According to those standards, a child is stunted when his/her height for age's z-score falls below two standard deviations from the reference median (WHO 2006). A z-score between 2 and 3 standard deviations below the reference median reflects moderate malnourishment. A z-score falling below 3 standard deviations reflects a case of severe stunting (Young & Jaspars 2009). The decision to set the cut-offs curves at -2 standard deviations is based on statistics. The z-scores were calculated using Anthro for personal computer,

a software developed by WHO to assess the growth of children and infants (WHO 2011).

3.5 Statistical analyses

Height-for-age z-scores were used in different regression analyses to determine the significant determinants of height for age z-score variations for DHS and field data. The difference in the mean of z-scores between Rukara and Mwiri for the large questionnaire field data survey was compared using a *t* test. Regarding the nutrition survey field data by Ochanomizu University, significant differences in median daily intakes of different food types were assessed using Mann-Whitney's U-test for non-normal distributions. All statistical analyses and tests were performed using Stata statistical software (Version 12.1; StataCorp LP, Texas)

3.6 Ethics

Regarding the field survey, the protocol of the study was explained to the local authorities. Moreover official approval was obtained by participants in the survey as well as by the Ethics Committee of the University of Tokyo and the National Ethics Committee of the Republic of Rwanda (RNEC) (no. 579/RNEC/ 2013).

IV. Results

4.1 Basic characteristics

A general summary of relevant variables calculated with GIS and taken from DHS is presented in table 2 below. The table shows the mean, variance, maximum and minimum value of each variable both at the province and district levels.

Table 2: Summary of basic variable statistics

		Mean	Variance	Max	Min
Bugesera (n=149)	Birth Order	3.50	4.84	10	1
	Time to fetch water (min)	32	534	120	0
	Coverage	0.38	0.25	1	0
	Time to Health Center (min)	51	1072	136	16
	Mother Education	0.88	0.25	2	0
	Wealth Index	-0.19	0.25	-0.79	2.77
	Distance to Road (Km)	3.10	4.6	0.13	6.90
	Preceding birth interval (months)	26	400	140	0
	Age (months)	31	289	58	0
	HAZ (z-score)	-1.60	2	3.14	-5.05
Gatsibo (n=142)	Birth Order	4	5.50	10	1
	Time to fetch water (min)	57	1408	180	0
	Coverage	0.44	0.26	1	0
	Time to Health Center (min)	53	464	89	17
	Mother Education	0.86	0.26	2	0
	Wealth Index	-0.23	0.19	1.90	-0.84
	Distance to Road (Km)	3	2.40	5.50	0.12
	Preceding birth interval (months)	31	529	124	0
	Age (months)	30	324	59	1
	HAZ (z-score)	-2	2.46	3.56	-5.53
Kayonza (n=125)	Birth Order	4	6.80	11	1
	Time to fetch water (min)	62	1713	180	0
	Coverage	0.38	0.25	1	0
	Time to Health Center (min)	56	1327	127	19
	Mother Education	-0.88	0.29	2	0
	Wealth Index	-0.10	0.45	-0.81	3.10
	Distance to Road (Km)	2.20	5.30	6.65	0.18
	Preceding birth interval (months)	31	784	168	0
	Age (months)	30	289	59	1
	HAZ (z-score)	-1.74	2.8	5.47	-5.37
Kirehe (n=128)	Birth Order	3.50	5.76	10	1
	Time to fetch water (min)	47	1923	300	0
	Coverage	0.31	0.23	1	0
	Time to Health Center (min)	68	724	126	28

		Mean	Variance	Max	Min
	Mother Education	0.89	0.20	2	0
	Wealth Index	-0.29	0.12	-0.84	1.40
	Distance to Road (Km)	3.80	9.40	11	0.25
	Preceding birth interval (months)	28	576	122	0
	Age (months)	30	256	59	1
	HAZ (z-score)	-2.06	1.56	2.06	-5.17
Ngoma (n=138)	Birth Order	3.40	5.76	11	1
	Time to fetch water (min)	44	1054	180	5
	Coverage	0.12	0.12	1	0
	Time to Health Center (min)	83	1165	126	6
	Mother Education	0.88	0.21	2	0
	Wealth Index	-0.20	0.15	-0.69	1.40
	Distance to Road (Km)	2.20	2.50	5	0.25
	Preceding birth interval (months)	27	576	124	0
	Age (months)	28	256	59	0
	HAZ (z-score)	-2.03	1.72	1.27	-5.59
Nyagatare (n=160)	Birth Order	4.02	7.29	13	1
	Time to fetch water (min)	42	1523	200	0
	Coverage	0.25	0.20	1	0
	Time to Health Center (min)	66	964	118	19
	Mother Education	0.81	0.26	2	0
	Wealth Index	-0.13	0.19	-0.83	1.70
	Distance to Road (Km)	2.40	2.50	5.27	0.23
	Preceding birth interval (months)	28	400	100	0
	Age (months)	31	256	59	3
	HAZ (z-score)	-1.80	1.56	1.65	-4.99
Rwamagana (n=132)	Birth Order	3	4	10	1
	Time to fetch water (min)	33	849	120	0
	Coverage	0.62	0.25	1	0
	Time to Health Center (min)	47	456	88	10
	Mother Education	0.97	0.32	2	0
	Wealth Index	0.22	0.75	-0.83	3.20
	Distance to Road (Km)	2	3.70	7	0.20
	Preceding birth interval (months)	30	1089	177	0
	Age (months)	29	324	59	0

		Mean	Variance	Max	Min
	HAZ (z-score)	-1.08	2.25	2.68	-4.95
Eastern Province (n=974)	Birth Order	3.60	5.76	13	1
	Time to fetch water (min)	45	1375	300	0
	Coverage	0.36	0.23	1	0
	Time to Health Center (min)	61	970	136	6
	Mother Education	0.88	0.25	2	0
	Wealth Index	-0.14	0.31	-0.85	3.20
	Distance to Road (Km)	2.70	4.50	0	11
	Preceding birth interval (months)	29	625	177	0
	Age (months)	30	289	59	0
	HAZ (z-score)	-1.76	2	-5.59	5.47

Source: Demographic Health Survey 2010

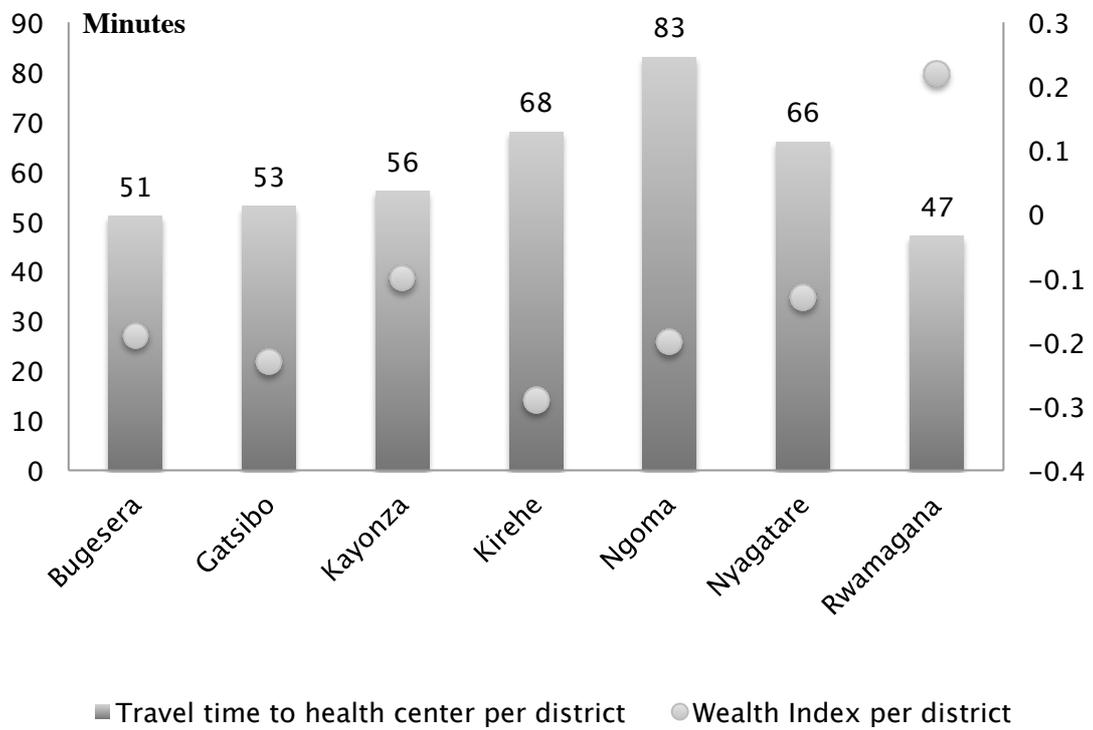
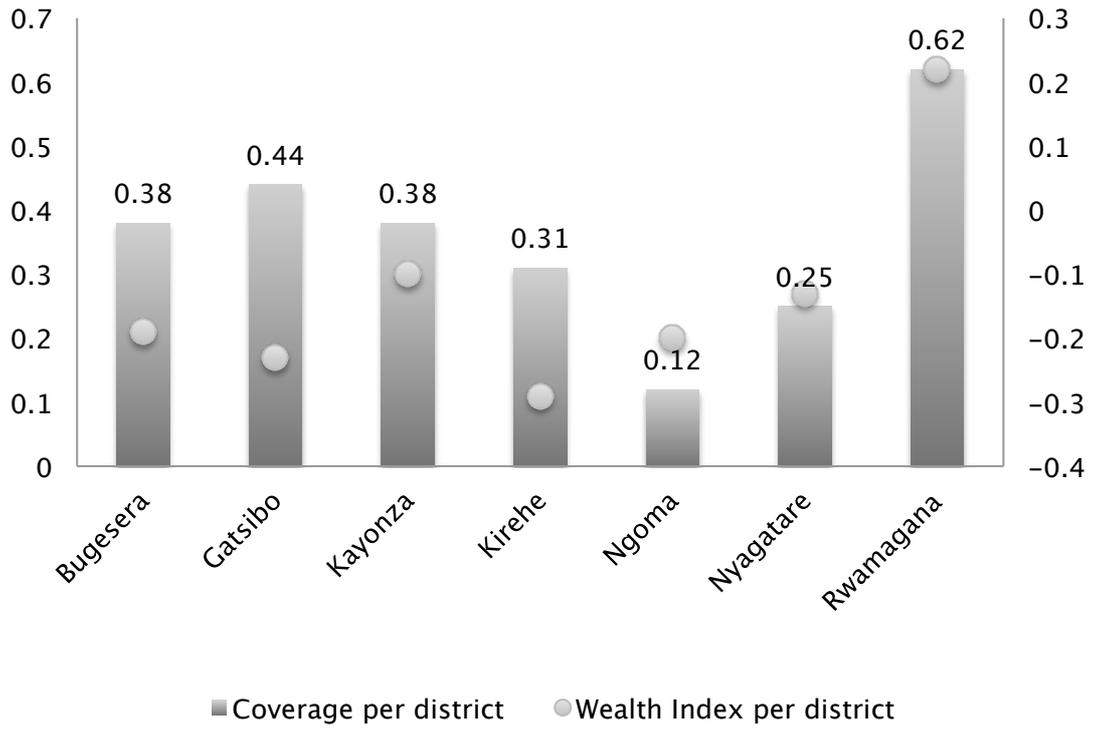
HAZ is the WHO z-score and the dependent variable. The detailed explanation of the z-score has already been provided earlier.

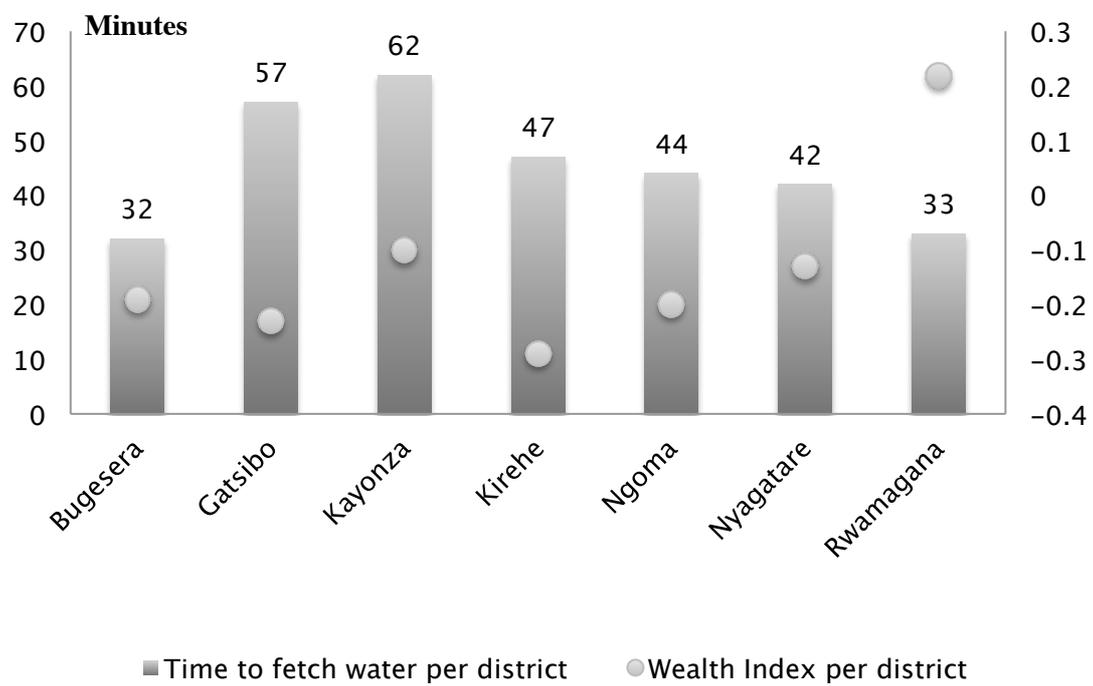
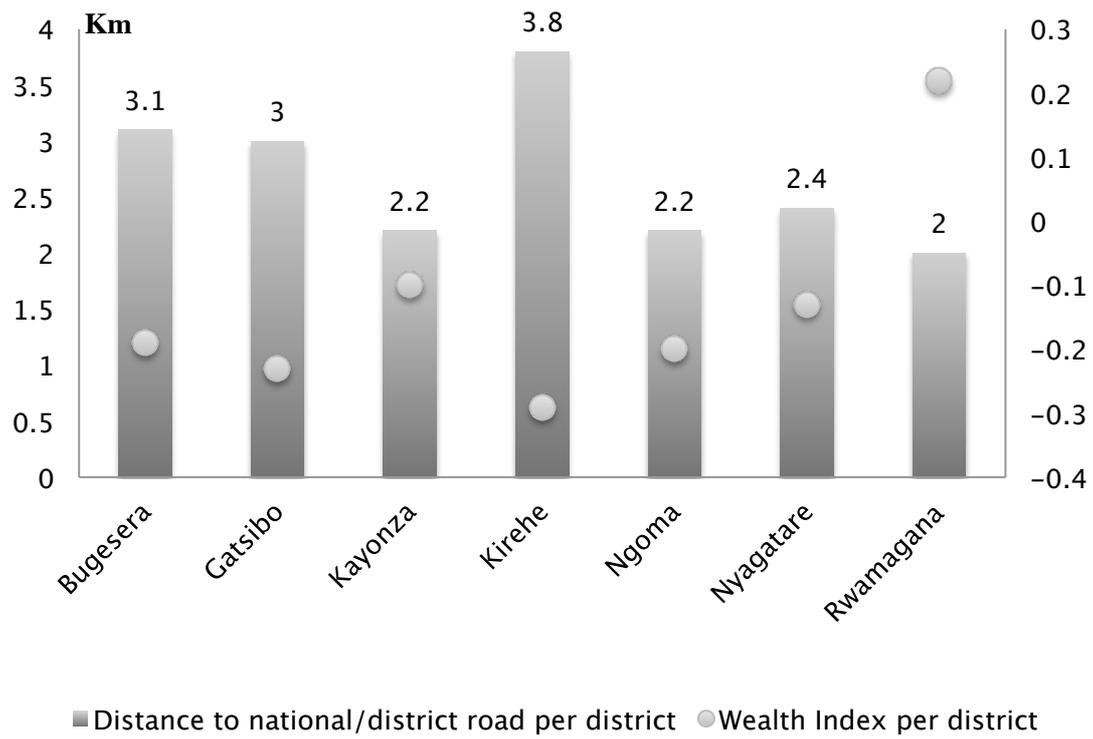
Birth order is an integer variable indicating the rank of the child relative to other children in the family (the eldest is 1, the second is 2 etc...). Time to fetch water is a continuous variable of the time in minutes it takes the mother to collect water. It was included due to the issue long walking times to fetch water poses in rural sub-Saharan Africa in general, and specifically in the Eastern province of Rwanda where residents have pointed it as a main concern (World Vision 2010). It can also create time management issues and potential conflicts with other important chores such as visiting health facilities. Time to health center is a continuous variable of the walking time from the household to the health center. It is measured in minutes. Mother education is an integer variable that assigns 0 to a mother with no education, 1 to a mother with primary education and 2 to a mother with secondary education (there are no cases of mothers with higher education in the sample). Household wealth is represented by the Wealth Index, a continuous variable score developed by DHS that

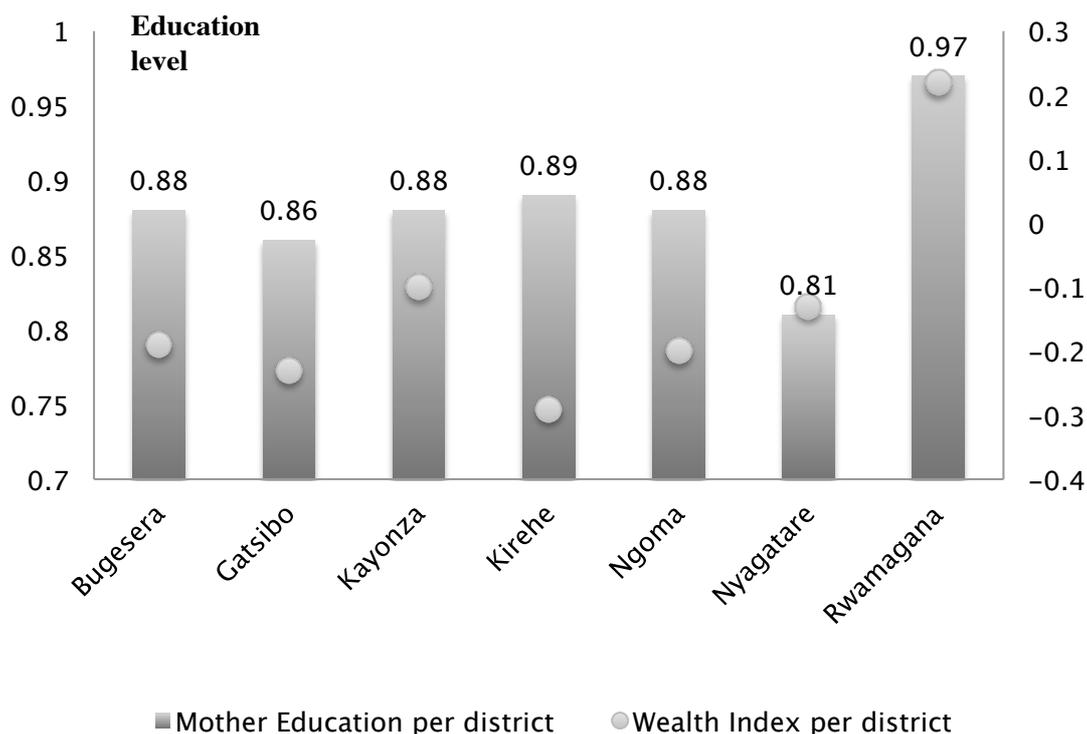
reflects household living standards. It is generated by principal component analysis using selected ownership of household assets such as television, radio etc.... (Rutstein & Johnson 2004). Distance to road is the distance from the household cluster to a district or main road, and it was included because the walking time to the road might be the main causal factor of lack of access to health centers since walking on district and main roads is faster than on footpaths that actually lead to the road (5Km/h compared to values around 1.67Kmh). It is measured in Kilometers and was extracted using GIS.

From table 2, it can be noticed that Rwamagana, probably due to its proximity to Kigali through the national road scores better in all variables. Figure 12 shows the relationship between wealth index and the very high coverage in Rwamagana as compared to other districts (note that the average wealth index for the sample is -0.14 which ranks in the “richer” category of Rwanda).

A similar relation is maintained for other infrastructural variables such as travel time to health centers, time to fetch water and distance to road in figures 13&14&15 respectively. It is also clear from the graph however that changes in wealth index are not necessarily accompanied by similar changes in the variables in the district. Similar observations can be made about mother’s education level in figure 16 below.







Figures 12-16: Coverage and Wealth Index per district; Travel time to health center and Wealth Index per district; Distance to national/district road and Wealth Index per district; Time to fetch water and Wealth Index per district; Mother education and Wealth Index per district.

Source: DHS 2010; GIS Data from The Geographic Information Systems and Remote Sensing Research and Training Center National University of Rwanda 2013

Note: Coverage and travel time were calculated from GIS data from above source. There are no units for wealth index and coverage since the wealth index is a dimensionless score and coverage is a binary variable. The wealth index's axis is on the right

Next, a summary of relevant variables for the field study analysis is present in table 3 below (note that similar variables to DHS could not always be collected in the field, which explains the difference in the indicators chosen in the table).

Table 3: Summary of basic field data variable statistics

		Mean	Variance	Max	Min
Total (n=260)	Travel Safety Issue	1.60	0.24	2	1
	Satisfaction with service	1.10	0.097	2	1
	Waiting time at health center (min)	83	8155	360	3
	Time to health center (min)	89.700	2760	240	3
	Distance (Km)	4.60	17.40	40	1
	Transportation cost (RWF)	939	331148	2000	20
	Transportation cost issue	1.40	0.24	2	1
	Consultation cost (RWF)	1053	447365	15000	150
	Consultation cost issue	1.58	0.24	2	1
	Health insurance coverage	1.10	0.11	2	1
	Number of visits to health center in past year	1.70	3.50	10	0
	Doctor availability	1.10	0.086	2	1
	Age (months)	31	289	59	0
	HAZ (z-score)	-1.19	2.80	3.78	-5.27
Mwiri (n=206)	Travel Safety Issue	1.59	0.24	2	1
	Satisfaction with service	1.10	0.11	2	1
	Waiting time at health center (min)	85	8473	360	3
	Time to health center (min)	95	2531	240	3
	Distance (Km)	4.80	20	40	1
	Transportation cost (RWF)	1049	355347	2000	20
	Transportation cost issue	1.40	0.25	2	1
	Consultation cost (RWF)	982	3187819	15000	150
	Consultation cost issue	1.57	0.25	2	1
	Health insurance coverage	1.10	0.11	2	1
	Number of visits to health center in past year	1.80	3.90	10	0
	Doctor availability	1.10	0.10	2	1
	Age (months)	31	289	59	0
	HAZ (z-score)	-1.20	2.90	3.78	-5.27
Rukara (n=54)	Travel Safety Issue	1.60	0.240	2	1
	Satisfaction with service	1.10	0.060	2	1
	Waiting time at health center (min)	74	6967	360	5

	Mean	Variance	Max	Min
Time to health center (min)	68	3092	240	3
Distance (Km)	4	6	12	1
Transportation cost (RWF)	721	218048	2000	100
Transportation cost issue	1.30	0.23	2	1
Consultation cost (RWF)	1341	9788441	15000	200
Consultation cost issue	1.57	0.25	2	1
Health insurance coverage	1.14	0.12	2	1
Number of visits to health center in past year	1.60	2.40	5	0
Doctor availability	1.02	0.020	2	1
Age (months)	29	289	59	2
HAZ (z-score)	-0.99	2.40	3.15	-4.82

Source: Field data unpublished

The travel safety issue variable is a binary (1=Yes, 2=No) variable that inquires whether the caregiver perceives the journey to the health center as physically dangerous. Satisfaction with service is a binary (1=Yes, 2=No) variable that inquires whether the caregiver was satisfied with the service offered to his/her child(ren). Waiting time at health center is the time the caregiver spends waiting to be received by the care practitioner in the health center. Time to health center is the time in minutes that it takes the caregiver to travel from the household to the health center. Distance in kilometers is the estimated distance by the caregiver from the household to the health center. Sex is a binary variable (1=Male, 2=Female) that reflects the gender of the child. Transportation cost is the estimated cost borne by the caregiver to reach the health center in Rwandese Francs (note that the average is only for people who actually paid a transportation cost and does not include those who traveled freely). Transportation cost issue is a binary variable (1=Yes, 2=No) that inquires whether the caregiver perceives transportation cost to be an issue to him/her going to

the health center (this variable also covers only those who paid a transportation fee). Consultation cost is the estimated cost of the health services borne by the caregiver in Rwandese Francs. Consultation cost issue is a binary variable (1=Yes, 2=No) that inquires whether the caregiver perceives consultation cost to be an issue to him/her (this variable also covers only those who paid a consultation fee). Health insurance coverage is a binary variable (1=Yes, 2=No) that reflects whether the household is covered by a health insurance or not. The number of visits to health center past year is a variable that counts how many times the child was taken by the caregiver to the health center in the past year. Doctor availability is a binary variable (1=Yes, 2=No) that inquires whether a doctor is present in the health center or not. It should be noted though that the latter variable might not reflect accurately whether a doctor was present or not due to the incongruence between field and government data regarding the presence of doctors in health centers (MoH 2009). Whereas the field data shows that doctors are present in almost every health center, government data and information actually points to the opposite. This might be due to the fact that people in the villages understood doctor as a general health practitioner. It is clear from the table that people in both sectors perceive the travel to the health center to be mildly unsafe. The majority is also satisfied with the quality of the service, although it was not possible to determine whether this answer was the politically correct choice. Time to health center and waiting time at health center however show marked differences between Rukara and Mwiri, with the former having lower travel and waiting times. The estimated distance seems also to be longer in Mwiri, although, as mentioned earlier it is not possible to determine the accuracy of this estimation. Again in Mwiri, transportation cost seems to be higher, although this issue along with consultation cost will be ignored due to the fact that most people travel by foot and are insured. The

number of visits in the past year does not seem to differ sensibly. The same can be said about z-scores with only a difference of 0.2, which is not large. In order to confirm the lack of statistical difference for z-scores a statistical *t* test was performed with a 5% significance level and it yielded a p-value of 0.32.

It is important to notice however that the z-scores are negative, which means that the children and infant population in the Eastern Province and these two sectors is growing below the required universal standard.

4.2 Travel time to health centers

Figures 17 and 18 show the results of the dasymetric mapping and the land cover of the Eastern province respectively. The two maps are plotted one after the other with the purpose of facilitating understanding of the relationship between land cover and population density. It should be noted that the white spaces in the population density map represent roads and water bodies that were removed as exclusion areas. Akagera National Park has also been categorized as exclusion area and has been removed from the map too. The traveling distribution grid is shown in Figure 19 below. Figure 20 shows the results of coverage areas along with the new positions of household clusters.

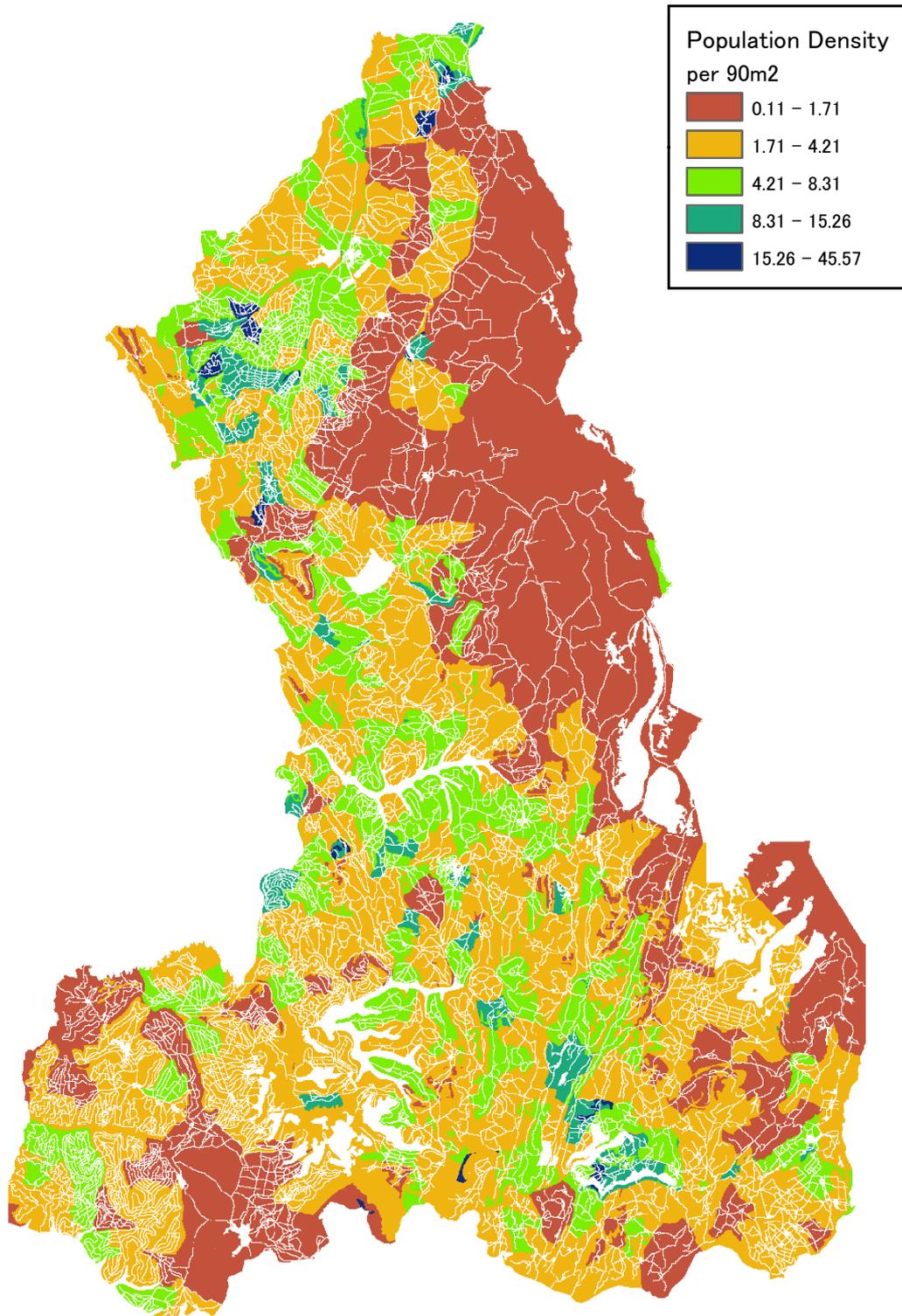


Figure 17: Population Density in Eastern Province of Rwanda

Source: Geographic Information Systems and Remote Sensing Research and Training Center National University of Rwanda 2013; Rwanda Natural Resources Authority 2013

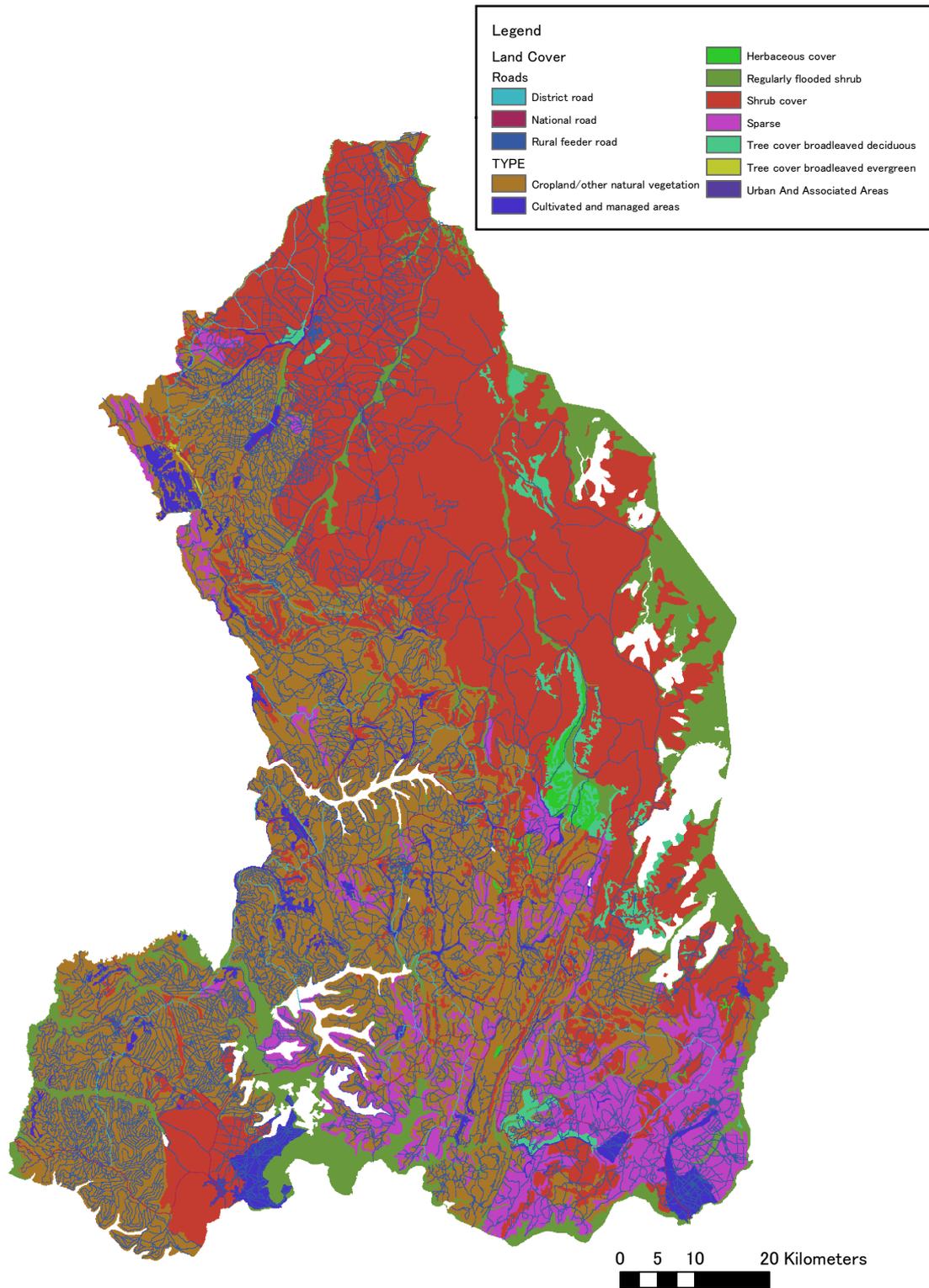


Figure 18: Land cover in Eastern Province of Rwanda

Source: Geographic Information Systems and Remote Sensing Research and Training Center National University of Rwanda 2013; Rwanda Natural Resources Authority 2013

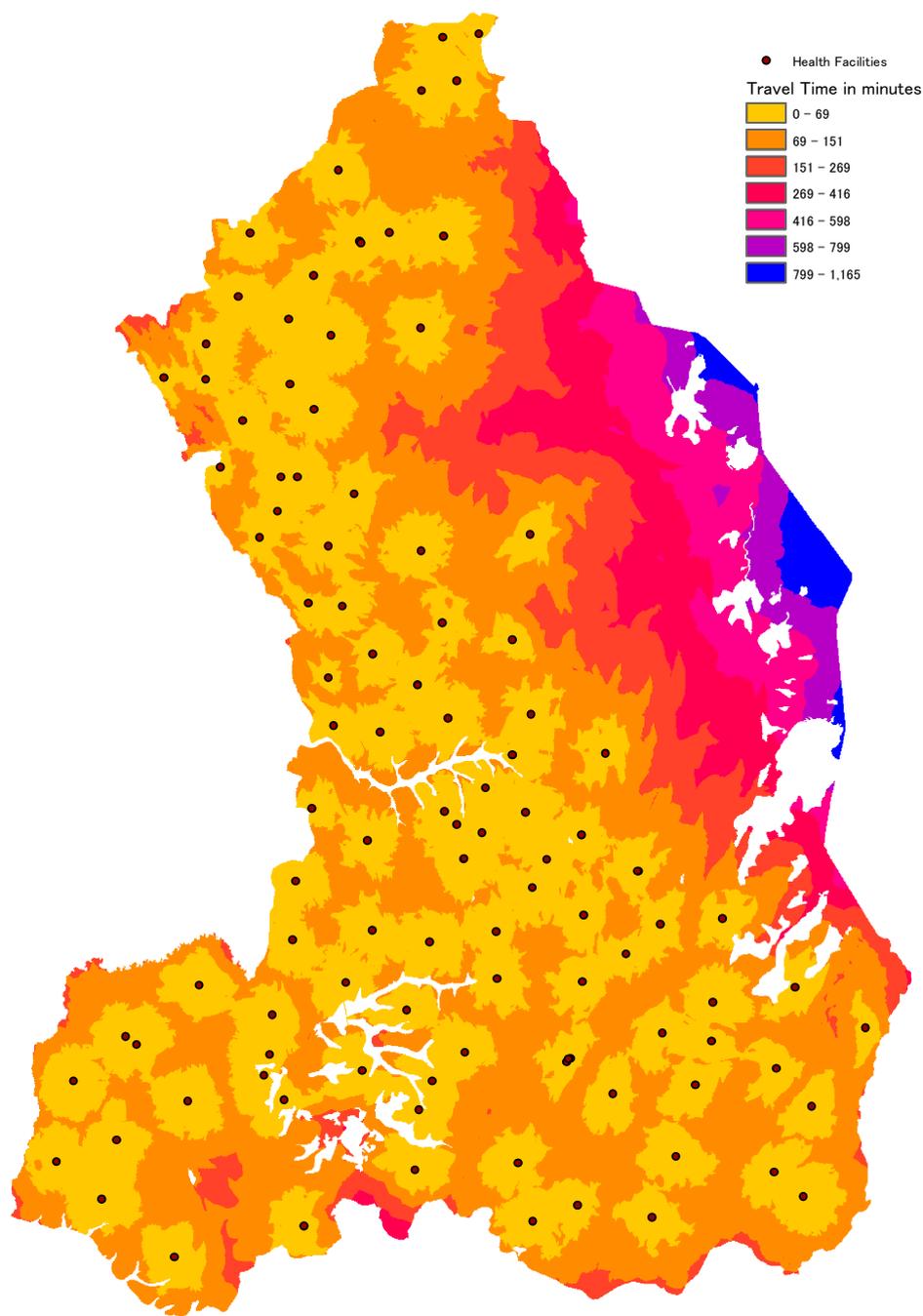


Figure 19: Traveling time distribution in Eastern Province

Source: Geographic Information Systems and Remote Sensing Research and Training Center National University of Rwanda 2013; Rwanda Natural Resources Authority 2013; SRTM 2009

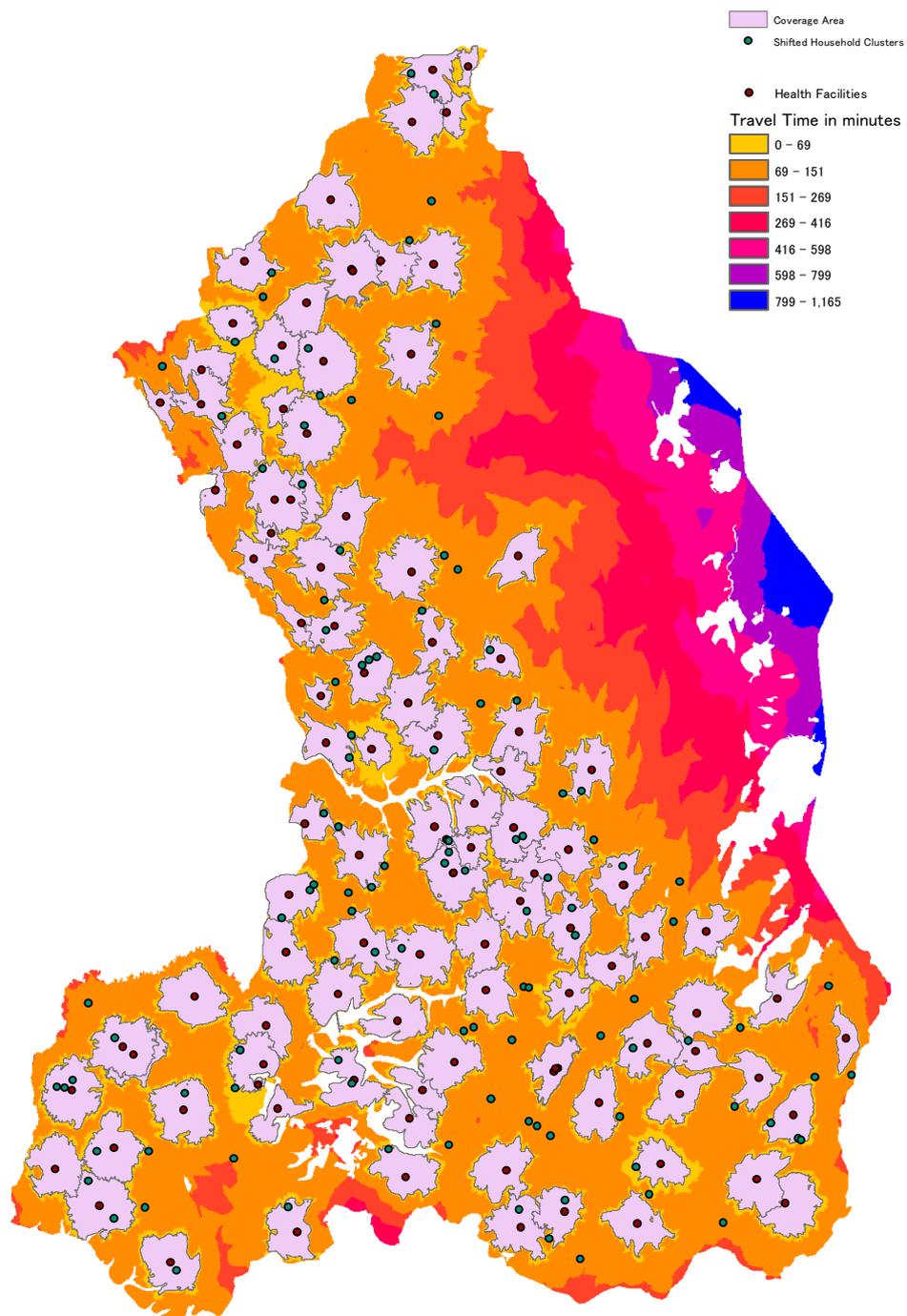


Figure 20: Coverage area of health facilities

Source: GIS Data from The Geographic Information Systems and Remote Sensing Research and Training Center National University of Rwanda 2013; SRTM 2009

4.3 Regression results with travel time

Having estimated travel time, its effect against the distribution of height z-scores was weighted against the other variables in a multiple regression analysis. Table 4 below shows the step-by-step analysis with the only inclusion of the variables that were found to be significant (Buor 2003). It is important to note that the best relation between time and height was found when the regression was applied for time values less than 120min. In that case the sample size decreased from 974 to 931. Birth order did not achieve any significance without the inclusion of preceding birth interval, a variable that measures the number of months between every birth delivery, and might also have cultural connotations.

Table 4: Regression coefficients of DHS and GIS independent factors on HAZ

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-1.55*** (10.70)	-1.49*** (10.36)	-1.63*** (13.48)	-1.53*** (14.12)	-1.69*** (14.90)	-1.56*** (16.11)
Time to health center	-0.37** (0.17)	-0.32** (0.16)	-0.35** (0.16)	-0.35** (0.16)	-0.36** (0.16)	-0.37** (0.16)
Wealth Index		7.00E-4*** (8.00E-5)	6.00E-4*** (9.00E-5)	6.00E-4*** (9.00E-5)	6.00E-4*** (9.00E-5)	6.00E-4*** (9.00E-5)
Mother Education			24.00** (9.30)	24.00** (9.30)	27.00*** (9.30)	23.00** (9.50)
Sex				-22.00** (8.90)	-22.00*** (8.90)	-23.00** (8.90)
Preceding birth interval					0.65*** (0.18)	0.79*** (0.20)
Birth Order						-3.80* (0.21)
Adjusted R-square	0.0043	0.072	7.50E-2	8.00E-2	9.40E-2	9.40E-2
F-value	4.99**	14.84***	26.17***	21.18***	19.72***	17.01***

Note: 10%, 5% and 1% significant levels are denoted by *, ** and *** respectively. The number between parenthesis is the standard error

Table 5: Regression coefficients of DHS and GIS independent factors on
without Wealth Index

Variables	coefficient
Constant	-176.17*** (16.15)
Time to health center	-0.43*** (0.16)
Mother Education	45.20*** (9.20)
Sex	-21.00** (9.11)
Preceding birth interval	0.82*** (0.20)
Birth Order	-3.12 (2.14)
Adjusted R-square	4.70E-2
F-value	10.15***

Note: 10%, 5% and 1% significant levels are denoted by *, ** and *** respectively. The number between parenthesis is the standard error

It is interesting in passing to note that when the Wealth Index variable is removed from the analysis, while keeping all the other variables, the p-value of the regression becomes 0.008, which satisfies the highest statistical significance level of analysis (Table 5). The reasons behind this however are beyond the scope of this study.

4.4 Regression results with waiting time

Table 6: Regression coefficients of field data independent factors on HAZ

Variables	(1)	(2)
Constant	-1.06*** (0.14)	-1.69*** (0.37)
Waiting time	-1.60E-2 (1.10E-3)	-2.20E-2* (1.20E-3)
Travel safety issue		0.43* (0.22)
Adjusted R-square	7.30E-3	1.70E-2
F-value	1.90	3.05**

Note: 10%, 5% and 1% significant levels are denoted by *, ** and *** respectively. The number between parenthesis is the standard error

In order to complement DHS results, field data was used in a similar fashion as DHS data. Bivariate regression results of z-scores of height with travel time to health center did not yield any significant results. Surprisingly, the coefficient of travel time to health center was positive. This surprising result does not challenge the DHS analysis. It is most probably due to the lack of clarification during the interview that travel time to health center means only the time it takes to go to the health center, and not the round-trip time. This might have caused inconsistency in the answers. Moreover, recall bias results that are inevitable in such questionnaires might have compounded the inaccuracies in the results. However, the waiting time variable yielded interesting results in multiple regression analysis. Table 6 shows the results of multiple regression analysis with variables that had significance.

In table 6 above, it is interesting to note that travel safety is even more significant than waiting time at the health center. Traveling long distances alone in a hilly landscape might be preventing caregivers from accessing health centers as often as they wish to. Interestingly enough in the field data, performing a regression analysis of the number of times health centers were accessed in the previous years with waiting time and

Table 7: Regression coefficients of field data independent factors on utilization

Variables	coefficient
Constant	1.84*** (0.20)
Waiting time	-3.70E-3** (1.50E-3)
Height z-score	-0.18** (8.10E-2)
Adjusted R-square	3.60E-2
F-value	4.54**

Note: 10%, 5% and 1% significant levels are denoted by *, ** and *** respectively. The number between parenthesis is the standard error

z-scores as dependent variables yields very robust results. Table 7 shows the coefficients and different statistical values. Long and unpredictable waiting times might be discouraging caregivers to go to health centers, especially that other vital and time consuming household chores such as fetching water might be non-postponable. Also, the number of visits to the health center during the previous year has a highly significant and negative relationship with z-scores of height. Including the variable in the regression analysis of table 6 greatly improves the results as shown in table 8 below. Again, an analysis of the reasons behind this behavior is beyond the scope of this thesis.

Table 8: Regression coefficients of field data independent factors on HAZ

Variables	coefficient
Constant	-1.31*** (0.45)
Waiting time	-4.20E-2*** (1.40E-2)
Travel safety issue	0.46* (0.25)
Number of visits to health center during past year	-0.14** (6.40E-2)
Adjusted R-square	7.80E-2
F-value	5.15***

Note: 10%, 5% and 1% significant levels are denoted by *, ** and *** respectively. The number between parentheses is the standard error.

4.5 Regression results with mother's status variables

As mentioned in the literature review, and as proven in section 4.3, mother education has positive effects on child health. It is therefore interesting to deepen the analysis of mother's status effect on the distribution of z-scores. The equation follows Kurosaki & Ueyama's (2001) model. The following table shows the regression results with height z-scores as a dependent variable, dummies for mother's education levels (primary and secondary), and dummies for mothers' and fathers' involvement in agricultural work as independent variables. The wealth index is also included in the equation to control for health improving as a result of a general increase in a household's welfare.

Table 9: Regression coefficients of DHS independent factors on HAZ

Variables	coefficient
Constant	-1.84*** (15.00)
Mother primary education	15.33 (11.90)
Mother secondary education	73.52*** (21.44)
Mother involvement in agricultural work	26.27* (13.62)
Father involvement in agricultural work	-30.17** (13.04)
Wealth Index	6.00E-4*** (9.10E-5)
Adjusted R-square	8.60E-2
F-value	16.82***

Note: 10%, 5% and 1% significant levels are denoted by *, ** and *** respectively. The number between parenthesis is the standard error

Confirming Kurosaki & Ueyama's (2001) study, we see that mother's involvement in agricultural work has a positive effect on the z-score distribution in Rwanda, which is similar to the results they obtained for the majority of Sub-Saharan African countries.

4.6 Results of nutritional survey analysis

Tables 10&11 show the daily average frequency of food intake for Rukara and Mwiri respectively, for the food types inquired for by the Ochanomizu team. The regions were not combined because measured z-scores for children under 5 years old were significantly different for Rukara and Mwiri in this survey, with Rukara's scores being much better (Mann-Whitney test yielded a z-value of 0.005). Given the very small sample of children whose heights were measured (17), this significant difference does not imply differences in the height distributions between Rukara and Mwiri.

Table 10: Basic statistics of average daily food intake in Rukara

n=85	mean	Variance	maximum	minimum
Agatogo	0.47	0.050	1.00	0.080
Soup	0.45	0.090	2.00	0.00
Soup without meat	0.48	0.11	2.00	0.00
Porridge	0.76	0.19	2.00	0.00
Umutsima	0.070	0.01	0.40	0.00
Ubugari	0.19	0.08	2.00	0.00
Boiled potato	0.30	0.11	1.00	0.00
Bread	0.17	0.14	2.00	0.00
Mandazi	0.13	0.040	1.00	0.00
Rice	0.13	0.020	0.40	0.00
Meat	0.11	0.020	0.40	0.00
Fish	0.030	0.010	0.40	0.00
Egg	0.080	0.050	1.00	0.00
Milk	0.46	0.22	2.00	0.00
Soft drink	0.030	0.00	0.40	0.00
Sorghum alcohol	0.16	0.060	1.00	0.00
Banana beer	0.010	0.00	0.080	0.00
Sweet Banana	0.11	0.020	0.40	0.00
Other Fruit	0.29	0.15	1.00	0.00

Source: Ochanomizu University Field Survey unpublished

Table 11: Basic statistics of average daily food intake in Mwiri

n=59	mean	variance	maximum	minimum
Agatogo	0.50	0.10	1.00	0.030
Soup	0.33	0.040	0.80	0.030
Soup without meat	0.34	0.030	0.80	0.030
Porridge	0.73	0.17	3.00	0.00
Umutsima	0.13	0.040	0.80	0.00
Ubugari	0.24	0.090	1.00	0.00
Boiled potato	0.26	0.070	1.00	0.030
Bread	0.13	0.030	1.00	0.00
Mandazi	0.12	0.050	1.00	0.00
Rice	0.11	0.010	0.40	0.00
Meat	0.070	0.010	0.40	0.00
Fish	0.020	0.00	0.14	0.00
Egg	0.050	0.010	0.40	0.00
Milk	0.27	0.15	2.00	0.00
Soft drink	0.040	0.00	0.40	0.00
Sorghum alcohol	0.12	0.050	0.80	0.00
Banana beer	0.020	0.00	0.40	0.00
Sweet Banana	0.11	0.020	0.40	0.00
Other Fruit	0.25	0.080	1.00	0.00

Source: Ochanomizu University Field unpublished

Table 12: Mann-Whitney's U test (10%) results for selected foods with significant average daily intake differences between Rukara and Mwiri

Food type	Prob > Z
Soup without meat	0.06*
Porridge	0.08*
Mandazi	0.02**
Milk	0.01**
Other Fruit	0.02**

Given that this data was not normally distributed a Mann-Whitney U-test was conducted to test for significant differences in the median frequency for different food types between Rukara and Mwiri. Table 12 shows results only for foods for which there were noticeable and significant differences at 10%.

Table 13: Regression coefficients of average daily intake of selected foods with significant differences on HAZ

Variables	Coefficient
Porridge (n=17)	1.31*
Meat (n=17)	3.90*
Milk (n=11)	4.90**

Note: 10%, 5% and 1% significant levels are denoted by *, ** and *** respectively. The number between parenthesis is the standard error

Table 13 shows bivariate regression analysis results with foods whose daily average intake frequency that showed high significance with the z-score dependent variable.

The table above shows that there is a significant and positive relationship between the intake of high-protein food (meat and milk) and the distribution of z-scores.

V. Discussion

5.1 Basic characteristics

The lack of statistical difference between z-score means does not mean that the intervention by World Vision is not having effects. In order to reach a definitive conclusion, households that received direct help from World Vision have to be identified and flagged, and the comparison can be made clearer. Moreover, a larger sample of less than 5 years old children would be necessary to find possible hidden patterns. Last but not least, the intervention was initiated only in 2009, and is expected to last for around 15 to 20 years. It is therefore possible that actual project outcomes have still not manifested themselves clearly, and will be detected through regular monitoring and assessments.

5.2 Travel time to health center

It is quite apparent from figures 17&18 that people tend be more concentrated in agricultural lands as opposed to areas covered with savannahs (equivalent to shrub cover land cover type on the map). Note that in Figure 20 most coverage areas follow the 60min boundary in Figure 19. This is due to the fact that many health facilities are operating below their capacity levels. Indeed, around 82% of health facilities in the analysis have reached the 60min time limit instead of full capacity. The total population covered by the health centers (i.e either within the 60min area or within the population catchment area of the health center) was found to be 43%. This number is very close to the estimation by the Rwandese government (MoH 2009) and much higher than the estimation in the Western Province (Munoz & Kallestal 2012). This low coverage means that a significant number of residents are underserved, with possible deleterious health effects on the population. In fact, the assessment by World

Vision did identify a shortage of health facilities and poor health as main issues in Rukara (World Vision 2009). Although it is premature to make definitive conclusions based on a GIS analysis alone, the result however does point to the direction that the issue might not be the lack of health facilities, but limitations on transportation infrastructure or housing units being built in places located far away from health centers. More in depth studies of transport infrastructure and the reasons and factors determining people's choice of the location of residence might shed more light and provide more information about possible solutions.

5.3 Regression analysis with travel time

The higher slope obtained for travel time alone for values less than 120min might confirm a similar flattening of health outcome or utilization values for time as observed in other studies after a certain distance from the health center was reached (Feikin et al. 2009).

The analysis proves that travel time to health center has consistently high p-values over different multiple regression trials, even though it is not the most significant of all variables. The high significance found for mother education proves the importance of mother's status and the positive effects it has on child health. The result also justifies the more focused analysis that was performed on mother's status and her involvement in agriculture.

5.4 Regression analysis with waiting time

The significance of waiting time's relationship with z-score was also validated, although the relationship is not as strong and stable as the one with travel time simulated with ArcGIS. The significance of waiting time might point to issues of time

management. When caregivers, who are mostly mothers, have to wait longer times in the health center, they might stop visiting health centers very frequently. This inference however has to be confirmed in further studies that inquire directly whether waiting time is an actual issue for frequent attendance, and that focus more generally on issues of caregivers' time constraints that arise from the competition between vital household chores such as fetching water and the mother's power in negotiating imperatives. The fact that waiting time and number of visits to health centers were significantly associated with a negative coefficient suggests that it might be a main issue for the lack of attendance. However, the fact that height z-scores were also significantly associated with number of visits to the health center during previous years with a negative coefficient suggests that other factors, such as child health also have a large bearing on attendance rates. The most interesting and underappreciated result however was the significant relationship between people's perception of travel safety and z-scores. Although Rwanda has been pacified, and the Eastern province is located very far away from the borders with the Democratic Republic of Congo, the field survey showed that a large number of people (even if less than 50%) still do perceive traveling to the health center as a safety issue, with possible consequences on child health. It is therefore interesting to first study whether the perceptions are well founded, meaning that there is a high rate of criminal activity or whereas it is simply a wrong perception.

5.5 Regression results with mother's status variables

The results do confirm past analysis on the positive role of mothers in the control and disposal of subsistence crops in other countries Sub-Saharan Africa (Kurosaki & Ueyama 2001). When agricultural production is sex-segregated (fathers controlling

cash crops and mother controlling subsistence crops), mothers are better able to allocate better nutritional inputs to children (Kurosaki & Ueyama 2001). Not only was mother's involvement in agriculture found to be significant and positively correlated with height z-scores, but the father's involvement was actually found to be negative. Many explanations have been suggested for this behavior, such as differing gender norms or economic calculations of future income based on differing survival probabilities between males and females (Kurosaki & Ueyama 2001). Noteworthy in this regression analysis is the strong significance of secondary education and the lack of any noticeable effect of the primary education of the mother. In the particular case of Rwanda there might be many explanations for this. A report by the World Bank in 2001 showed that the probability of being literate after completing five years of primary education (the usual cycle in Rwanda) is close to 100%, whereas it is less than 50% for those who have completed three years (World Bank 2004). Those probabilities are lower for females (World Bank 2004). Literate mother are better able to access and understand relevant information for their children's health (Riley 2001).

5.6 Results of nutritional survey analysis

Rukara households seem to consume more portions of soup without meat, yet have similar intake of soup with meat as in Mwiri. Given the lack of significant differences in meat consumption between the two regions, the result makes sense, as far as the lack of difference in consumption of soup with meat is concerned. The reason behind Rukara's higher consumption of soup in general cannot be inferred from the results. Rukara households also seem to consume higher intakes of porridge, Mandazi and other fruits. The most interesting result is the higher consumption of milk by Rukara. Knowing that there is active intervention by World Vision in Rukara to increase

knowledge of appropriate nutritional practices of caregivers (usually mothers) and donate cows to households, the result might seem obvious. A definitive conclusion however is not possible due to the very small sample size and lack of appropriate and accurate data about mother's educational level and nutritional practices. A possible inference could be made however by comparing the food intake of children under 5 years of age, in an attempt to analyze the differences in the z-scores. The significant and positive relationship between the intake of high-protein food (meat and milk) and the distribution of z-scores can potentially be explained by combining the results from field and DHS data analysis. The mother's (caregiver) higher status due to her involvement in agricultural production and disposal of agricultural products as well as her education, has resulted in better allocation choices of food resources to the children as proven in the higher consumption of protein rich foods. The exact linkages and mechanisms however still need to be made explicit and clarified, and therefore more research should be invested in this subject in Rwanda.

VI. Conclusion

Data analysis of both DHS and field data presented interesting results. Of special interest to this study is the fact that waiting time, travel time to health center by foot and mother education were all significant determinants of HAZ scores. Interestingly also, other determinants of mother's status such as preceding birth interval (an indirect proxy for mother's status since a mother with better education and power can delay births) and her involvement in agriculture were found to be significantly related to stunting. In addition, travel safety to health centers also appeared as a new and unexpected determinant of malnutrition in the Eastern province. Finally, socio-cultural variables such as gender and birth order were also notable and in the case of gender the bias against boys that was found at the national level was confirmed at the Eastern province level (NISR 2012).

Effective alleviation of stunting and malnutrition requires action at the community level in general, and not only at children who are stunted according to the statistical WHO cut-off (Young & Jaspars 2009). The results in this study present us with two possible courses of action. The first focuses on "hard" policies such as improving accessibility by building more health centers, improving staffing in health centers and increasing and assuring the security of travel. Traditional ways of remedying such shortcomings consist of building more infrastructures, increasing the number of health personnel as well as upgrading their training and skills set and creating new performance based measures for rewarding public employees. Most of those recommendations however require large amounts of funds. In 2005, Rwanda's health expenditure per capita was 13 U.S dollars, which is way short of the 45 U.S dollars recommended minimum standard in developing countries (MINECOFIN 2008). Compounding this problem is Rwanda's health budget's heavy reliance on NGOs and

international donors (Wen & Char 2011). In 2005, international partners contributed 52% of the budget (MINECOFIN 2008). Moreover, Rwanda's hilly topography would make policing harder, especially in remote rural areas where civil infrastructure is sometimes inexistent.

The other course that is more efficient to follow is to focus on community involvement in reducing malnutrition. Since mother's education and power status (such as higher bargaining power and control over agricultural production) were also found to be significant determinants of stunting, interventions at the household level promise to be better and empowering caregivers might be more successful than infrastructural investments. A possible drawback in interventions targeting intra-household relations is the limited government control over the process, as opposed to physical infrastructure solutions. Socio-cultural dynamics can be slow to change and modern governments cannot get involved in the intricate relationships and dynamics inside individual household units. Results elsewhere however have been encouraging. In Nepal and Papua New Guinea, as already mentioned earlier, children of women with high social capital and who are members of local women's or mothers' organization were less stunted and malnourished (Eklund et al. 2003; Imai & Eklund 2006).

There were many limitations to the study. First, the method of correcting for cluster displacement was not the ideal method. DHS has proposed a better method, however, due to time constraints it could not be implemented. Moreover, the simulation on ArcGIS assumes that the Eastern Province is a closed and isolated system, and consequently people do not cross to bordering provinces. This is obviously not true in reality. Last but not least, the simulation on ArcGIS assumes that people go to the nearest health center, which might not be the case in reality. Not only people might be

crossing to other provinces while traveling to a health center, but they also might be seeking health centers that are in other provinces but closer to their place of living. The study also did not look at the supply-side of health services thoroughly. As mentioned earlier, there are staffing, competency and management issues in health centers in the Eastern province and Rwanda as a whole. There is a lack of appropriate nutritionists both in quality and quantity, and the infrastructure leaves to be desired. A more complete study would address these drawbacks. Regarding the field data, two important limitations were the collection of data about travel times to the health center and mother's education. Travel time to the health center did not show any significant correlation with HAZ scores. This however does not mean that the complementary field data contradicts the GIS analysis. The question inquiring about travel to health centers did not clarify that travel time to health center means one way only, and there might be issues of recall bias (Taiar et al. 2010). People in poor rural areas generally do not carry watches and the ideal way to measure travel time is to actually do the journey with a sample of households while measuring the time (Taiar et al. 2010). This was obviously not possible due to financial and time constraints. Regarding mother's education, the possible answers in the questionnaire were not compatible with the actual schooling system grades in Rwanda. There were therefore a surprising majority of respondents who answered the same to the question about education, and the answer itself is quite ambiguous and might be interpreted to cover differing grades in the Rwandese system.

Since interventions strengthening mother's status have improved the nutritional status of children in other countries such as Ethiopia, Indonesia, Nepal and Papua New Guinea (Eklund et al. 2003), it would be of special interest to study how mother's status affects children's nutritional status and stunting in Rwanda through the change

in a mother's time constraints, bargaining power and control over household resources and her enhanced social capital (Rutherford et al. 2009; Kurosaki & Ueyama 2001; Lisa et al. 2003). In fact, the relationship between status and child or infant nutritional status is not as straightforward as it seems. Studies have shown that women who are more educated and have more control over their time might join the labor force and might actually have less time to nurture their children, most importantly during the critical breastfeeding period (Rutherford et al. 2009; Lisa et al. 2003).

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