ALTERNATIVES TO FOREST BIOMASS FUEL FOR FOREST DEPENDENT COMMUNITIES: A CASE STUDY IN SOUTH-WESTERN BANGLADESH

A Thesis

by

HOSSAIN MD ASHRAF 47-136838

in partial Fulfilment

of the Requirements of the Degree

Master of Sustainability Science

Advisor: Professor YAMAMOTO Hirokazu

Co-Advisor: Project Assistant Professor SEKIYAMA Makiko

Graduate Program in Sustainability Science-Global Leadership Initiative

Graduate School of Frontier Sciences

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ABSTRACT

Biomass fuel remains the prime source of energy extensively used for domestic cooking in rural as well as urban Bangladesh. The major portion of this fuel is collected from local environment. Due to natural and anthropogenic drivers, land use change occurred in some part of this country followed by several socio-economic as well as ecological problems including acute shortage of fuel. The south-west region of Bangladesh has been suffering from biomass fuel crisis, most remarkably since 90's. The communities existing adjacent to Sundarbans Reserve Forest (SRF), the largest mangrove forest in the world located at south-west corner of Bangladesh, were reported the mostly affected and found heavily reliant on the forest resources especially for cooking fuel in absence of affordable and legally available local fuel resources. This study investigates the factors responsible for compelling these forest dependent communities (FDCs) to be over dependent on the resources of Sundarbans, especially for biomass fuel. In terms of final outcomes, the study recommends several alternatives to forest biomass fuel for FDCs that might contribute to the diminution of fuel crisis as well as their fuel dependency on the forest.

The study adopted qualitative and quantitative approaches for securing its objective. Secondary data were collected through the review of relevant literature and documents including studies, journal papers, media reports, books, Government's office records etc. The study followed purposive sampling method, according to which, five villages/communities located the most adjacent to the SRF were purposively selected for primary data collection with semi-structured questionnaire. Besides, group discussion and observation through field visit to FDCs were happened to gather more raw data and have deeper understanding about the problem and sustenance of the FDCs livelihood in connection with fuel crisis.

The study reveals that several factors such as widespread brackish water shrimp farming, frequent natural disasters, unproductive homegarden and saltwater based other land use cum economic activities forced communities to be dependent on forest fuel. These factors drove away traditional fuel options such as homegarden fuel, cowdung and agriculture residues from the study area and the majority of communities' members engaged themselves in illegal collection of biomass from SRF. However, the study demonstrates the conflict in respondents' attitude towards forest conservation and illegal collection of forest fuel biomass under the current context.

The study also recognizes all respondents much aware of traditional biomass alternatives such as homegarden fuel, cowdung and agriculture residues, and some other alternatives like fuel efficient stoves, liquid petroleum gas (LPG) and kerosene. Though alternatives like biogas and solar cooker were reported very new energy options to majority of them, evidences of very limited use of homegarden fuel and cowdung were also recorded. According to the respondents' opinions, lack of government initiatives was the main issue for generating extreme situation that created barrier for respondents to accepting their desired fuel alternatives.

With respect to the availability of the alternatives being accessible for respondents in future socio-economic as well as environmental context, the study suggests biomass fuel from homegarden (bamboo, tree parts etc), agriculture practices (agriculture residues) and livestock rearing (cowdung, buffalo dung, poultry litter etc) in combination with certain type of fuel efficient smokeless stoves as alternatives to existing forest fuel biomass.

Under the prevailing circumstances, it is recommended for the management and use of affordable and legally as well as locally available fuel resources, restoration of agro-ecological environment through appropriate policy or community initiatives and enabling respondents through awareness creation, technology transfer and marketing interventions in

order to ensure the sustainable supply of affordable and legally available energy for domestic cooking. Besides, the study discourages all sorts of brackish water based land use as well as economic activities in and around the study area.

More studies on the management of ever increasing household energy demand with application of governance without government approach may be fruitful under the context of least developing countries.

ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to my supervisor, Professor Yamamoto Hirokazu, and co-advisor, Assistant Professor Sekiyama Makiko for their invaluable guidance in the completion of this study.

Secondly, my deep appreciation goes to the members belonging to Graduate Program in Sustainability Science (GPSS) Seminar and Forestry and Landscape Planning Seminar for their critical comments and suggestions on the contents of my research.

Furthermore, this study is also indebted to Forest Department, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh; Forestry and Wood Technology Discipline, Khulna University; and Divisional Forest Office, Satkhira Range Office and Kadamtala Forest Station of Sundarbans West Forest Division. The assistance and support they extended for making my data collection process smooth are highly appreciated.

I must thank to all the inhabitants, especially the survey respondents from five villages namely Koikhali, Kalinchi, Munshigonj, Burigoalini and Dumuria of Shyamnagar upazila under Satkhira district of Bangladesh for their hospitality and participation in the interview.

I am very much grateful to Marcin Pawel Jarzebski for extending help in satellite images analysis, to the staff of GPSS Office for their kind supports in printing it out smoothly.

I would also like to thank especially my wife Parvin Linza and my friends for their assistance throughout the study.

Finally, I am thankful to many other people not listed here, but made this study possible.

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ACRONYMS

ASIRP	Agricultural Services Innovation and Reform Project
BCAS	Bangladesh Centre for Advanced Studies
BDT	Bangladeshi Taka
BARCIK	Bangladesh Resource Centre for Indigenous Knowledge
BB	Bangladesh Bank
BBS	Bangladesh Bureau of Statistics
BPDB	Bangladesh Power Development Board
DECC	Department of Energy and Climate Change
EU	European Union
FD	Forest Department
FDCs	Forest Dependent Communities
INFOSAN	International Food Safety Authorities Network
INAFI	International Network of Alternative Financial Institution
IUCN	International Union for Conservation of Nature
LDCs	Least Developed Countries
LPG	Liquid Petroleum Gas
MW	Mega Watt
NGOs	Non-Government Organizations
SADKN	South Asian Disaster Knowledge Network
SRF	Sundarbans Reserve Forest
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNEPA	United Nations Environmental Protection Agency
USD	United States Dollar
WB	World Bank

CHAPTER 1: INTRODUCTION

1.1Background

1.1.1 Overview of biomass energy in Bangladesh

Bangladesh is one of the least developed countries (LDCs) in the world (UNCTAD, 2013). It is located in South Asia and bordered by India to its west, north and east; Myanmar to its south-east and the Bay of Bengal to its south (BBS, 2014). Though the number of people living under poverty line reduced to around 25% (BBS, 2014), the country still owns many socio-economic problems (Mohajan, 2014). Bangladesh has been facing acute power crisis for last few decades (Halder et al., 2014). Despite the allocation of about 20% of total public investment for the development of energy sector during last decade, country's per capita consumption of commercial energy and electricity is still one of the lowest among the developing countries (BBS, 2014). There was deficit in electricity supply against its demand in 2012. Maximum capacity of electricity supply on national grid was then 6,350 MW against its estimated demand 7,518 MW. In the same year, 60 % of the population was found to be availing electricity supply through national grid or renewable energy sources(BPDB, 2015a; BPDB, 2015b). As of 2013, nearly 65% of total final energy consumption was estimated to be met by biomass fuels (BBS, 2014).

More than three-fourth of Bangladesh's 152.25 million population lives in its rural areas. Most households in rural (94.17%) and urban areas (51.76%) use biomass fuels for cooking (BBS, 2014). In connection with domestic use, biomass fuels accounts for 59.5% of the total energy consumption. Traditional biomass fuels include wood, bamboo, twigs, wood shavings, sawdust, bark, roots, shell and coir of coconut, agricultural residues such as paddy husk and bran, straw, biogases, jute stick, charcoal and cow dung. Among them, majority of the rural population use wood fuels, crop residues and cowdung for their daily cooking (WB

and BCAS, 1998). Dominance of biomass fuels can also be found in figure 1. According to this figure, the share of biomass fuels (straw, leaf, dried cowdung and wood) in 2013 was 85.91% in the total fuel consumption for cooking purpose. Besides, Jashimuddin*et al*. (2006) cited the energy consumption status in rural areas dominated by traditional biomass fuels, of which 15.5% was wood fuel, 66.7% agricultural residues and 17.8% cowdung.

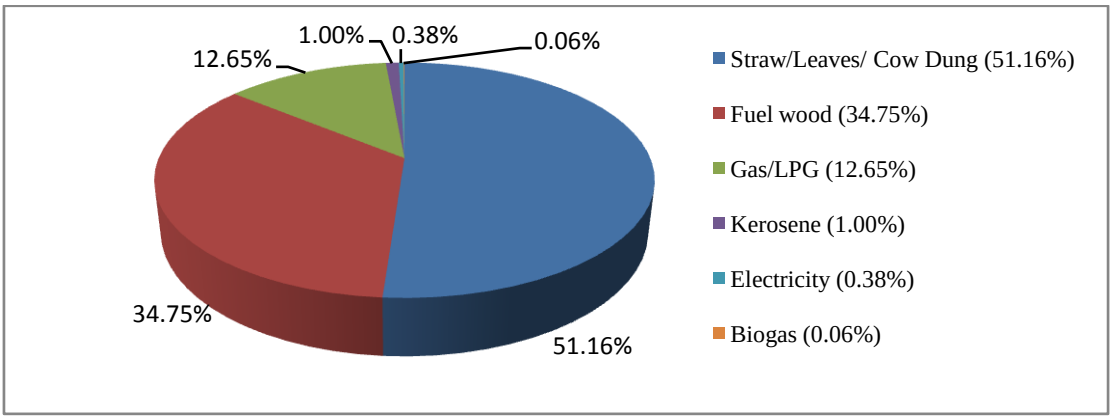

Figure 1: Types of cooking fuels used by household (%) in Bangladesh (BBS, 2014).

Biomass fuels are mainly collected from the local environment particularly in rural Bangladesh. Akther et al.(2010) found rural people collecting fuel biomass mostly from their own homestead and agricultural land (74%) followed by neighbor (18%) and market (8%). Miah at al. (2009)reported homestead (homegarden) and local market as the most common rural sources of biomass where homestead was exploited by 40% households, market by 13% household, and homestead and market by the rest (47%).The common presence of market in the supply chain of biomass fuel indicates its scarcity and high demand in the rural areas.

1.1.2 Biomass fuel and related issues in south-west region of Bangladesh

Bangladesh still suffers from scarcity of fuels specially biomass fuels. More than 90% of the total fuel wood supply comes from homestead garden and the rest (around 10%) from conventional forests and others sources. The country owns forests on around 15% of its total land area, though actual tree cover area might be limited to 7-8%. Only biomass fuels are

available for household consumption in the rural areas and there is still scarcity of wood fuels (Atikullah and Eusuf, 2002).

The south-west part of Bangladesh has also been suffering acute fuel crisis since a long time ago. This coastal region, about 8,000 Km^2in area, belongs to greater Khulna (Khulna, Satkhira and Bagerhat) and Jessore districts, excluding parts of Sundarbans (Tutu, 2005). Sundarbans is the largest mangrove forest in the world and an UNESCO World Heritage Site as well. The location of the forest includes parts of Khulna, Satkhira and Bagerhat districts of Bangladesh (Forest Department, 2010).Local people are very much reliant on ecosystem services of this reserve forest for their subsistence and income. Sundarbans also acts as resilient buffer for the lives and assets of these forest dependent communities (FDCs) living in its immediate vicinity (Kabir and Hossain, 2008). Figure 2 shows the overall problems of FDCs which includes lack of fuel and energy supply.

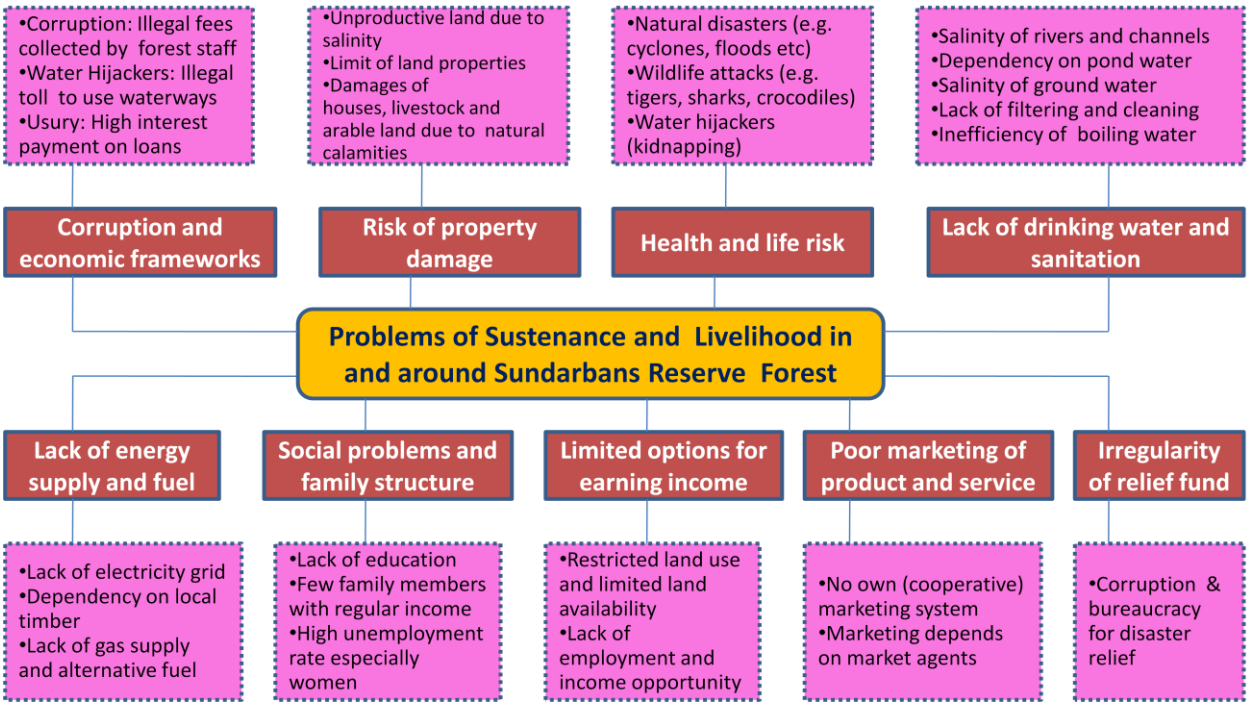

Figure 2: Problem of securing subsistence and livelihood in and around Sundarbans Reserve Forest (Gatzner and Islam, 2013).

The south-west coastal belt is very prone to multiple hazards such as cyclones, floods, tidal surges, periodic water-logging and land erosion. Besides, this area is now subject to

human-induced disaster such as salinity which is putting an increasingly detrimental effect on the livelihood and local environment (Solidarity Internation and Uttaran, 2013).According to figure 3, this region remains within both drought prone zone and cyclone prone zone. During disaster, cooking may not be possible due to lack of facility or fuel (INFOSAN, 2005). This is how this region suffers due to frequent disasters.

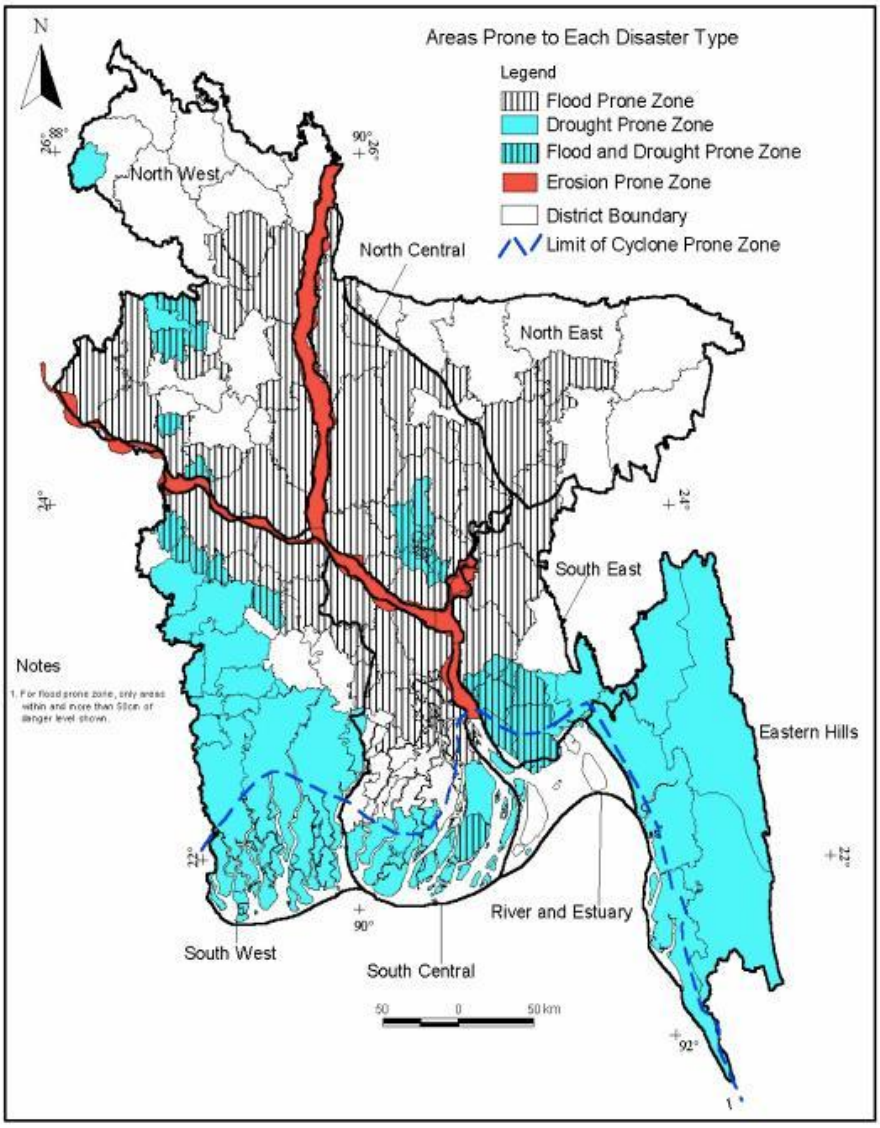

Figure 3: Parts of Bangladesh prone to each disaster type (SADKN, 2013)

In this connection, Khan (2012) reported declining agriculture production, decrease of cattle heads and local tree species as the immediate impact of water logging due

to storm surge and cyclone occurred in this region. Local people used to extensively exploit these sources for meeting up their household energy need (Miah et al., 2003).

The region was once an agricultural hub, but the area is now wrecked by salinity, natural disasters, poverty etc. The impact of the embankment system since 1960's andsubsequent spread of shrimp farming throughout the region contributed environmental degradation. Since the 80% of the bagda (saltwater shrimp) production comes from this region, intensive shrimp production leads to a significant decrease in livelihood options with reduced resilience and increased vulnerability of communities. Subsequently, a number of other problems including declinedfuel sourceshave alreadybeen reported (Solidarity International and Uttaran, 2013).

1.2 Analysis and statement of the problem

The south-west part of Bangladesh is deemed to be the most disaster-prone region which is very exposed to frequent climatic events like tropical cyclones, tidal surges, floods, repeated water logging etc (Tabrig et al., 2013; Solidarity International and Uttaran, 2013; Khan, 2012). The Cyclone 'Sidr' struck the region in 2007 and subsequently another Cyclone 'Aila' struck on 27 May 2009. The next disaster came in the form of unusual flood during July to August, 2011.Cyclone 'Aila' caused long-term saline water-logging in this region and it contaminated fresh/ground water and the soil on which agriculture practices were nearly impossible (Braun and Saroar, 2012).

The south-west Bangladesh was historically dominated by single or mono crop farming system up-to 1980. Starting from early 1980s, brackish water shrimp farming appeared as vital land-use option and in some areas of this region (such as Shyamnagar, a sub-district/upazila of Satkhira district). Soon, it was found as the sole land-use activity through all the year round (Miah et al., 2003). In this regards, Hossain (2011) reported that shrimp farming first began at Munshigonj (a village of sub-district Shyamnagar) in 1972 and its wide

access opportunity into international market and short-term huge profit brought local people into shrimp business. Besides, salinity level of this region including Shyamnagar, increased by 3.02% during the time starting from 1979 to 2009 (Khan, 2012). Due to increased salinity, people became more encouraged to start shrimp farming on their land (Haider and Hossain, 2013). By every next year shrimp farming area enlarged itself at a higher rate replacing agricultural land (Miah et al., 2003; Hossain, 2011). Gradually this farming started rolling itself and reached Khulna and Bagerhat district by 1980. By next decade, shrimp business emerged as round-the-year activity in this region (Hossain, 2011).

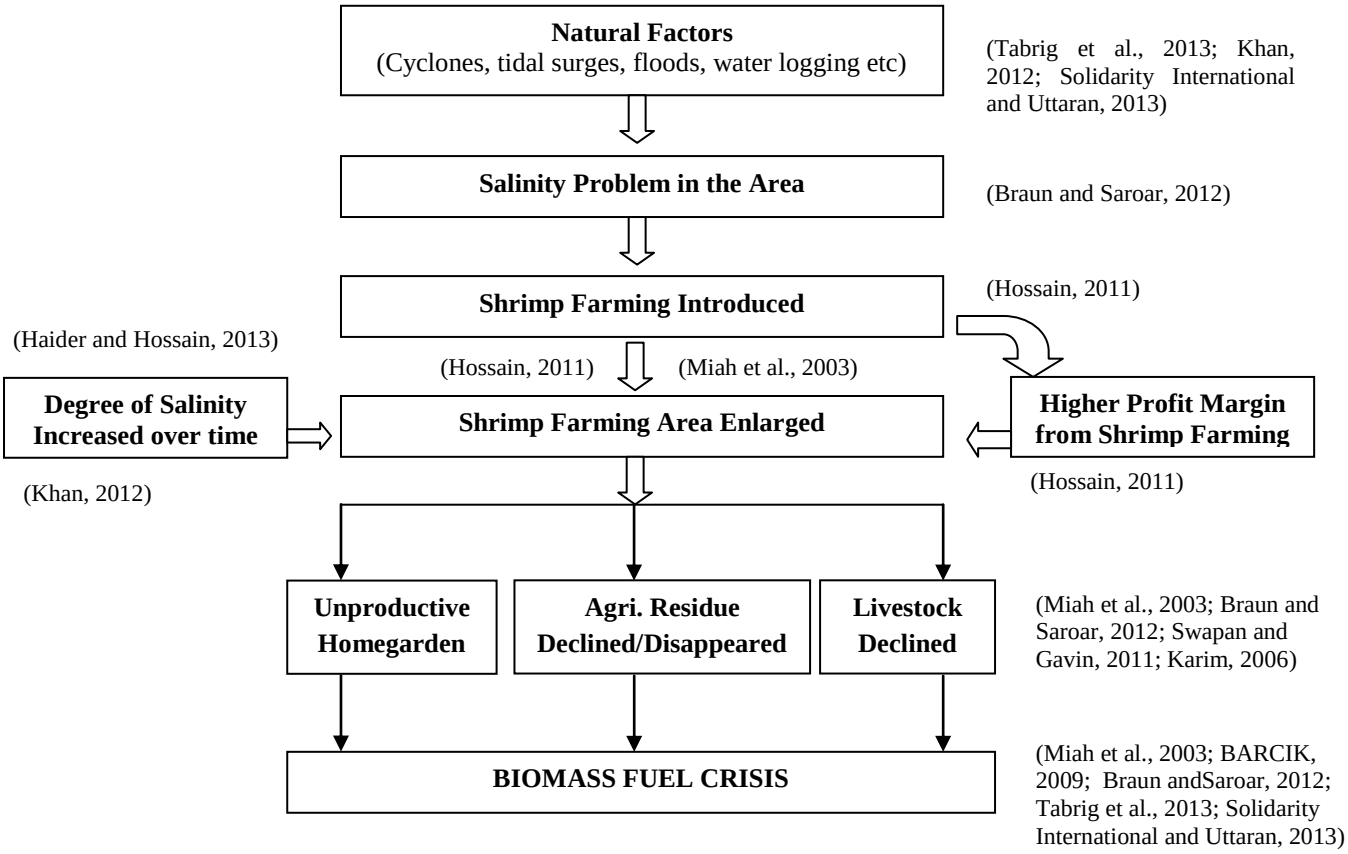

Figure 4: Flow chart shows how biomass fuel crisis evolved in the south-west Bangladesh

Along with some amount of fuelwood collected from Sundarbans, villagers living in Khulna, Bagerhat and Satkhira districts especially adjacent to this forest used rice straw, cowdung, twigs and leaves of homestead plantation as fuel materials. Brackish water shrimp farming, together with its negative ecological impact, was then replacing traditional

agricultural practices in the region. Gradually water salinity, soil fertility deterioration, depletion of homestead plantation, declination of livestock population and other natural vegetation increased and secondary issues like biomass fuel crisis, food security problems, poverty were being evolved (Miah et al., 2003). Several other studies (Ghosh et al., 2014; Alamand Chowdhury., 2010; Swapan and Gavin, 2011; Paul and Vogl, 2011; Karim, 2006; BARCIK, 2009.) claimed that shrimp farming played the prime role in land use change, especially turning agricultural land into shrimp farms in south-west Bangladesh. As result, rice residues and cowdung became disappeared (Braun and Saroar, 2012). Besides, sharp decline in the number of livestock population was reported in that area (Swapan and Gavin, 2011; Karim, 2006). Some other studies (Swapan and Gavin, 2011; Karim, 2006; Rahman et al., 2011) reported that tree coverage and production of homegardens significantly declined due to the aggression of shrimp farming. As a result, domestic fuel shortage evolved as one of the problems of FDCs in south-west Bangladesh (Miah et.al., 2003; BARCIK, 2009; Braun and Saroar, 2012; Solidarity International and Uttaran, 2013; Tabrig et.al., 2013; Gatzner and Islam, 2013).

Table 1: Fuel usage patterns by the FDCs in south-west Bangladesh (Miah et al., 2003)

Fuel Types	Percentage of Respondents					
	Mongla (Bagerhat District)		Dacope (Khulna District)		Shyamnagar (Satkhira District)	
	1981	**2001**	**1981**	**2001**	**1981**	**2001**
Cowdung	100	25	100	20	100	20
Agri. Residues	100	90	100	100	100	100
Homegarden	85	70	90	35	80	40
Biomass fuel from Sundarbans	30	75	35	70	25	75

Since the biomass fuel such as rice straw, cowdung, twigs and leaves of homegardens were unavailable within their local environment; people gradually became dependent on forest. It was reported (table 1) that FDCs' dependency on Sundarbans forest for biomass fuel

increased 2-4 times over 20-years of time starting from 1981 (25%) to 2001(75%) where dependency on traditional fuels especially cowdung and homegarden dramatically decreased (Miah et al., 2003).

Alam and Chowdhury (2010) reported that woody biomass fuel from Sundarbans was found to be mostly used by the highest number of local households (71.67%) followed by branches of trees (65%), leaves (60%), cowdung (43%), fruits of mangrove trees (41.67%) and rice straw (35%) respectively. According to the Figure 5, use of biomass from Sundarbans and market were found to be increasingly used by respondents and, on the contrary, dependency on agriculture land (agri. residues), homestead garden (homegarden), domestic animals/livestock (cattle) and local area resources was found to be dramatically reduced after shrimp farming introduced in that particular area.

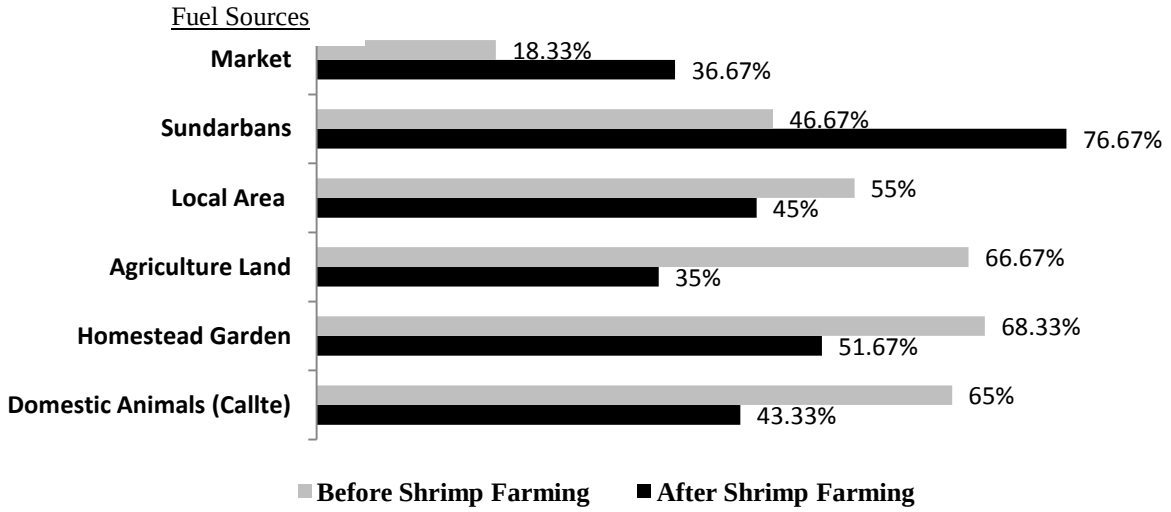

Figure 5: Exploitation of fuel sources in south-west Bangladesh (Alam and Chowdhury, 2010)

Even in more recent study (Getzner and Islam, 2013), each household was reported to be collecting annually 1300 – 1400 kilogram fuel wood from SRF, of which 1100 kg was used for domestic cooking and the rest for selling at the local markets. Braun and Saroar (2012) also reported fuel dependency of local communities on SRF at a large extent.

Hence, this research attempted to address the biomass fuel crisis of FDCs in the south-west region of Bangladesh.

1.3 Rationale of the study

The communities living adjacent to Sundarbans depend on this forest for their substantial subsistence and cash income through selling ecosystem products at local markets. These FDCs lack energy supply such as electricity, gas, alternative fuels. They depend mainly on Sundarbans resources for cooking fuel. To reduce the biotic pressure from forest, alternatives to biomass resources are to be identified, established and developed especially for FDCs (Getzner and Islam, 2013). Widening people's range of choices can be done through diversifying alternatives to forest resources (Badola, 1998). Getzner and Islam (2013) also suggested developing alternatives to forest woody biomass for meetingup communities'domestic energy need.

This study aims to identify alternatives to forest biomass fuels for FDCs living in south-west region of Bangladesh. It may pave the pathway to increase their number of fuel choices and, substantially reduce their dependency on forest resources for cooking fuel.

1.4 Objective and research questions

1.4.1 Objective

The objective of this research is to identify alternatives to forest biomass fuel for the forest dependent communities (FDCs) in order to meeting up their energy need for cooking as well as reducing their dependence on forest resources.

1.4.2 Research questions

For securing the objective, four research questions were developed as follows:

a) What are the factors compelling FDCs to be over-dependent on the resources of Sundarbans, especially for biomass fuel?
b) What are the FDCs' attitudes towards alternatives to forest biomass fuel and conservation of forest resources?
c) What are the potential barriers to accepting those fuel alternatives by the FDCs? and
d) What are the potential alternatives to forest biomass fuel to be used by the FDCs?

CHAPTER 2: LITERATURE REVIEW

2.1 Alternatives to forest biomass fuel

In general, alternative fuels are meant to be used as alternatives to conventional fossil fuels like gasoline and diesel. Some of its examples are bio-diesel, natural gas, propane, alcohol, electricity etc (EPA, 2013). It can replace fossil fuel sources in the energy supply to specific use (EU, 2012). Hence, an alternative fuel may be any fuel other than the traditional options used to produce energy or power for specific use. This study rather focuses on alternative sources of forest biomass fuels for cooking in domestic environment, than alternative fuels. Here, alternatives to forest biomass fuels mean alternative sources of cooking fuels, of course, derived from other than forest resources such as branches, twigs, leaves, wood and other tree parts from homegarden and other legally accessible biotic resources, cowdung, agriculture residues , solar power, petroleum oil, biodiesel, ethanol, electricity, propane, compressed natural gas, hydrogen etc.

2.2 Potential alternatives to forest biomass fuel in rural context

2.2.1 Asian perspectives

Under the socio-economic context of rural remote, several renewable and promising energy options have already been retrieved in different Asian countries. For the southwest region of Bangladesh, Rashid (2012) examined the appropriateness of six promising alternative sources of energy as follows:

a) Biomass (Biogas) Plant

The raw materials used in biogas plants are dead trees, tree branches, yard clippings, left-over crops, wood chips and bark, sawdust from lumber mills, even livestock manure. Biogas plants make use of these waste materials. Once plant is set up, getting energy supply is almost free. Though setting biogas plant is comparatively expensive, some NGOs have

been trying to explore its market through different projects. In relation to this, insufficient supply of raw materials might appear as another problem. Local tree resources and livestock such as number of cattle and poultry can be good sources of raw materials. Since this region produces huge amount of shrimp, waste produced from shrimp processing units or depots might also be regarded as potential source of its raw materials. NGOs' role in awareness rising on the benefit of biogas plant is expected for further promotion of this green energy.

b) Mini (Small Scale) Hydropower Plant

Small scale hydropower or mini-hydropower plant, built in small rivers or streams with little or no environmental effect, has been gradually accepted as an alternative energy source, especially in remote areas where other power sources are not available. It is relatively more reliable, constant and quick source of energy than wind, solar or wave power. Once the plant is installed, availing energy supply involves almost no cost. Moreover, south-west region of Bangladesh is blessed with several rivers. Hence, hydropower plant might get enough flow of water all the year round. On the contrary, it has some detrimental impacts on lives and environment. Along with its huge installation cost, it can favor fish migration and create negative impact on residents, environment, and plant life on the downstream. So, finding a suitable site is a great challenge for the implementation of this plant. NGOs can play critical role regarding carefully execution of such a relatively new project to this region.

c) Solar Energy

Using solar energy, electricity can be generated through photovoltaic (solar cell) systems. In remote rural lacking supply of electricity, it might be a convenient source of energy especially for low power applications. After installing solar system, it involves no further cost and produces no waste or pollution. Being unreliable power source in absence of sun light, it is not recommended for countries with little sunny climate. Besides, installing solar station requires huge investment and larger area of solar panels to get a decent amount

of power. Local people looking for high power electricity and the poor lacking economic ability to pay the relatively bigger re-payment installment for solar panels, are not interested in solar power. Due to intervention of some NGOs and availability of open sun in most of the days in this region, solar power was found familiar to inhabitants for specific use (especially for indoor lighting). Since there was still some information gap existing among the mass people regarding solar energy, measures along with appropriate marketing mechanism (such as provision of repaying the cost of solar systems by installments compatible to the financial ability of general people) could carefully be taken with efficient procedural manner.

d) Wind Power

Turning kinetic energy of the wind into mechanical energy, electricity can be produced and transmitted through electricity grid to the households. It is one of the methods appropriate for channeling power to rural remotes suffering from adequate power supply. It involves almost no production cost except installing wind power station in suitable as well as high valued coastal areas. It produces no waste, pollution, even green house gases. Moreover, land left beneath and around the wind power station can be used for farming as well as spot for tourist attraction. Being unreliable source of energy and disturbing to the flying birds, television signal, it owns some negative impression. As its generator makes constant noise all the time, it might be sometimes intolerable to local inhabitants. Besides, transmission line needs to set up for household supply which might not be feasible due to its location and economic consideration. Since south-west region is bordered by coastal line to its south, it may receive full flow of wind, which can be used for generating electricity all the year round.

e) Tidal Power

Tidal power can generate electricity through capturing moving water energy mass due to tides. Though tidal power plant requires huge investment to be installed across an estuary, it reliably and predictably produces green energy involving no further cost. Site selection and

execution of this project are also challenging due to uncontrolled and unexpected environmental impacts that might take place in future. However, offshore turbines and vertical-axis turbines which are comparatively less expensive with limited environmental impact may be considered for this region.

f) Wave Power

Power generation through capturing ocean surface energy is a distinct form of green energy, though it is not extensively used technology worldwide. It requires relatively huge investment and, in return, can produce huge amount of energy depending on the availability of desired ocean surface current in a suitable site. Along with great challenge in site selection and applying appropriate technology to withstand rough weather, some of its design is noisy and threatening to the lives living around coastal zones. It may contribute fish migration in the long run. Moreover, it can create sedimentation, flood as well as water logging situation followed by increased level of salinity. However, south-west region is bordered by coastal line, wave power plant can get uninterrupted ocean surface current for power generation, provided that it's positioning should be technically sound in all sphere.

Considering the advantages, disadvantages and potential of the following options, the study (Rashid, 2012) recommended biogas and solar energy as renewable and viable sources for this region.

Another study (Alam and Chowdhury, 2010) reported fuel saving by one-third (1.5 kg/household/day) through improved earthen stoves in the south-western region of Bangladesh. Roy (2008) also advocated for improved cooking stove for FDCs to reduce their dependency on the forest biomass fuels. Besides, Atikullah and Eusuf (2002) suggested improved cooking stove for rural people to reduce pressure on agricultural residues and save biomass fuel as well.

Since majority of the households in the rural Bangladesh extensively depends on homegarden to meet their domestic fuel demand, rich homegarden system near forest regions might reduce pressure on the forests (Mukul et al., 2014).

Considering the perspective of rural India, Agoramoorthy and Hsu (2012) recommended cowdung as alternative source of renewable energy that can significantly reduce pressure on forests.

Besides, Dhanai et al. (2014) mentioned kerosene, as an alternative source of energy in northern India, which can reduce pressure on natural forests.

2.2.2 African perspectives

Along with the role of fuel efficient stoves in saving cooking fuel in Bangladesh, Alam and Chowdhury (2010) mentioned several empirical evidences from African context where each household was found to save yearly 394 kg of charcoal costing USD 84 in Rwanda, 613 kg of charcoal costing USD 65 in Kenya and 50% of total fuel in Malawi.

Gaudreau and Gibson (2015) cited agricultural residues as a cooking fuel offering an attractive means of reducing deforestation in Senegal. Bekele (2001) found agriculture residues and cowdung replacing woody biomass in rural Ethiopia.

Kerosene (paraffin) can sometimes be only option left for the rural people which have positive correlation to reduce deforestation. In support of using kerosene as an alternative fuel in Nigeria, Oyekale et al. (2012) recommended subsidy on the price of kerosene.

2.2.3 Developing countries' perspectives

Several studies separately recognized the role of biogas as well solar energy in supplying household energy. The hybrid application of biogas and solar resources may be more effective to address energy crisis in rural areas in developing countries (Rahman, et al., 2014).

Liquid Petroleum Gas (LPG) can also be treated as an alternative option to forest biomass fuel. Shifting from fuelwood to LPG can reduce deforestation (Asante, 2010).

Moreover, evidences were found in support of the substitution between forest fuelwood and private energy sources like dung, residues and tree parts from homegardens in developing nations (Beyene, 2010).

This study took biogas, solar cooker, improved cooking stove, homegarden, agriculture residues, cowdung, LPG and kerosene into account as alternatives for further investigation as well as checking their appropriateness for the FDCs in the south-west region of Bangladesh.

It is to be mentioned here that the study didn't consider electricity, since electricity was not a reliable source of energy and peak demand never met in Bangladesh. All the people do not have access to national electricity grid especially people living in rural remotes, though more than 75% of the country's total population (152.25 million) live in rural villages. Excluding urban segment, only 48.84% of rural people were found to be connected to electricity grid (BBS, 2014).

CHAPTER 3: MATERIALS AND METHODS

3.1 Conceptual framework

The structure of the study was planned based on the literature review and conceptual framework (figure 6) in aligning with the problem evolution and its negative impact on the livelihood of FDCs. The conceptual framework includes problem evolution phase, impact phase and solution phase including proposed measures for addressing the problem.

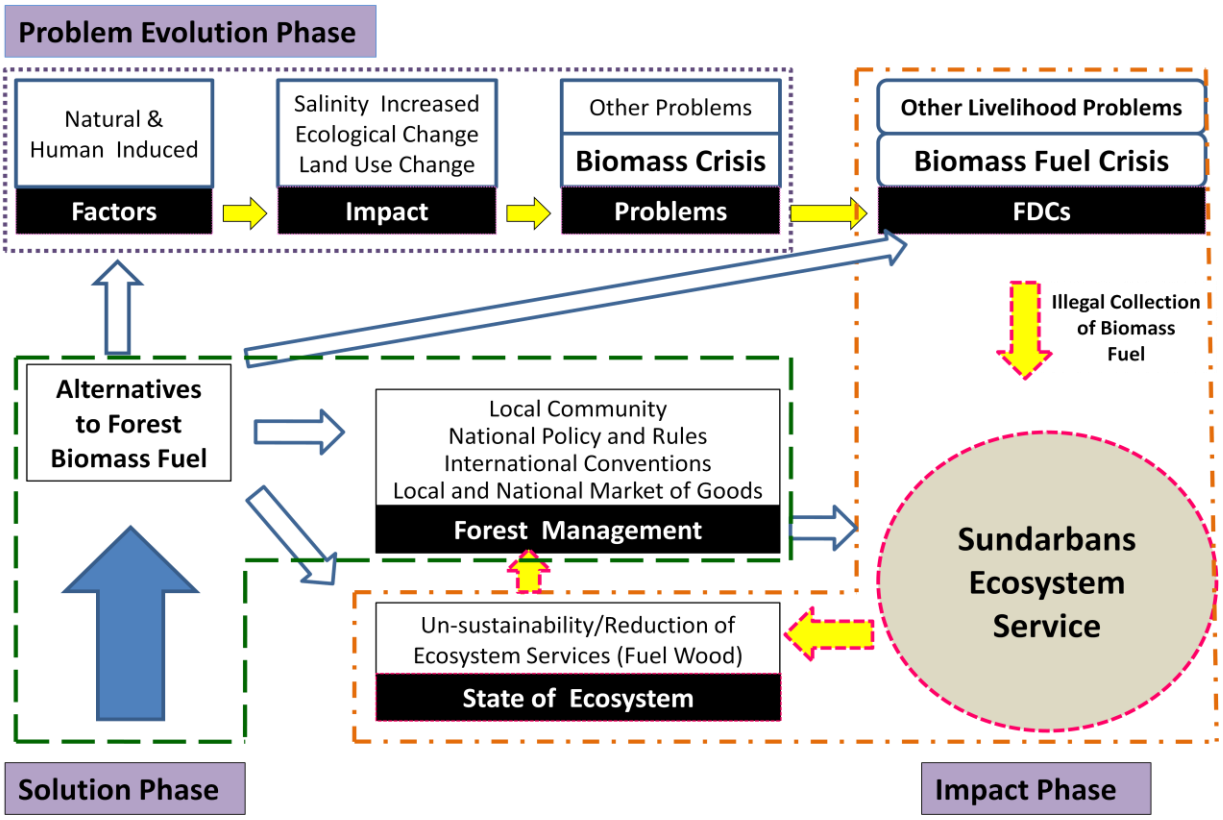

Figure 6: Conceptual framework of the study

The problem evolution phase includes factors responsible for increasing salinity, land use change and ecological change in the study area. These changes contribute many problems such as unavailability of biomass fuel, fresh water scarcity, food and fodder shortage, loss of biodiversity etc in the south-west region of Bangladesh.

Impact phase shows how fuel unavailability in the local environment forces people to be dependent on the forest resources and its impact on ecosystem services, sustainability and

management strategies of SRF. Since, SRF is a reserve forest, entering and collection of forest resources is strictly prohibited by "Forest Act 1927 (amended in 2000)" unless or otherwise permitted by the government or any authority of the government like Forest Department (FD).Moreover, collection of resources from SRF was banned by the government (Forest Wing-1, Ministry of Environment and Forest) via Office Order No. PaBaMa(BaSha-1)18/2004/1008, dated the December 3rd, 2007. Getzner and Islam (2013) reported involvement of communities living around the SRF in illegal collection of forest resources. The illegal collection of forest fuel biomass results in reduction of ecosystem services, which may contribute un-sustainability of the SRF in some extent. The fuel use behavior of FDCs also influences the forest conservation strategies that might not be effective without appropriate solutions.

The solution phase includes measures to address the biomass fuel crisis in FDCs and set strategies for SRF management by reducing dependency on forest resources. Identifying and supplying forest fuel alternatives to FDCs may ultimately solve their fuel crisis and, simultaneously, may reduce their dependency on forest resources.

3.2 The study area

The study was conducted in Shyamnagar upazila, a sub-district of Satkhira district occupying south-western corner of Bangladesh (figure 7). Satkhira district consists of seven-upazila of which Shyamnagar is one of the most adjacent sub-districts to SRF (figure 8).

3.2.1 Shyamnagar upazila

Geographically Shyamnagar is situated between 21º36' and 22º24' north latitudes and between 89º00' and 89º19'east longitudes (BBS, 2012). Its south is bordered by SRF and west by India. The Bay of Bengal also lies beyond the SRF to the south of this upazila (Alam and Chowdhury, 2010).

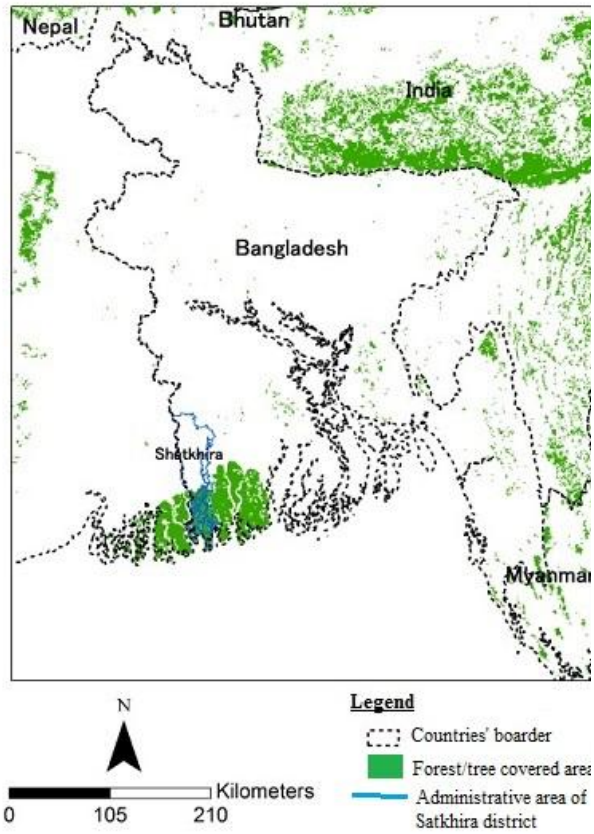

Figure 7: Location of Satkhira district

Figure 8: Location of study area (Shyamnagar upazila) within Satkhira district.

(Sources : Global Administrative Areas, 2015; Geographic Information System for Biodiversity Research, 2015)

Shyamnagar occupies an area of 1968.23 Km^2 with 13 unions (smaller administrative part of a sub-district and consists of bunch of villages) and 218 villages. It owns an enumerated population of 318,254 with 72,279 households. More than half of the population (51.40%) are illiterate and major share of this illiterate people belongs to female (56.10%) than male (46.20%) (BBS, 2012).

Around one and a half decade ago (2001), about 60% of the populations were engaged in agriculture activities. Then, fishing and shrimp farming were found to be the dominant secondary occupations in the area. Besides, occupations like shrimp fry collection, fuelwood collection, honey collection, golpata (*Nypafruitican*) collection, day-labor and engaging in small business and trading were identified as other important secondary income

generating activities (IGAs) in Shyamnagar(Miah et al., 2003). According to the most recent study (Getzner and Islam, 2013) which included part (Munshigonj village) of Shyamnagar upazila, fishing was reported as the most prominent occupation of 67% of the households (respondents) followed by crab catching (14%), honey and golpata collection (9%) respectively. In terms of individual land holding capacity, Miah et al. (2003) found small farm as dominant category belonging to 35% of the households (respondents) followed by marginal and medium farm (20% each) respectively earlier in Shyamnagar. Please see 'Categories of farm households' given in footnote.

The study area seems flat alluvial plain with apparent homogenous land and similar soil condition (Rashid, 2012). However, a considerable portion of the study area contains acidic sulfate soil. Salinity affects major portion of this upazila, since this area is included in the saline zone of Bangladesh. Overall, more than 60% area of this upazila was affected by salinity (Miah et al., 2003). The area is also categorized into moderate to highly saline zone categories where the pH value ranges from 5.94 to 7.44 (Islam et al., 2012).

During last decade, significant landuse change was observed due to anthropogenic as well as natural causes like cyclones, tidal floods etc in this upazila. Major changes included conversion of agricultural land into shrimp farm. Besides, local forest land also converted into shrimp farm and agricultural land (Khan, 2012). It was estimated that shrimp farms encroached around 44.44% land area of this upazila during the time starting from 1977 to 2011. At the same time, agriculture land was found to be decreased from 65.26% to 27.55%. Shrimp farming was recognized as the 'prime cause' of environmental degradation including water scarcity, decreased land fertility, increased salinity, increased health hazard, destruction of mangrove forest and agriculture land loss (Ghosh et al., 2014).

Categories of farm households (ASIRP, 2003): Landless (0.00 to 0.49 acre), Marginal (0.50 to 1.49 acre), Small (1.50 to 2.49 acre), Medium (2.50 to 7.49 acre, and Large (Over 7.50)

3.2.2 Sundarbans Reserve Forest

Geographically Sundarbans Reserve Forest (SRF), the largest single patch of mangrove forests in the world, is situated between 21º30' and 22º40' north latitudes and between 88º05' and 89º55' east longitudes (Barlow, 2009). The forest is naturally formedat the delta of the Ganges, Brahmaputra and Meghna rivers on the Bay of Bengal. Its total area is around 10,000 Km^2, 60% of which is found in Bangladesh and the rest in India.According to the legal status of SRF, there is no legal right of local people to entry and collect forest produce within the reserved forest, without being subject to permits issued by the Forest Department (IUCN, 1997).

Change in fresh and saline water flow in the Sundarbans occurred due to shift in rivercourses.Besides, level of salinity variation across the area was observed due to tidal fluctuations, changing moon phases between spring and neap tides, and variation in freshwater inflow. Besides, salinity was found to be increased from east to west direction with the starting of the dry season. During this time, there are still traces of saline waterin the north-west, since the Kobadok and Betna rivers are no longer connected to the Ganges-Brahmaputra system (Barlow, 2009).

SRF is a biodiversity hub with the presence of colorful and diverse flora and fauna. Occurrence of 334 plants, 49 mammals, 315 birds, 53 reptiles and eight amphibian species were recorded in different studies. Besides, over 120 species of fish were reported to be caught by the commercial fishermen in the area of Sundarbans (IUCN, 1997).

At certain seasons of the year, SRF provides a livelihood for an estimated 3 million people who are mainly of wood-cutters, fishermen, and collectors of honey, golpata leaves and grass. Out of these forest dependent people, around 2.5 million people live in small villages around the SRF. Apart from mentioned necessities, the local people are also dependent on the forest and waterways for firewood, timber for boats, poles for house-posts

and rafters, golpata leaf for roofing, grass for matting, reeds for fencing and fish for their own consumption (IUCN, 1997). It was reported that these Forest Dependent Communities (FDCs) were engaged in collecting forest resources indiscriminately (Sarwar, 2015). As a result, harvesting of wood, thatching materials, fisheries and other products from SRF decreased over time (Uddin, 2011).

3.3 Approach and methodology

3.3.1 Overall approach

The study adopted qualitative and quantitative approaches for satisfying its objective. Secondary data were collected through the review of relevant literature and documents including studies, journal papers, media reports, books,website, office records etc.

For primary data collection, questionnaire survey was conducted in the study area. Besides, group discussion and observation through field visit to the study area were happened to gather more raw data and have deeper understanding about the problem and sustenance of the FDCs livelihood in connection with fuel crisis. The flow of research activities is presented in Figure 9.

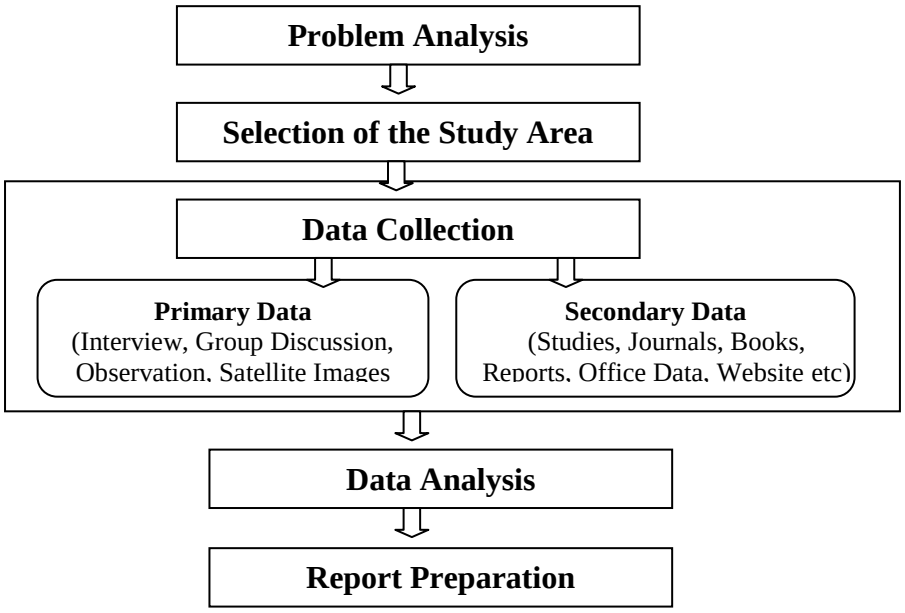

Figure 9: Flow of research activities

3.3.2 Sample selection

The study followed purposive sampling method, according to which, fivevillages located at the most adjacent tothe SRFwas purposively selected for primary data collection. Earlier, out of 13 unions of Shyamnagar Upazila, five unions closest to the SRF were primarily selected. Then, depending on the closeness of the villages to SRF, five most adjacent villages - one from each of the selected unions, were chosen for conducting face to face interview through semi-structured questionnaire and five group discussions. Figure 10 shows process of village selection for conducting questionnaire survey and group discussion.

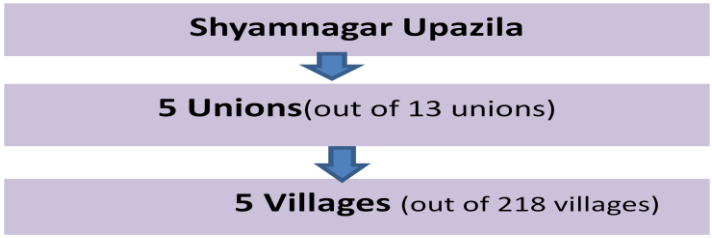

Figure 10: Selection of villages for conducting questionnaire survey and group discussion

The study sample was composed of 50 respondents, counting 10 respondents randomly selected from each of five villages. The selected villages were namely Dumiria, Burigoalini, Munshigonj, Kalinchi, and Koikhali (figure 11). In this connection, table 2 also includes the particulars of the selected villages as well as distribution of sample size.

Table 2: Particulars of the selected villages and distribution of sample size

Serial No	**Village Name**	**Union Name**	**Population** (FD, 2010)	**No of Respondents**
1	Dumuria	Gabura	3768	10
2	Burigoalini	Burigoalini	1514	10
3	Munshigonj	Munshigonj	2499	10
4	Kalinchi	Ramjan-nagar	2138	10
5	Koikhali	Koikhali	2000	10
Sample size				50

Out of 218 villages of Shyamnagar, these selected villages were judged to share relatively similar socio-economic background. Before executing the actual questionnaire survey, a preliminary survey was carried out to examine the features of study site which

favored the selection of the respondents for this study. The common characteristics of these villages were as follows:

a) The villages were detached from SRF by river channels and situated along the south most boundary line of Shyamnagar;
b) The villages were found to be heavily depended on the ecosystem services of SRF for their livelihood;
c) Most of their income, on an average, was very low;
d) The villages share similar problems including fuel crisis; and
e) Majority of the villagers were literally illiterate.

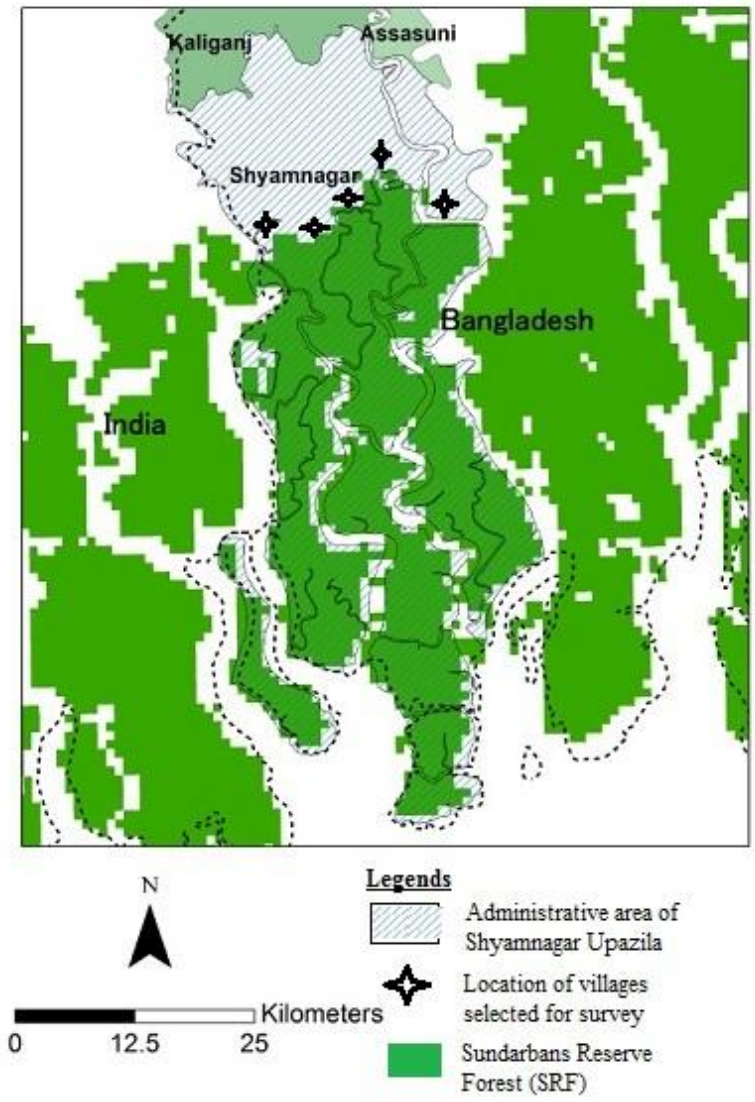

Figure 11: Location of villages selected for conduction questionnaire survey
(Sources: Global Administrative Areas, 2015; Geographic Information System for Biodiversity Research, 2015)

Since the objective of this study was to explore alternative means of tackling fuel crisis, larger and statistically appropriate sample size might not be so crucial in determining final outcomes. Hence, sample size as much as 50 respondents from 50 households were finally accounted for primary data collection.

3.3.3 Data collection

Online extensive literature review was ensured for secondary data collection in the form of related published journals, papers, studies, books, seminar proceedings, reports, newspapers articles, government's record and policies etc. For collecting more literature and related information, Bana Bhaban Library of Forest Department, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh and seminar library of Forestry and Wood Technology Discipline, Khulna University were also visited. Besides, Divisional Forest Office, Satkhira Range Office and Kadamtala Forest Station of Sundarbans West Forest Division were also visited for government records and necessary information on study issue.

The field data were collected by visiting and surveying the target households in the study area during August-September, 2014. Data collection was intended to capture respondent's basic demographic data (such as age, family size, education level, occupation, level of income and expenditure, physical and livestock asset), fuel use status(such as type, amount, price), fuel dependency on forest resources (such as sources of fuels, number of days involved in collecting fuels, trend of fuel use etc) and responses against the queries in the line with the spirit of the study objective and research questions. Please see Appendix A for detail questionnaire prepared for household survey.

In order to get the collective responses, five group discussions – each in every selected village, were organized with 6 to 8 community members including community elders and educated individuals. Community's overall socio-economic status together with major

issues relating to fuel crisis, fuel alternatives and necessary measures for solving the problem was extensively discussed. Additionally, their responses were justified, with a framework developed through consulting relevant literature, for selecting appropriate alternatives to forest biomass fuels for communities. Please see Appendix B for group discussion topics and fuel alternatives assessment framework.

Since majority of the villagers were illiterate, local assistance, in terms of helping author to make questions to the respondents and translating/explaining their responses in understandable manure by some community people, was ensured throughout the survey.

During the time of executing field survey and group discussion, political turmoil in Bangladesh restricted free movement in some parts of study area. Field work was also constrained by limited transport accessibility due to political disturbance and remoteness of the study site.

3.3.4 Data processing and analysis

The respondents' feedback in the form of data and information were carefully reviewed, checked by telephonic contact in case of ambiguous response and sorted according to the sequence and requirements of the study. Microsoft Excel was used to analyze the collected data for generating information. Hence, nearly all necessary tables, graphs and figures cited in the result and discussion section were generated through Excel. All other unwanted part of the collected data and information were discarded to avoid bulky size of the thesis.

For validating the land use change in the study area, two high resolution multi-spectral satellite imagery SPOT 10m Color (taken on December 11, 2013) and SPOT 20m Color (taken on February 27, 1989)were collected and processed. Land use classification was conducted in eCognition Developer 9 (Trimble) and further processed in ArcMap 10 (Esri). In eCognition, land use classes were as follows: shrimp farms, agricultural land, inland

vegetation (including homegardens and houses densely mixed with trees), rivers and mangrove forest. Afterward, images were segmented (multi-resolution segmentation) and a sample for each class was taken with features such as layer values mean, standard deviation, and geometry (length of objects). Images were next verified against high resolution images from Google Earth. In Arc Map eCognition, Developer shape file with classification was reprocessed into dissolved classes, clipped to inland area boundaries and the area of each specific land use was calculated. The limitation of the classification was a difference in the resolution, which might affect the recognition of less dense inland vegetation.

CHAPTER 4: RESULT AND DISCUSSION

4.1 Socio-economic and demographic characteristics of the respondents

The socio-economic and demographic data were collected through face-to-face questionnaire survey of a sample of 50 households. Respondents were mainly of female (56%) than male (44%) in terms of gender as well as representatives of households. Their average age was just above 40years ranging from minimum 16 years to maximum 78 years old. Major portion of the respondents (76%) belonged to an economically active age (25-year to 54-year). Overall family size was found 5.08 which was higher than national average (4.44), even than that of Satkhira district (4.21) in 2011 (BBS, 2013). The detailed demographic profile of the respondents (table 3) was as follows:

Table 3: Demographic profile of the respondents

Variables	Frequency	Percentage
Gender		
Female	28	56
Male	22	44
Total	50	100
Age		
Less than 25 years	3	6
25-34 years	16	32
35-44 years	12	24
45-54 years	10	20
55-64 years	5	10
65-74 years	3	6
75 years and above	1	2
Total	50	100
Education		
Illiterate	29	58
Did not complete primary education	7	14
Primary (Class I-V) education	7	14
Secondary (class VI-X) education	5	10
Higher Secondary (class XI-XII) education	2	4
Total	50	100

Education is considered as a catalyst for enhancing desired social change, economic growth and human development (UNESCO, 2012).In the study area, more than half of the

respondents (58%) were found illiterate followed by just literate – who did not complete their primary education (14%), primary education (14%), secondary education (10%) respectively. Only a few of them completed higher secondary level of education (4%) and got admitted to highereducation (undergraduate) level, though they did not able to complete their courses (please see table 3). Hence, the share of literate respondents in the study area was estimated as42% which was relatively lower than that of national (51.77%) as well as Satkhira district (52.07%) (BBS, 2013). It was found even lower than overall literacy rate of Shyamnagar Upazila (48.6%) in 2011 (BBS, 2012).

During the field survey, respondents' family income (in BDT - Bangladeshi Taka/currency) was collected to know about their socio-economic status. According to the study findings (figure 12), the majority of the households (88%) having monthly income around BDT 15,000 (USD 191*) belonged to poor income group followed by medium income group (8%) and high income group (4%) respectively.

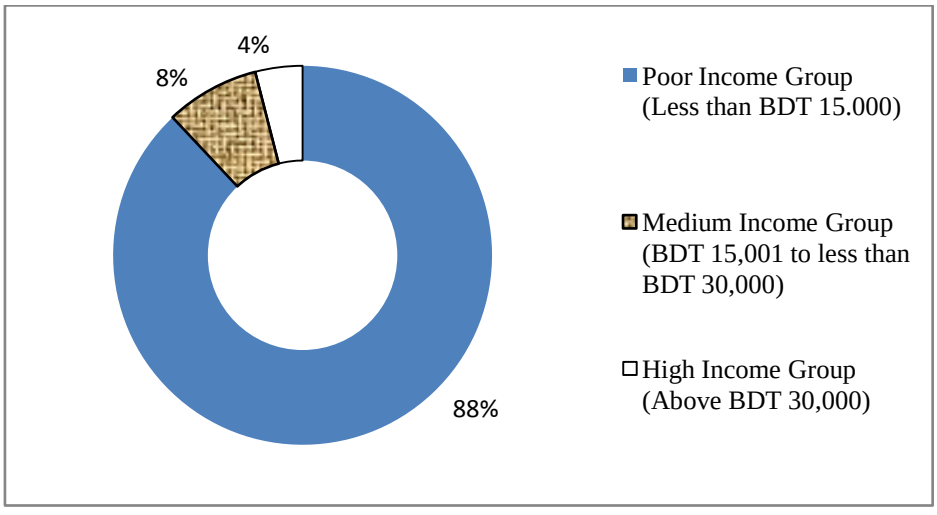

Figure 12: Grouping of households based on their average monthly income (BDT)

Klasen (2013) mentioned that the people earning less than USD 1.25 per day is considered as poor living under the poverty line as per definition of poor by World Bank (WB). So, families consisting five members each may be considered as poor, since their

monthly average income remains lower than BDT 15,000 equivalent to USD 193*(USD 1.25 X 5 X 30). The study confirmed average household size of 5.08 with monthly average income of BDT 10,310 (around USD 133). Hence, major portion of respondents (88%), in general, was poor and living under the poverty line.

The study also revealed that households in the study area were found poor with limited unmovable assets in terms of land ownership. Depending on the size of farm household, around three-fourth of the respondents (72%) was categorized as landless followed by marginal (18%), medium (6%), large (4%) respectively (figure 13). According to figure 13, no small farm household was found during the execution of survey, though Miah et al. (2003) reported small farm (35%) as dominant category earlier in Satkhira. It seemed small farms households turned into landless households.

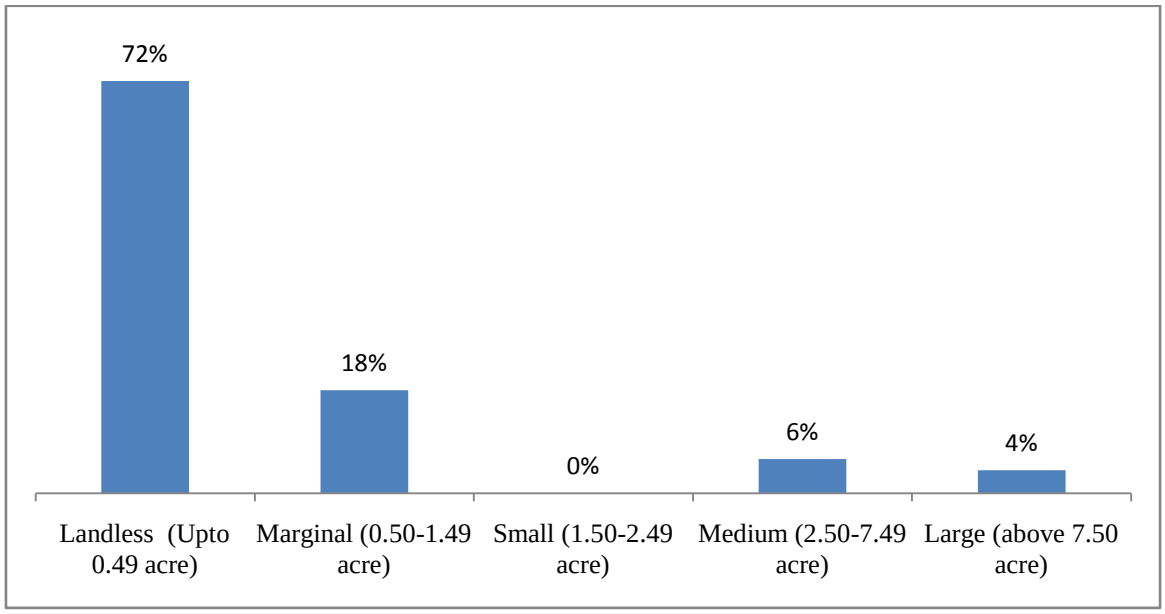

Figure 13: Categories of farm households by ownership

In this concern, figure 14 presents respondents' overall land ownership scenario which reflects huge disparity in access to land resources between the respondents who were occupationally shrimp farmers and who were involved in different occupations other than shrimp farming. Shrimp farmers, consisting 10% of the total respondents, controlled overall

*The exchange rate on June 24, 2015 was BDT 77.80/USD by the central bank of Bangladesh (BB, 2015).

76.10% of the total land resources owned by all respondents together. On the other hand, majority of the respondents (90%) owned 23.90% of their land resources and belonged to poor income category.

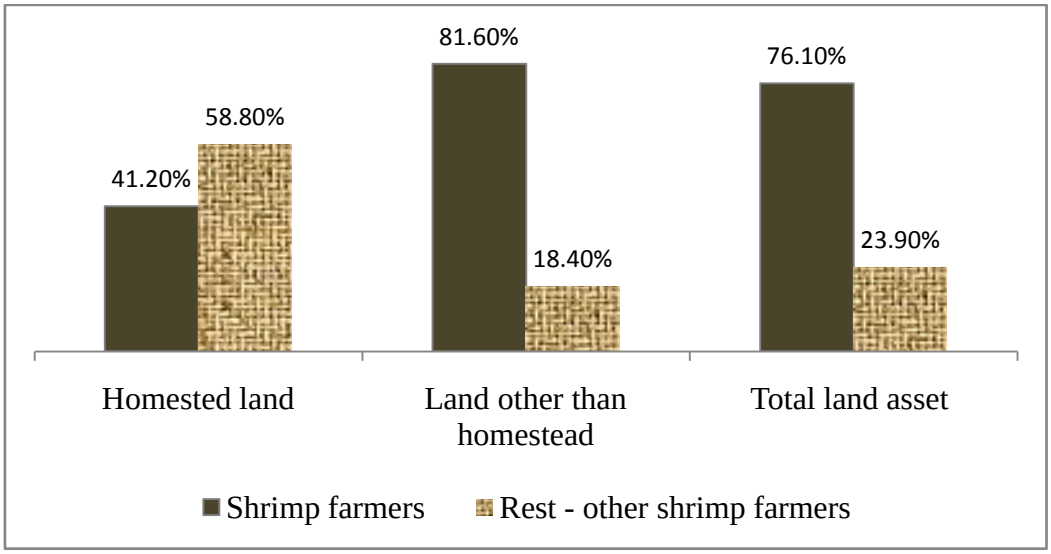

Figure 14: Land resources (in percentage of area) owned and controlled by the respondents

Number of livestock population belonged to households was very poor (figure 15). The survey counted only the number of cattle head and goat belonged to the respondents.

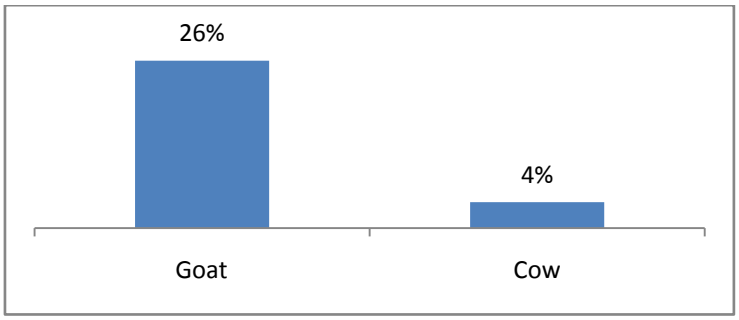

Figure 15: Number of households (%) having livestock asset (for each case N=50)

According to the figure 15, only 4% of the respondents owned single cattle head per household, where 26% households were found to be rearing goat under the limited scope of livestock rearing in the study area.

4.2 Dependency of respondents on forest

4.2.1 Means of livelihood

The interview with the household representatives revealed that around 78% of respondents' occupations were somehow related to the ecosystem services of SRF. These respondents were found to be engaged in a number of occupations such as shrimp fry collections, fish catching, crab catching, honey collection etc from Sundarbans. It was also observed that 62% households' earnings came from more than one occupation. Based on the leading occupation of the households, fishing in terms of shrimp fry collection and fish catching, was found dominant means of livelihood to 50% of the respondents followed by small business and trading (16%), shrimp farming (10%), crab catching (8%), brick field worker (8%) and others (8%) such as day labor, honey collection etc (figure 16).

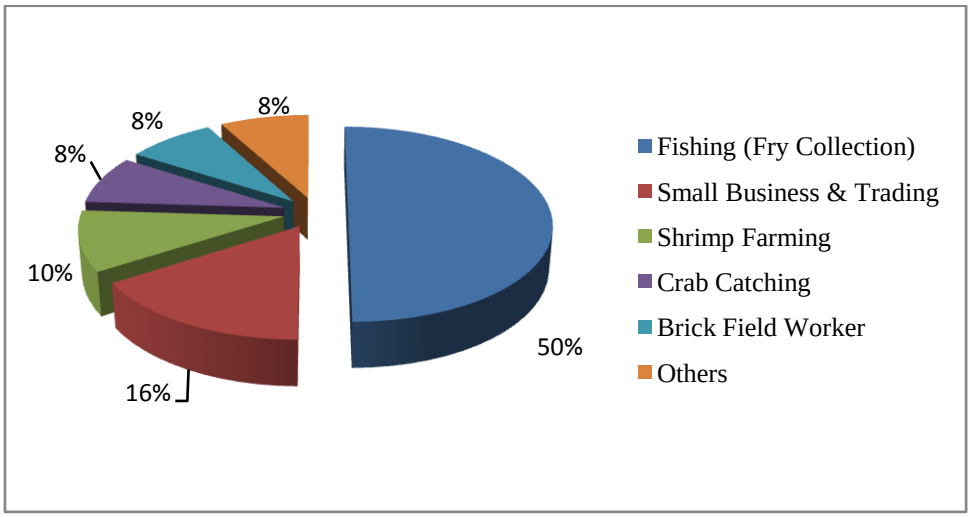

Figure 16: Leading occupations of the households (%)

Getzner and Islam (2013) reported fishing as the main occupation of the inhabitants of a village (Munshigonj) in the study area, where other important occupations were crab catching, honey and golpata collection. Around one and half a decade ago, Miah et al. (2003), on the contrary, found major share of the population (60%) employed in agriculture as their dominant occupation in the study area, where fishing and shrimp farming were mentioned as second most important occupations for the local people.

4.2.2 Use of forest biomass fuel

It was evident from the household survey that almost all of the respondents (94%) partially or fully were dependent on forest biomass resources for their cooking fuel. Rest of the respondents (6%) never used forest biomass for their domestic cooking.

Most of the respondents who were using forest biomass fuel, collected fuel from more than one sources such as forest (for wood-fuel, floating forest biomass i.e., fruits, leaves and branches washed away with tide and river current), homegarden (for tree parts and bamboo parts) and livestock (for cowdung). Only 4% of those respondents were found to be fully dependent on homegarden fuel and rest (2%) on both homegarden fuel and cowdung.

According to the findings (figure 17), overall 82% respondents were found to be using forest woody biomass from SRF. Besides, 40% of them were using floating fruits, leaves and branches washed away with the steam of tidal rivers coming through SRF. Of the total surveyed, 16% respondents used homegarden fuels such as fruits, leaves, branches and other parts of bamboo and trees. Some 4% were observed to be using cowdung, though its amount was insufficient to the household need.

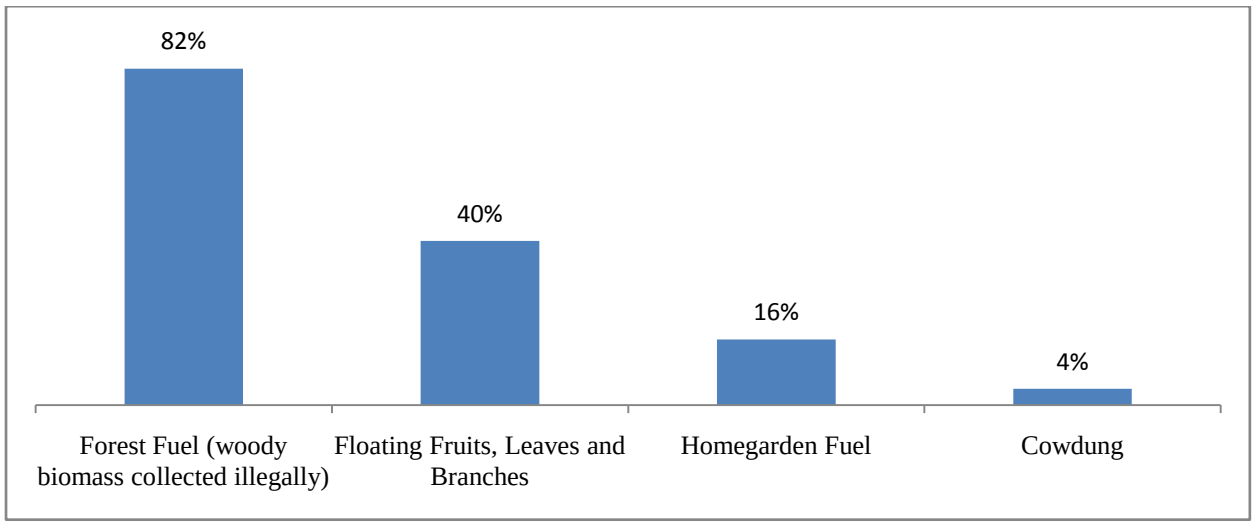

Figure 17: Kinds of biomass fuelused by households (for each case N=50)

Of the total surveyed, 72% respondents acknowledged their direct involvement in illegal fuelwood collection from SRF. On an average, they collected forest biomass 2-3 times in a

month. Getzner and Islam (2013) reported the illegal collection of fuel wood ranging from 1100 kilogram to 1300 kilogram per household per year. It was mentioned that 14% of the respondents were found to be collecting biomass fuel from market. They also informed that almost all of the fuel available in market came from forest. Among them only 4% of them declared forest and market as sources of their cooking fuel. Hence, 82% respondents were found directly dependent on forest woody biomass.

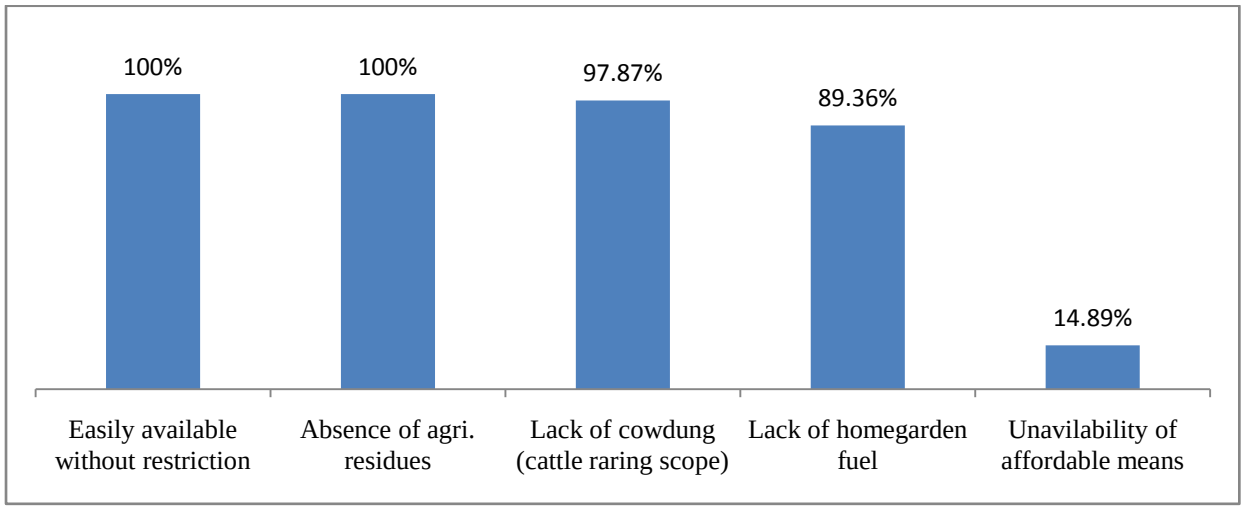

Figure 18: Reasons for exploiting forest biomass as domestic cooking fuel (for each case N=47)

Though extraction of fuel biomass from SRF and its use as well as selling in the market is illegal and subject to be punished by law, most of the local people were found reluctant to maintain this provision in real sense. According to the survey records, almost all of the respondents (94%) were recognized to be using biomass fuel illegally collected from SRF. In response to why they were using forest resources as domestic cooking fuel, all respondents using forest biomass agreed on the ground of its easy availability within their reach and without any visible restriction from Forest Department (FD). No respondents reported any incidents of monetary exchange during collection, transport and using of forest fuel biomass. They all also claimed absence of agriculture residues in their locality which was once extensively used as fuel for meeting household energy need. Besides, they mentioned unavailability of cowdung due to lack of cattle raring opportunities (97.87%), lack

of homegarden fuel (89.36%) and unavailability of other affordable means (14.89%) around their communities. Figure 18 shows reasons for exploiting forest biomass as domestic cooking fuel.

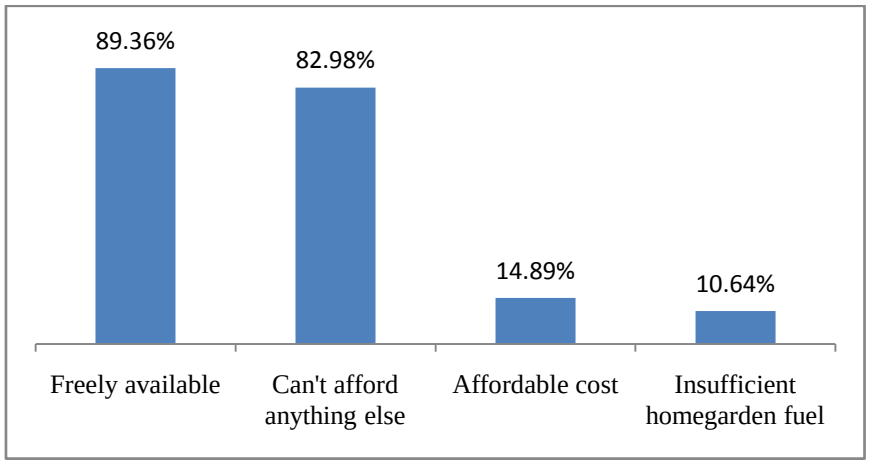

Figure 19: Reasons for using forest biomass by the respondents (for each case N=47)

There was another query to investigate the causes for using only forest biomass other than alternatives to biomass fuel options such as paraffin/kerosene, LPG etc. Figure 19 shows the reasons for using forest biomass other than alternatives fuels by the respondents. Out of the respondents using forest biomass (94%), 89.36% respondents availed fuel biomass fully or partially for free, since they collected it illegally from forest or market. Additionally, cost un-affordability (82.98%) of using biomass fuel from market and even, other alternative fuel options like kerosene or LPG, was another major cause behind their fuel use behavior. A small portion of the following respondents (14.89%) collected biomass fuel from market, since it was affordable or partially affordable for certain period of time to them. A few of respondents (10.64%) found the amount of fuel produced in homegardens insufficient to meet their domestic need, which forced them to use forest resources.

In search of actual reasons of dependency on forest biomass fuel, it was observed that economic condition in terms of limited household-income was negatively correlated with the respondents' dependency syndrome. Since most of the respondents were poor (Figure 12) and

absence of traditional sources of biomass fuel (cowdung, agriculture residues and homegarden fuel) was reported, respondents were unable to manage other available fuel options such as paraffin/kerosene, LPG etc. Subsequently, they became dependent on forest resources for fuel.

4.3 Factors compelling FDCs to be dependent on forest biomass fuel

The interview result identified several factors contributing fuel crisis in the study area and compelling FDCs to be fully or partially depended on forest resources. All respondents acknowledged the biomass shortage in their respective localities. According to their opinion, the shortage of fuel energy occurred due to several natural and human induced factors (figure 20). During the execution of the survey, almost all of the respondents (94%) mentioned extensive brackish water shrimp farming as the dominant factor followed by frequent natural disasters (58%), unproductive homegarden (50%), and other saltwater based landuse-cum-economic activities around their communities (30%) respectively.

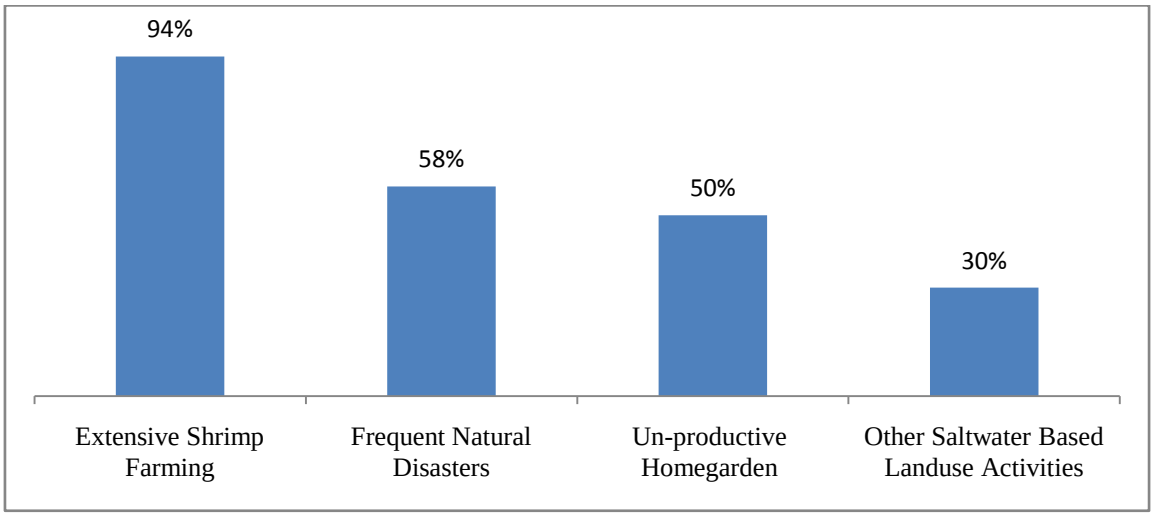

Figure 20: Factors affecting respondents to be dependent on forest biomass fuel (for each case N=50)

As seen in figure 20, brackish water shrimp farming is the major factor contributing biomass fuel shortage in the study area. Like in tropical Asia and Latin America, part of coastal Bangladesh has been experiencing land-use change such as transformation of rice fields into shrimp farms with degradation of soil quality and agro-ecological environment

(Ali, 2006; Khan, 2012). Miah et al. (2003) also identified shrimp farming and its associated activities adversely influencing ecological and socio-economic set of the south-west region of the country. Several studies (Miah et.al., 2003; Karim, 2006; Braun and Saroar, 2012) reported its impact on disappearance of agriculture residues which was widely used as fuel earlier in this region including study area. Besides, it contributed natural vegetation loss from the area (Swapan and Gavin, 2010). Shrimp farming limited the livestock rearing opportunities with declined number and production of livestock (Swapan and Gavin, 2010; Miah et.al., 2003; Hossain, 2011; Karim, 2006; Ali, 2006). Subsequently, cowdung which was also used as fuel earlier disappeared from the study area (Braun and Saroar, 2012).

In relation to the overall landuse change, the study analyzed satellite imagery in order to validate the recurrent occurrence of land conversion in the study area (table 4). The land cover change analysis indicated significant change in landuse pattern in the study area over the time (figure 21).

Table 4: Summary statistics of the landuse classification and the land cover change in the study area

S. No.	**Land Use Class**	**Area (in hectare)**		**Area (in percentage)**		**Change (in percentage)**
		1989	**2013**	**1989**	**2013**	
1	Agriculture land	4311	1117	66.79%	17.30%	(-) 49.49%
2	Inland Green Vegetation (including homegarden)	1270	1658	19.67%	25.69%	6.02%
3	Rivers	255	151	3.97%	2.34%	(-)1.63%
4	Shrimp Farms	618	3529	9.57%	54.67%	45.10%
Total		6454	6454	100%	100%	

According to the table 4, agricultural land, in terms of percentage of total area 6454 hectares, decreased by 49.49% starting from 66.79% in 1989 to 17.30% in 2013 respectively. On the contrary, shrimp farm increased by 45.10% starting from 9.57% in 1989 to 54.67% in 2013 respectively. Similarly, area under inland green vegetation including homegardens and houses densely mixed with trees increased by 6.02% during the same time. This might be due to increased pressure from population who occupied more land for house building over time.

The result may fluctuate at little due to the difference in image resolution. Islam et al. (2012) reported more or less similar pattern of land use change in the some parts of the study area.

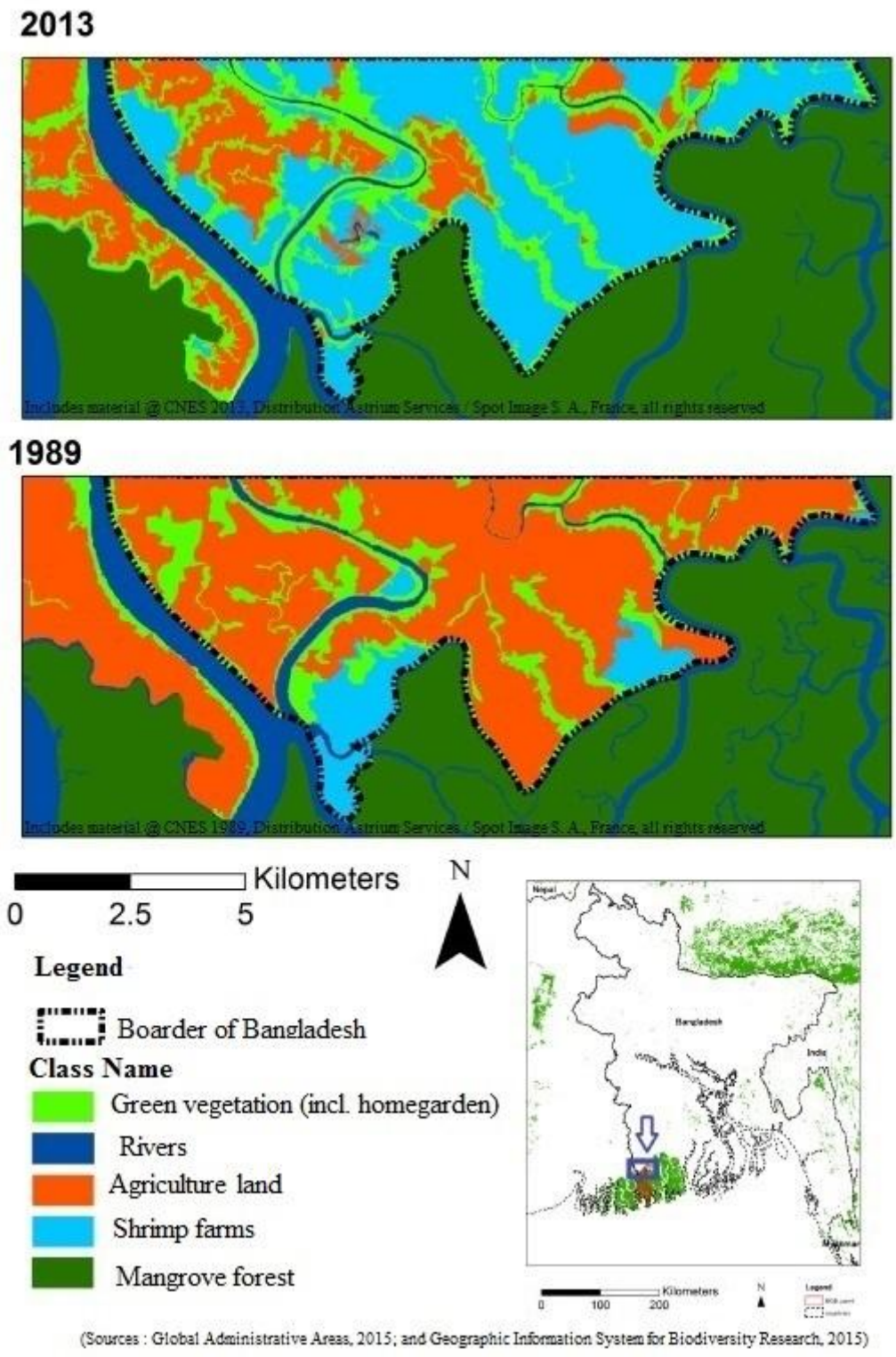

Figure 21: Historical maps of 2013 and 1989 showing change in landuse pattern in the study area.

Image 1: Shrimp farm grabbing agriculture land in the study area

According to figure 20, more than half of the respondents (58%) reported unwanted disturbances such as water logging, salinity intrusion, damaging agricultural crops and homegarden etc due to the frequent occurrence of natural disasters. According to their opinions, frequent occurrence of natural disaster resulted fuel crisis in their locality. Significant part of coastal Bangladesh has been facing problems related to salinity intrusion, cyclone and tidal surges, erosion, water logging (Tabrig et al., 2013). The study area was also found susceptible to various landuse changes exacerbated by different disasters such as cyclone, tidal flood, salinity and water logging. It resulted with declining agriculture production, decrease of cattle and tree species in homegarden, enhanced deforestation and decreased household income (Khan, 2012). Tabrig et al. (2013) found salinity problem setting huge obstacles against livelihood options and economic development in the region. It ultimately encouraged shrimp farming which created obstacles to agriculture practices (Haider and Hossain, 2013; Hossain, 2011). Many farmers compelled to get into shrimp farming in their arable land since rice production continued to decline due to natural intrusion or leaching out of saline water from nearby shrimp beds (Hossain, 2011).

The encroachment of shrimp farms near homestead area increased salinity level in south-western Bangladesh (Rahman et al., 2011). Homegardening was reported to be extremely difficult due to the increased salinity. A wide range tree species grew abundantly

in homegarden before shrimp farming introduced in the region. Recently aggression of shrimp farming caused serious problem for the survival of those tree. Only a few tree species bearing no fruits survived to a limited extend (Karim, 2006).

Image 2: Unproductivehomegarden in the study area

Several other studies (Miah et al.,2003; Hossain, 2011; Rahman et al. 2011) reported decline of both number and productivity of homegarden species. In some part of this region, most of the fruit trees were found dead (Hossain, 2011). Besides, Paul and Vogl (2011) mentioned impact of shrimp farming in limiting homegardening opportunity. Since, homegarden was one of the most common sources of cooking fuel in the study area, decline in the number and productivity of homegarden plantations contributed fuel crisis (Miah et al., 2003).

Image 3: A crab farm in the study area (INAFI and PROCASUR, 2014)

Apart from shrimp farming, around one-third of the respondents (30%) reported a few other saltwater based economic-cum-landuse activities such as crab farming, hatching shrimp fry

etc to be practicing in the study area. Since Bangladesh exports crab, it has been playing critical role in securing livelihoods of the farmers in south-west region of the country since 1990 (INAFI and PROCASUR, 2014). Respondents claimed crab farming as second major economic as well as land-use activity contributing increased salinity in the study area. These saltwater based economic activities like shrimp farming also contributed fuel shortage in the FDCs.

4.4 FDCs' attitude towards forest conservation

4.4.1 Perception on the benefits of forest

According to the study findings, respondents were found to be more or less aware of the benefits of forest. They all claimed that SRF provides fuel wood. According to their opinion in figure 22, other major benefits provided by this mangrove forest were thatching material (86%), food (46%), timber (30%), livelihood support (10%), recreation (4%) and religious (spiritual/cultural) support (2%) etc.

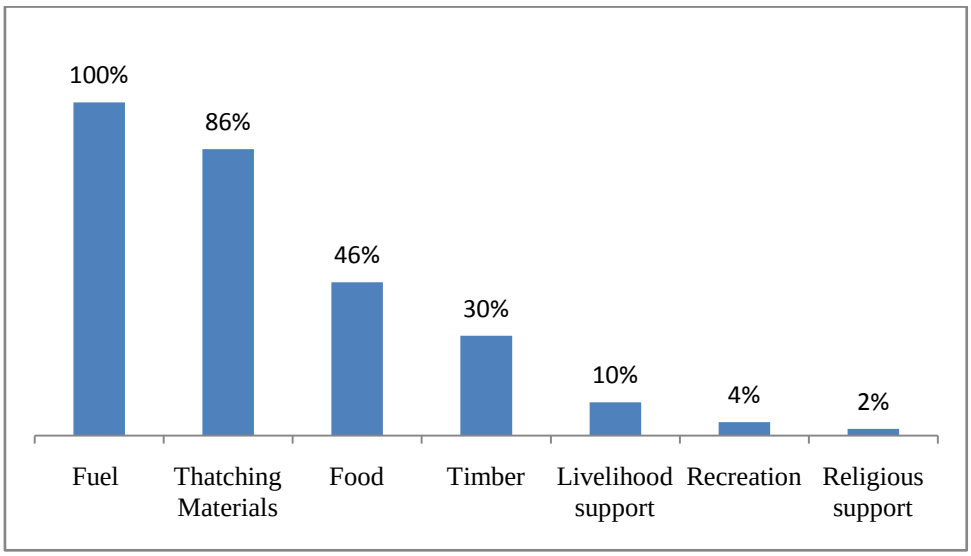

Figure 22: Respondents perception on the benefits of forest (For each case N=50)

4.4.2 Awareness on the role of forest

Along with the findings shown in figure 22, respondents, in response to an open ended question, recognized some additional supports of forest indicating their level of

awareness (figure 23). Of the total surveyed, majority (78%) mentioned the role of forest in disaster prevention. They described SRF as 'live wall' saving their lives and properties through reducing the speed of cyclone and storm surge. Around one-third of the respondents (32%) reported forest as the supplier of oxygen. Some of them (20%) advocated for the role of forest in keeping environment healthy and some other (12%) for providing tangible benefits. A very few of them mentioned forest based community activities as source of income (6%) as well as overall national development (2%).

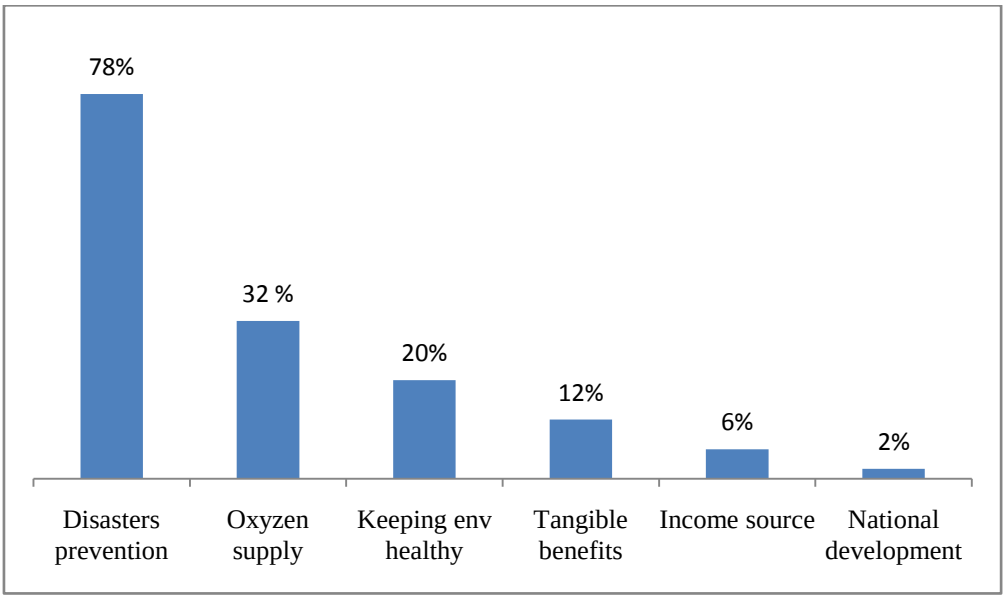

Figure 23: Respondents awareness on the role of forest (For each case N=50)

4.4.3 Attitude towards forest conservation

The interview result revealed respondents' positive attitude towards forest conservation (figure 24). Almost all of the respondents (96%) wanted SRF to be conserved with more efficient manner. Only 2% of them were found reluctant to emphasis on forest conservation and they desired to set priority of securing livelihood over conservation practices. Rest (2%) was unaware of such kind of forest management approach.

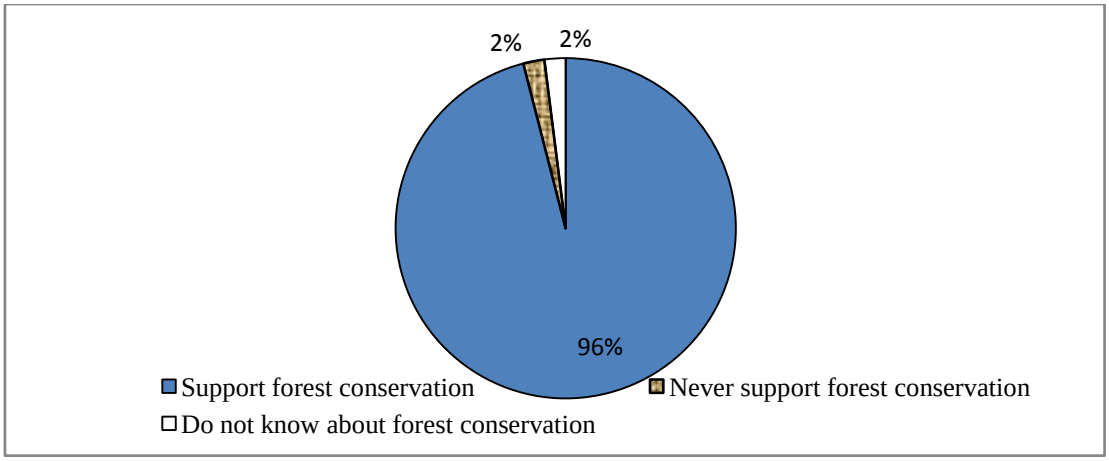

Figure 24: Respondents' attitude towards forest conservation

The higher level of awareness regarding the forest conservation might also be due to the interventions of development as well as forest conservation projects implemented by government and NGOs in the study area.

4.5 FDCs' attitude towards alternatives to forest biomass fuel

4.5.1 Awareness on the alternatives to forest biomass fuel

The study conceived several fuel options as alternatives to forest biomass fuel such as biogas, solar cooker, fuel efficient stove, homegarden, agriculture residue, cowdung, liquid petroleum gas (LPG), petroleum oil like kerosene or paraffin.

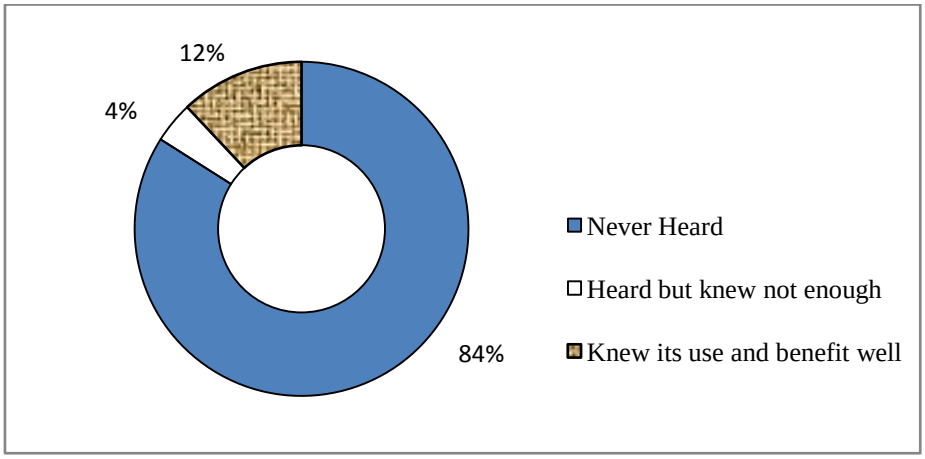

Figure 25: Respondents' awareness on the use of biogas

Of the total surveyed, 84% respondents never heard the name of biogas in their lifetime where only 4% of them knew very little about its benefits. Rest (12%) was found to be well informed about this alternative and its benefits in terms of fuel saving in domestic cooking. Figure 25 represents the respondents' awareness on the use of biogas.

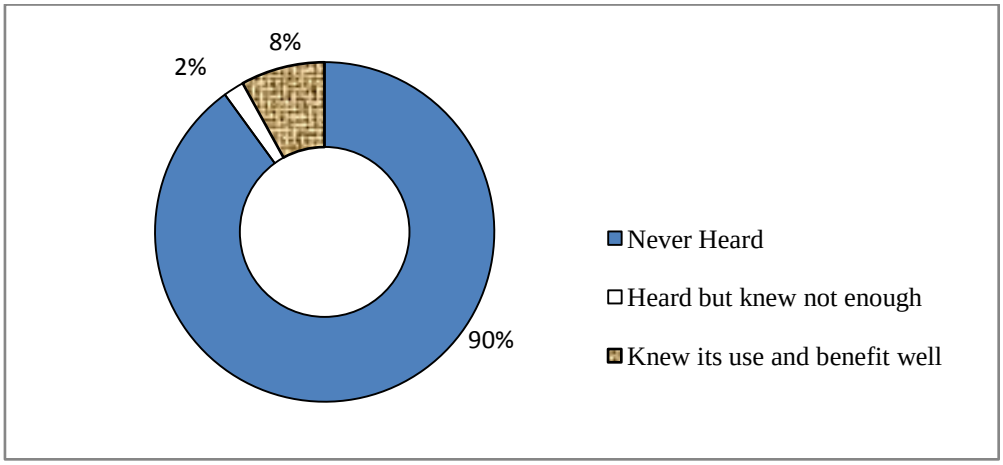

Figure 26: Respondents' awareness on the use of solar cooker

In case of solar cooker, most of the respondents (90%) were found ignorant of it. Only few of them (2%) knew very little about solar cooker. On the contrary, 8% of them were found aware of its use and benefits as well. Figure 26 shows the respondents' awareness on the use of solar cooker.

According to the study findings, respondents all were well informed of homegarden fuel, agriculture residues and cowdung. These alternatives once were widely used as fuel before shrimp farming extensively introduced in the study area (Miah et al., 2003).

According to respondents' information, they used LPG/kerosene during disasters, especially emergency situation. As they found these alternatives very expensive for them to use as cooking fuel, they used any of these both alternatives for short or certain period of time. Hence respondents all were very much familiar with LPG and Kerosene.

Survey findings also identified fuel efficient stoves as well known fuel using device for producing fire and heat for cooking in the study area. Respondents all knew about this device and its benefit due to the intensive interventions of NGOs.

4.5.2 Priority of using alternatives in absence of affordable and legally available fuel resources

Figure 20 shows the factors compelling communities' people to be forest dependent through driving away the traditional as well as local biomass fuel resources such as homegarden fuel, agriculture residues and cowdung from the study area. Though limited use of homegarden fuel and cowdung was reported, survey findings confirmed no evidence of using agricultural residues by the respondents (figure 17). It seemed agriculture residues disappeared from study area. Due to the high cost involvement, respondents rejected LPG and kerosene to use for long time in normal situation. Additionally, they were not much informed of using biogas and solar cooker for cooking purpose. Only they could use was fuel efficient stove, if affordable and legally available fuel resources were existed in and around their communities. Since there were no such fuel sources available within their reach, communities became reliant on SRF resources for cooking fuel.

According to the survey findings, almost all of the respondents (94%) were found fully or partially dependent on forest biomass fuel (sub-clause 4.2.2). To meet up the domestic fuel need, these respondents all supported purchasing fuel from local market, followed by switching to fuel alternatives (82.98%), stealing (illegal removal of fuel biomass) from forest (76.60%), growing fuel in their homegarden and fallow lands (25.52%) respectively. Respondents' reactions to the absence of affordable and legally as well as locally available fuel resources were documented according to their multiple choices of preferences (figure 27).

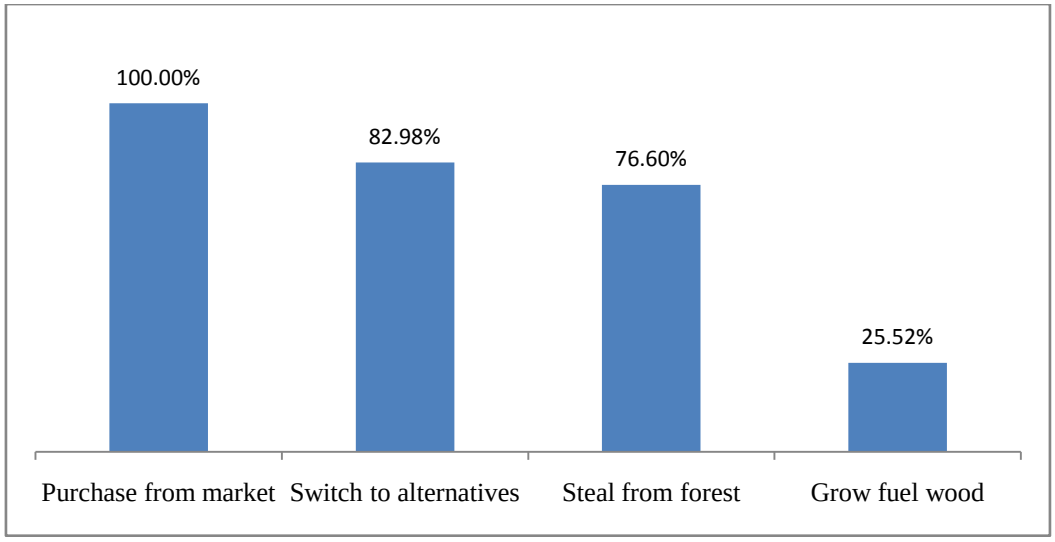

Figure 27: Respondents' multiple reactions to the absence of affordable and legally available fuel resources (For each case N=47)

Out of the total surveyed, only 6% respondents owned relatively large tract of homegarden that produced enough fuel biomass for meeting their household need. They showed no reaction to unavailability of affordable and legally available fuel resources.

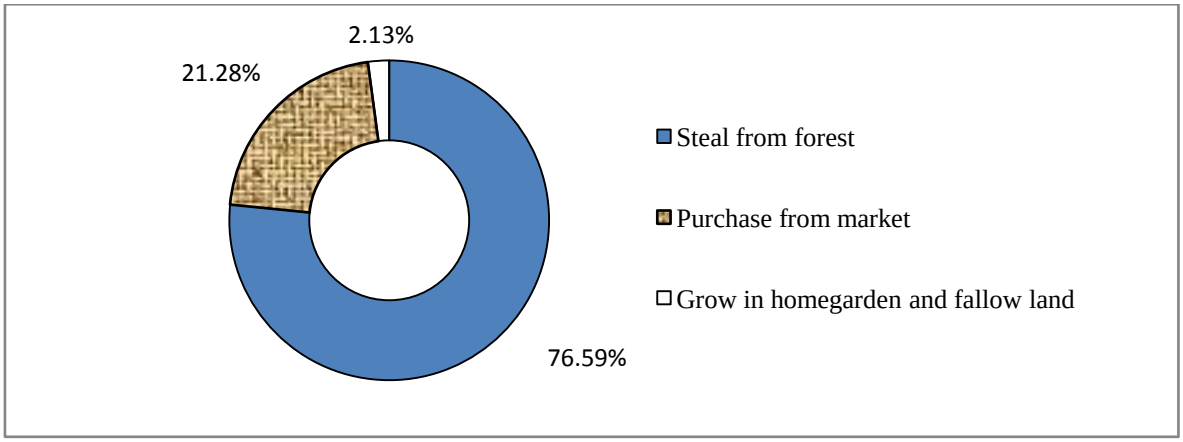

Figure 28: Respondents' immediate reactions to the absence of affordable and legally available fuel resources (For each N=47)

Even though respondents expressed their intention to use biomass fuel alternatives in multiple choices of preferences (figure 27), they did not choice any of the alternatives as their immediate choice under the similar context (figure 28).Then, stealing fuel biomass from forest got the priority of 76.59% respondents which might due to absence of affordable/free as well as legally available fuel resources and lack of economic capacity to purchase fuels

from markets (figure 28). According to the figure 28, purchasing fuel from local market was preferred by 21.28% of respondents and growing fuel in the homegarden and fallow lands by the rest (2.13%).

Under the following circumstances, respondents were asked to sort out the desired characteristics of biomass fuel alternatives they could use in future. Based on their collective opinions expressed in the group discussions, their desired alternatives would have the following major features as follows:

a) Alternatives should be free or at least, inexpensive and affordable for poor income households;
b) It should be available within their reach e.g., in and around their communities; and
c) It should be available in sufficient amount to meet household need.

In case of fuel alternative device, it should be additionally fuel efficient, smokeless, technologically sound and handy enough to feed with woody and non-woody biomass.

4.6 Barriers to accepting fuel alternatives by FDCs

4.6.1 Barriers to accepting forest biomass fuel alternatives

There were several barriers to accepting fuel alternatives recognized by the respondents during the field survey. According to the respondents' opinions, these barriers, in terms of their capacity in favoring factors compelling FDCs to be dependent on forest for fuel, are shown in figure 29. Majority of them (96%) found lack of government initiatives as the main issue for generating extreme situation that compelled them to be over dependent on forest biomass fuel. In relation to the fuel crisis, respondents translated lack of government initiatives as the ignorance of central as well as local government. Government took no step in combating negative ecological change followed by drastic landuse change unfavorable for livelihood, agriculture practices, natural vegetation and livestock etc. Besides, Government put minimum effort in solving local livelihood problem as well embankment construction and

maintenance. Due to weak embankment and lack of flood and disaster control infrastructure, these communities were reported very much vulnerable to the most of the natural calamities frequently occurred around this region.

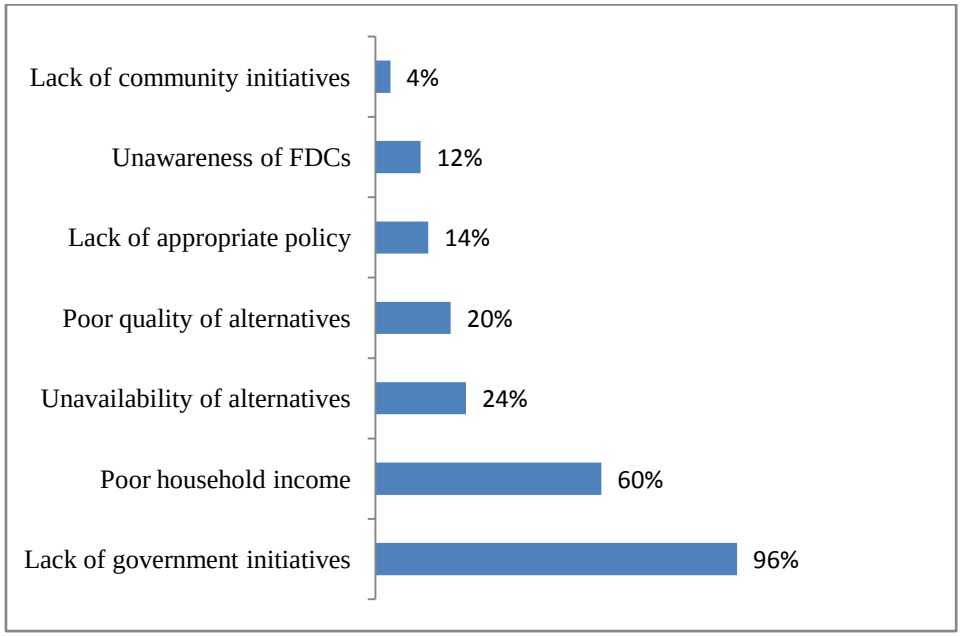

Figure 29: Barriers to accepting forest biomass fuel alternatives by the respondents (For each case N=50)

According to around two-third of the respondents (60%), poor household income was one of the major blockades to accepting fuel alternatives. In absence of traditional fuel such as agriculture residues, homegarden fuel and cowdung, these respondents expressed their intention to use fuel alternatives like solar cooker, kerosene, LPG etc., if they had enough income or financial solvency.

As per figure 29, around one-fourth (24%) of the respondents mentioned the issue of unavailability of the alternatives. According to their information, several of these alternatives such as biogas plant, solar cooker, and LPG, were not available in and around their communities, even in markets within their reach.

Of the total surveyed, 20% of the respondents complained about the poor quality of alternatives, especially about poor quality of fuel efficient stove available in their respective

communities. They expressed their dissatisfaction, since this stove failed to produce desired heat while feeding with non-woody biomass. They also informed that stoves were not that much of fuel efficient, rather they found it smoke efficient.

Some 14% recognized lack of appropriate policy which favored unplanned salt water based landuse-cum-economic activities such as shrimp farming, crab farming etc. It ultimately increased the level of salinity and further, contributed biomass fuel shortage in the study area.

Another 12% claimed that they were unawareness regarding the study issue and fuel alternatives. Only few of them (4%) found lack of community initiatives as an obstacle to receiving such kinds of alternatives for meeting their fuel crisis.

4.6.2 Measures for overcoming barriers to accepting forest biomass fuel alternatives

Respondents, along with mentioning barriers to accepting biomass fuel alternatives (figure 29), recommended a bunch of measures for overcoming those obstacles. The measures for overcoming barriers to receiving fuel alternatives are shown in figure 30.

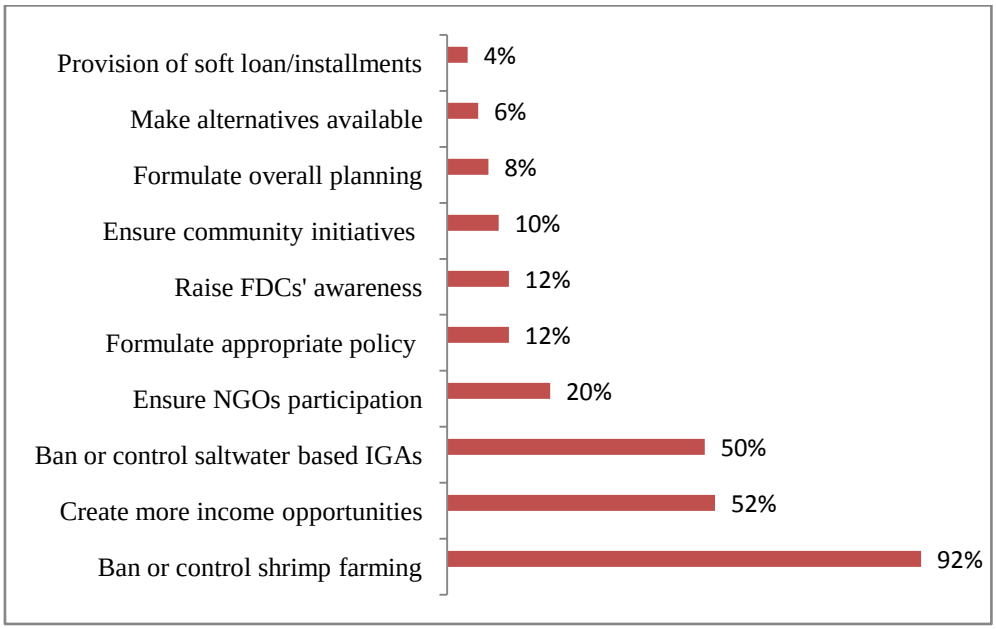

Figure 30: Measures for overcoming barriers to accepting forest biomass fuel alternatives (For each case N=50)

According to the study findings (figure 30), banning or controlling shrimp farming (92%) was the highest recommended measure followed by creating income opportunities (52%), banning or controlling other saltwater based landuse-cum-economic activities (50%), ensuring NGOs participation (20%), formulating appropriate policy (12%), raising FDCs' awareness (12%), ensuring community activities (10%), formulating overall planning (8%), making alternatives available (6%) and provisioning of soft loan/installment in purchasing alternatives (4%) respectively.

With detrimental effect on the livelihood of landless and marginal farmers, shrimp farming made their life hard to survive in the communities (Karim, 2006). So majority of the respondents (92%), as shown in figure 30, wanted it to be banned or controlled. Hossain (2011) reported similar stand of the local people for drawing attention of government and mass media on this issue. Since, saltwater based economic as well as land use activities (such as crab farming, hatching shrimp fry etc.) produced similar impact, exactly half of the respondents (50%) asked for controlling or banning these activities.

Since majority of the respondents were poor (figure 12), more than half of the total respondents (52%) recommended for creating more income earning opportunities in the study area so that they could be able to purchase daily necessities including fuel alternatives. A few of them added that rate of local employment as well as household income might be increased in case of introducing rice cultivation on the same land being used for shrimp production.

Exactly 20% of the respondents asked for ensuring involvement of NGOs in dealing with the study issue. According to their opinions, NGOs were pioneering several development interventions including fuel efficient stoves in their area. Along with government initiatives, NGOs were found trusted partner for implementing development alternatives in the study area.

Some 12% advocated for developing appropriate policy to regulate and restrict brackish water shrimp farming. They believed that banning or controlling shrimp farming through policy interventions would bring back the environment that favors agriculture practices. Then traditional fuel resources would automatically be restored for meeting household energy need. They also urged for having control over encroachment onto agriculture lands. Miah et al. (2003) suggested similar policy intervention to control shrimp farming in the study area.

Out of total surveyed, 12% of the respondents asked for awareness raising interventions to be implemented along with the ongoing projects run by the government and NGOs in their communities. According to their opinions, awareness of local communities might somehow assist them to realize the negative impact of unplanned brackish water based land use activities like shrimp farming, crab farming etc as well as illegal removal of biomass from SRF. This might constitute a well convincing starting point for introducing technologically sound and efficient biomass fuel alternatives such as biogas plant (in case of cowdung being available), solar cooker, fuel efficient stoves etc.

A small number of the respondents (10%) suggested community initiatives for meeting fuel energy shortage through management of common resources like embankment plantation, char plantation, strip (roadside) plantation etc. Respondents recognized themselves unorganized; hence they asked NGOs or local government as binding agent as well as guiding agent to solve their problems.

A few of the respondents (8%) mentioned the need of overall planning for up-lifting socio-economic as well as environmental problems including biomass fuel crisis. They emphasized mainly on the management and utilization of common resources pools.

Very few of the interviewees (6%) urged for making alternatives available in the markets or

growth centers located within their reach. According to their opinions, this initiative might encourage them to use alternatives for domestic cooking.

Since major portion of the respondents were poor (figure 12), only few (4%) asked for extending soft loan, repayable by small installments, in case of purchasing fuel alternatives devices.

4.7 Potential alternatives to forest biomass fuel

Based on the findings derived from individual interview and group discussion, potential alternatives to forest biomass fuel were identified, which were supposed to be capable of meeting fuel energy crisis at a great extent. The choices of alternatives were made with respect to their availability and accessibility in future socio-economic as well as environmental context.

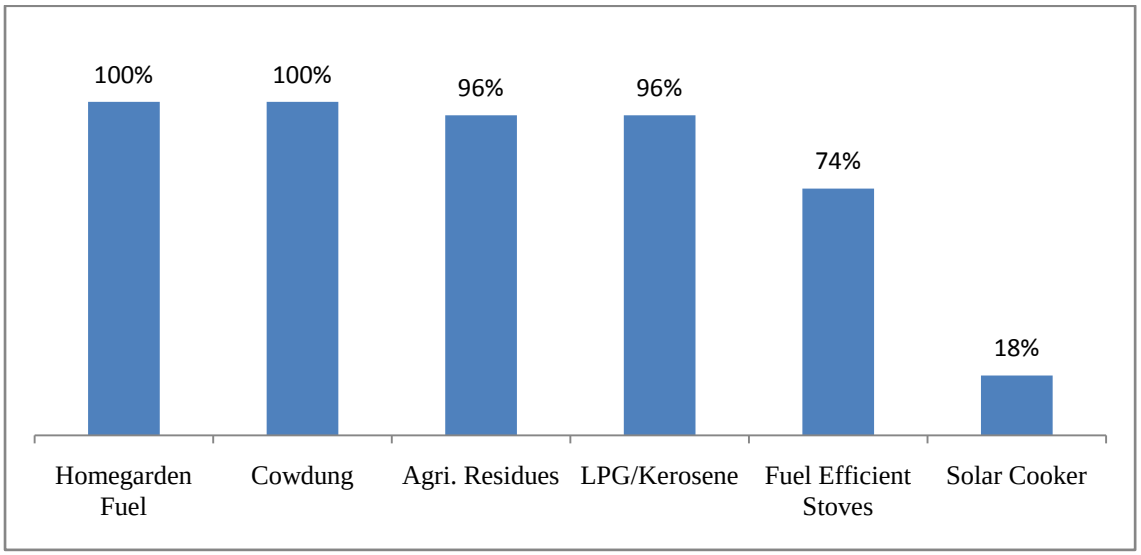

Figure 31: Respondents' preference of fuel alternatives to be used in future (For each case N=50)

According to the figure 31, homegarden fuel (100%) and cowdung (100%) achieved great acceptance of all respondents who would like to use those for domestic cooking in future. Besides, almost all of them (96%) preferred to use both agriculture residues and LPG/Kerosene where use of later alternatives were conditional subject to emergency, disastrous as well as abnormal situation lacking dry wood or unavailability of any form of wood in and around their communities.

Out of total surveyed, 74% of the respondents chose fuel efficient stove as their future alternative where some 18% found solar cooker as one of their preferred alternatives which might reduce fuel energy crisis.

For screening and identifying best suited alternatives to forest biomass fuel for the study area, a framework consisting of several aspects/indicators of fuel poverty as supported by related literature and websites, was developed and justified by the outcomes of group discussion and related policy review. In this study, fuel alternatives assessment indicators include household behavior (users' previous experience or prior knowledge on fuel use), household preference (Users' intention to use in future), affordability, feasibility and legal barriers.

It is well recognized that household behavior is one of the vital factors influencing fuel poverty situation (Edinbvrgh, 2012; Hills, 2011). According to Hills (2011), users' knowledge on how to use fuels for producing optimum heat is a major issue in this concern.

Household preference of fuel is another factor that determines the household energy cost (Hills, 2011). Hence, household preference, with respect to its overall financial condition, may influence the selection of fuel alternatives.

Affordability, in terms of household income and fuel price, can play vital role in identifying best alternatives from an energy mix. Several studies (UKPower.co.uk, 2015; Energy UK, 2015; Edinbvrgh, 2012; Hills, 2011) recognized both household income and fuel price as pivotal drivers in understanding household fuel poverty situation.

Energy efficiency is also recognized as one of the key factors stating the definition of fuel poverty (UKPower.co.uk, 2015; Energy UK, 2015; Hills, 2011). In this case, energy efficiency of cooking apparatus is taken into consideration. DECC (2013) emphasized on the 'composition of household' to explain fuel poverty scenario. According to Hills (2011), household energy need reflects household composition, energy efficiency and size of a particular dwelling, energy system in place, amount of time during which the following dwelling remains occupied on. Here,

household energy need was meant to reflect household composition, energy efficiency and size of a particular cooking apparatus and amount of time during which the following apparatus was used for cooking on fire. Based on overall energy being assumed to be generated by each fuel options against household need, respondents assessed feasibility of alternatives with their fuel use experiences.

Sometimes, policy intervention can influence fuel poverty scenario (Energy UK, 2015). Presence or absence of active policy statements followed by related law and guidelines may encourage or discourage the use of certain type of fuel. Hence, presence of legal barrier in case of using alternatives was examined through consulting energy related policies of Bangladesh.

Fuel Alternatives	Previous User or Prior Knowledge	Intention to Use in Future	Affordability	Feasibility	Legal Barrier	Type
1	2	3	4	5	6	7
Agri. Residues	++++	++++	++++	++++	No	A
Homegarden Fuel	++++	++++	++++	++++	No	A
Cowdung	++++	++++	++++	++++	No	A
Fuel Effi. Stove	++++	+++	++++	++++	No	B
LPG/Kerosene	++++	++++	++	++++	No	C
Solar Cooker	+	+	+	++++	No	C
Biogas	+	+	+	++++	No	C

Remarks:

	Column 2	Column 3	Column 4	Column 5	Column 7
Degree of Choices	Previous User or Prior Knowledge	Intention to Use in Future	Affordability	Feasibility	**A. Highly potential** ('No' with at-least++++ in each column 2-5) **B. Potential** ('No' with at-least +++ in each of column 2-5) **C. Non-potential** (except A & B)
+	No	Never thought	No	No	
++	Little	Not interested	Low	Some extent	
+++	Better	Thinking	Moderate	Better	
++++	Enough	Determined	High	Best	

Figure 32: Fuel alternatives assessment framework (filled with group discuss outcomes and policy review)

According to the figure 32, agriculture residues, homestead fuel, and cowdung were found highly potential alternatives and fuel efficient stoves as potential fuel alternative for FDCs. In search of renewable energy options for the same study area, Rashid (2012) recommended biogas and solar energy, both of which, as per figure 31 and figure 32, were found quite unexpected to respondents under the prevailing situation.

However, under the current socio-economic context, agro-ecological environment needs to be restored immediately for ensuring un-interrupted supply of biomass fuels from agricultural field and homegarden. It may assist and extend scope for increasing household cattle head which can supply cowdung for domestic cooking. Together with awareness rising about biogas, it may constitute a good pavement for introducing biogas energy plant in the study area.

Fuel efficient stoves might be of great use not only for fuel saving but also for reducing pressure on the biomass fuel resources including reserve and protected forest standing in and around the communities. Stone et al. (2008) reported reduction of frequency of collecting fuelwood per week by 40%-57% with the use of certain type of fuel efficient stove in Darfur. In order to reduce fuel dependency on forest resources in Pakistan, introduction of 'Fuel Efficient Smokeless Stove' brought great success in terms of fuel saving by 50% (Gitonga, 2003). Alam and Chowdhury (2010) mentioned more or less similar other findings in relation to the use of fuel efficient stove. Hence, use of biomass fuel from homegarden, agriculture practices and cattle in combination with certain type of fuel efficient smokeless stoves may reduce fuel crisis as well as respondents' dependency on forest resources.

Due to some existing challenges solar cooker may not be recommended for the time being. Awareness raising activities should be conducted before it is supposed to be introduced in the FDCs. Besides, household income earning status needs to be improved

through various means of interventions implemented by community itself, NGOs as well as local and central government.

4.8 Limitation

This study is to propose some fuel alternatives for the FDCs to make them less depended on forest biomass fuels from Sundarbans. The proposed alternatives may not be able to fully replace the existing fuel options and even, change the fuel use behavior of the FDCs. It may rather diversify their range of fuel choices that can be used as alternatives to forest biomass resources. Besides, this study may contribute in maintaining sustainability of Sundarbans at a little extent.

CHAPTER 5: RECOMMENDATIONS AND CONCLUSION

5.1 Recommendations

With respect to the current situation prevailing in the study area, several measures can be recommended for ensuring long term solution to the study problem. Towards ensuring the sustainable supply of affordable and legally available energy supply for household cooking, appropriate measures driven from literature review, field survey and observations, are to be implemented with joint efforts from communities, non-government, autonomous government and government organizations.

5.1.1 Management and use of affordable and legally as well as locally available fuel resources

Since the study area lacks affordable and legally as well as locally available fuel resources and FDCs own fascination for biomass fuel materials, effort can be taken to diversify biomass fuel sources in and around their communities. This requires engaging communities in rearing and using strip (roadside) plantation and embankment plantation (including char plantation) by themselves. During the time of field visit, it was evident that communities were unorganized and most of them were frustrated with their several problems including fuel crisis. Hence, some binding agents such as NGOs, autonomous government organization(such as local government), government, even government – NGOs collaboration in the form of various projects may appear for organizing communities to develop, manage and use of strip plantation and embankment plantation.

In one of villages where field survey was executed, 'Tiger Conservation Project' was found to be running hand to hand with village (community) committee. The project started in 2004 with several wildlife conservation strategies including gender engagement and improving livelihoods for conservation (Four-year tiger conservation project, 2013). It organized villagers and formed a village committee for casual monitoring of the activities of

people living on forest ecosystem services. The committee, being well supported by the project, found itself successful in preventing people to go into the forest for collecting fuel and other resources. Alternatively, they raised embankment as well as char plantations close to their communities for meeting their biomass fuel need.

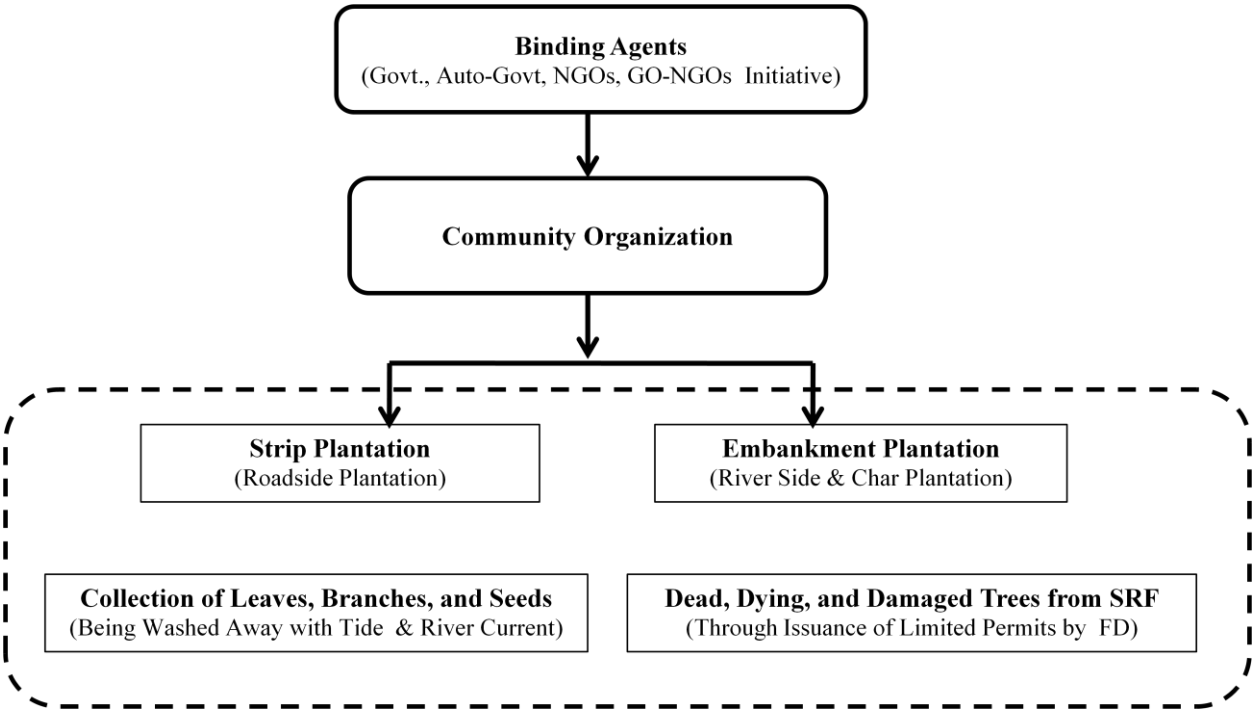

Figure 33: Affordable and legally as well as locally available fuel resources for immediate supply of biomass fuel.

Respondents have already been enjoying the right to collect and use the floating forest tree parts such as floating leaves, branches and seeds being washed away with tides and river current coming through Sundarbans. According to survey findings, around 40% respondents were observed to be using this floating forest biomass for domestic cooking (figure 17).

Besides, Forest Department (FD) can allow limited permits for collecting dead, dying and damaged trees and their parts every year. It will not only meet up FDCs' fuel demand but also lessen biotic pressure on local resources for certain period of time. By this time, communities can develop common biomass resources like strip plantation, embankment plantation, char plantation etc. Figure 33 shows affordable and legally as well as locally available fuel resources that can be exploited immediately for ensuring fuel supply.

5.1.2 Restoration of agro-ecological environment through appropriate policy intervention or community initiatives

According to the study findings, respondents showed keen interest in bringing back traditional fuels such as agriculture residues, homegarden fuel and cowdung in their locality (figure 31). Unfortunately, these fuels have been almost disappeared from the study area due to extensive shrimp farming, frequent natural disasters, unproductiveness of homegarden, other saltwater based land use as well as economic activities like crab farming (figure 20).

Shrimp farms encroached 44.44% land area of Shyamnagar upazila during the time stating from 1977 to 2011. Besides, agricultural land decreased from 65.26% to 27.55% during same time (Ghosh et al., 2014).Khan (2012) also reported the increase of shrimp farms and decrease of agricultural land occurring during last 13 years (1999-2012) in this sub-district.

Increase of shrimp farms and decrease of agricultural land were also reported as the main land use changes in the study area. Invasion of shrimp farms, in terms of percentage of land area, increased from 39.31% in 2002 to 61.94% in 2012 in Gabura and Munshigonj unions. During the same time, land area under crab farming increased from 0.2% to 1.53% and agricultural land decreased from 24.52% to 15.10% (Islam et al., 2012). Since, Gabura and Munshigonj unions represent part of the study area, similar trend of land use patterns was assumed to be found in the rest part of the study area.

This study also figured out the change in land use scenario in some parts of the study area (figure 21). According to the table 4, agricultural land decreased from 66.79% in 1989 to 17.30% in 2013. Side by side, area under shrimp farms increased from 9.57% in 1989 to 54.67% in 2013. The occurrence of widespread shrimp farms was also observed during the field visit. Besides, agricultural practices were found to be concentrated within a few patches of land throughout the study area.

Major portion of the respondents (92%) wanted to see no shrimp farming in and around their communities (figure 30). Besides, they blamed government for not taking appropriate measures in addressing their sufferings (figure 29). It requires appropriate policy intervention from the government end. Swapan and Gavin (2011) found livelihoods and ecological problems due to brackish water shrimp farming as policy failures in Bangladesh.

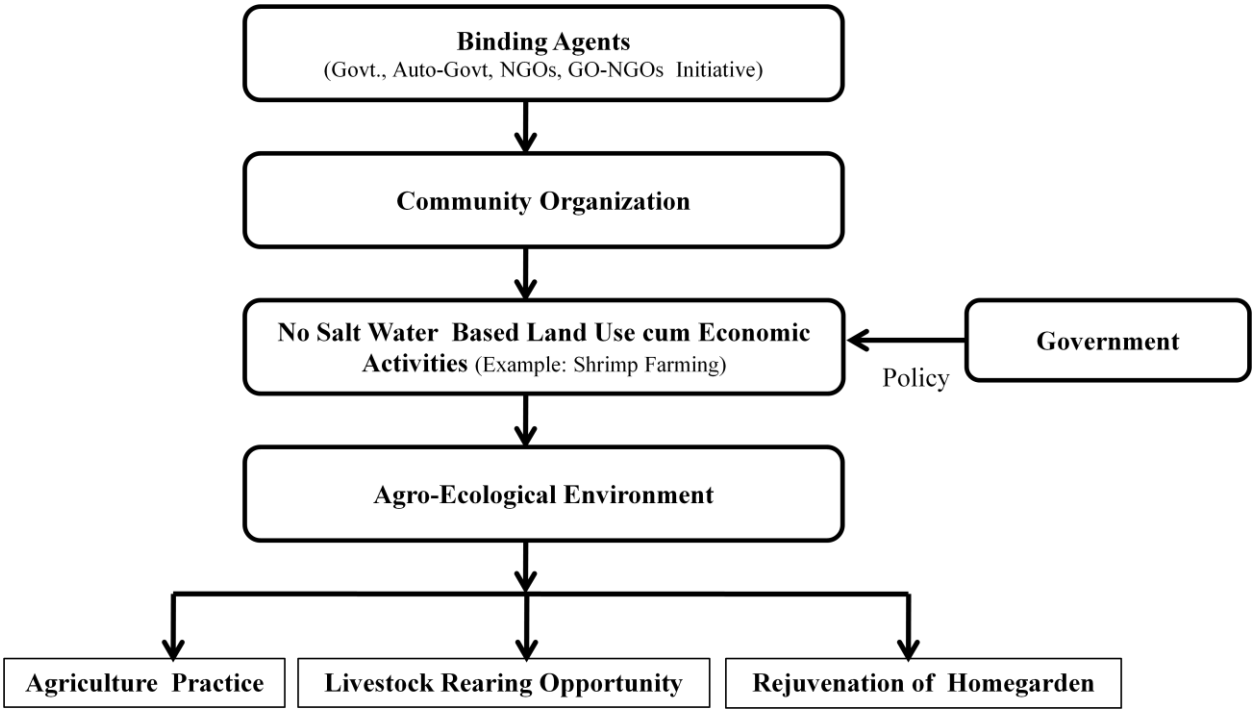

Figure 34: Appropriate policy intervention or community initiatives for the restoration of traditional fuel sources in the study area.

Alternatively, FDCs, being organized by some binding agents, may constitute a mutual agreement for banning or controlling salt water based activities in and around their communities. Since government was found inactive since the starting of this problem, question may arise on how FDCs can motivate themselves for bringing change in existing land use pattern. Here, conflict may arise between shrimp farmers and rest of the community people engaged in occupations other than shrimp farming.

According to the figure 14, shrimp farmers control more than two-third (76.10%) of the total land resources owned by all the respondents together and harvest every possible benefit from it. On the other hand, respondents who engage themselves in different

occupations other than shrimp farming (90%) own poor share of total land resources (23.90%). It was also observed during the time of field visit and further supported by figure 14 that, shrimp farmers own comparatively larger tract of homegarden. Hence, they get mentionable supply of fuel materials from their own homegarden where the rest of the respondents need to depend on other biomass sources along with their own sources of fuel if any.

In addition to their own land, 71.5% shrimp farmers take lease-in lands from neighbors to expand their shrimp farms where leasing periods range from one to five years. Many small farmers leased out their land to the large shrimp farmers due to tiny size of their land surrounded by counterparts, lack of investment capital, and migration to other area for maintaining livelihood (Paul and Vogl, 2011).This is how most of the small and marginal farmers are trapped and lose their controlling right over their own land for a certain period of time. Since, they lacks authority over the controlling of the major share of the available land resources in the study area, it is almost impossible for them to bring their desired land use opportunities to be implemented without legal and community support.

Many respondents found existing problems as the impact of shrimp farming. They found their scope only if there would be no saline water based landuse as well as economic activities allowed in and around their communities. This can be done through mutual understanding among the communities or government initiatives. Besides, some binding/guiding agents (such as NGOs, autonomous government organization, local government, government, even government – NGOs collaboration in the form of various projects) may help communities to be organized for building mutual understanding among them. In that case, all the cultivatable land would come under agricultural practices. Collection of agriculture residues would be then easy with almost free of cost. Besides, it would pave the scope of rearing cattle and buffalos which could be good sources of dung.

This initiative may also help in getting agro-ecological environment back, which further may favor extensive agricultural practices, cattle rearing opportunities and rejuvenation of homegardens. This is how FDCs can sustainably get supply of most desired biomass such as agriculture residues, cowdung and homegarden fuel respectively. Figure 34 shows appropriate policy intervention or community initiatives for the restoration of traditional fuel sources.

In case of policy intervention for food security as well as economic well being, Ali (2006) advocated for government and local community formulated land use planning regulations which might be well capable to stop shrimp farming on the prime quality rice field. The same study recommended shrimp farming only on agriculturally marginalized land. Karim (2006) also urged for relatively similar land use planning with reducing the area under shrimp cultivation and with due consideration given to the capacity of the environment under a comprehensive approach to sustainable development. According to Haider and Hossain (2013), it involves strong zoning of the cultivable land followed by installing heavy drainage system which is impossible without assistance from government and NGOs. Otherwise, seepage of saltwater from the shrimp farms might damage the rice crop on the adjacent plots (Hoanh et al., 2006).

Under these circumstances, freshwater shrimp (*Macrobrachiumrosenbergii* De Man) might be an option not only for whom dying hard for shrimp farming and its associated business but also to revive agro-ecological environment as well as to extend the scope of practicing agriculture. Rahman et al. (2011) mentioned cultivation of freshwater prawn in the rice fields being practiced in some parts of Bangladesh and several Asian countries. This type of innovative approach can be promoted through economic as well as regulatory policy interventions (Swapan and Gavin, 2011). For this study, economic instruments may include financial incentives in the form of providing (a) soft loan facility, (b) interest subsidy, (c) tax

exemption etc. Besides it may also include some disincentives for brackish water shrimp farming such as (a) higher land use tax, (b) higher charge on salinity contamination to the productive soil and fresh water reserve, (c) charge on salinity intrusion or seepage to the adjacent homestead and agricultural plot, (d) effluent charge on water pollutants disposed from shrimp processing depot and industries etc. On the other hand, regulatory instruments may take account of(a) banning, controlling and zoning of land use, (b) reformation and enforcement of existing related policy, (c) developing legal bindings in the form of laws and regulations to regulate and restrict saltwater shrimp farming onto agricultural lands etc.

Agro-ecological environment may also encourage communities to rear livestock such as poultry, goat, cattle, buffaloes etc. It may create the scope of introducing biogas plant in the study area, since cowdung, buffalo dung and poultry litter can be used as the raw material for producing gas in the biogas plant. Since practicing agriculture is labor intensive activity, it may generate employment opportunities for local people. Besides, rearing livestock might be an income earning option for the communities. Then it might reduce their livelihood dependency on the ecosystem services of Sundarbans.

5.1.3 Enabling FDCs to receive fuel alternatives through awareness creation, technology transfer and marketing interventions

Study findings implied that respondents were not that much of aware regarding fuel alternatives such as solar cooker and biogas (figure 25 and 26). So, introduction of both these alternatives may not be recommended for FDCs unless they are aware about the benefits of alternatives. According to the field observations, many of them were found ignorant of their stoves not fuel efficient, rather smoke efficient. Even, they were not informed of fuel efficient smokeless stoves already invented and introduced in some parts of Bangladesh. At this stage, appropriate awareness creating activities should be conducted in the study area so that people feel interested to use these alternatives and they start thinking on their benefits in terms of saving fuel and cost as well. FDCs, being organized by some binding agents such as NGOs,

autonomous government organization, local government, government, even government – NGOs collaboration projects, may conduct community awareness raising programs such as holding procession, organizing rally, distributing handbill, showing related video, organizing demonstration etc. Forest Department (FD) can also initiate such programs for promoting alternatives to reduce local pressure on forest.

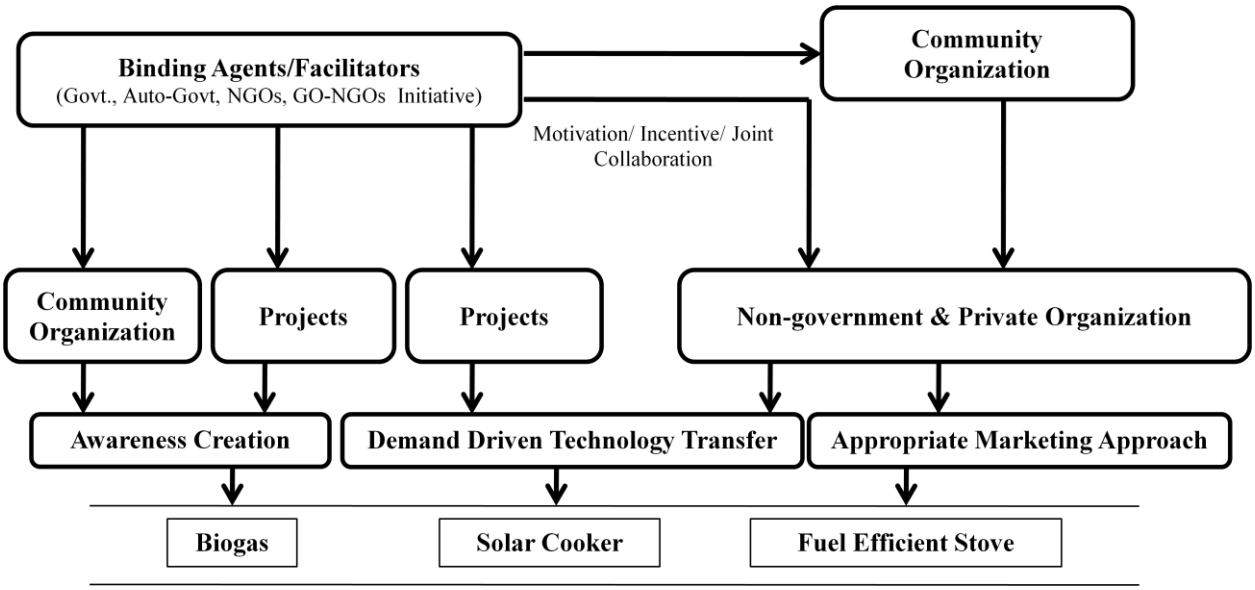

Figure 35: Strategies for enabling respondents to receive alternatives to forest biomass fuel.

A small portion of the respondents also complained about stove, since they didn't it find it not much fuel efficient as they expected (sub-clause 4.6.1). It might happen due to the lack of appropriate technology in manufacturing this alternative device. Effort should be made to identify the technological gap that can be fulfilled through separate projects or part of other projects to be executed by government, non-government, autonomous government organizations. These organizations, through some motivations in terms of incentives or joint collaboration, can also encourage non-government and private organizations to execute demand driven technology transfer activities in the FDCs. Here technology transfer activities are meant to transfer skills, knowledge, technologies, manufacturing method, facilities and continual improvement strategies from experts' ends to relatively novice stakeholders for culturing of the development in the study area. For encouraging non-government and private

organizations, economic instruments, part of economic policy interventions, might include (a) soft loan facility, (b) interest subsidy, (c) tax exemption etc.

The non-government or private company engaged in manufacturing and sellingof alternative fuel devices may come forward with their attractive marketing approaches like provision of paying device-price through small installments. Related government, non-government, autonomous government organizations can motivate these companies through joint venture initiatives as well as similar incentives mentioned earlier. Community organization can also help in expanding market for these companies by creating local demand through awareness raising activities and advocating for alternatives fuel devices.

5.2 Conclusion

The inhabitants living in south-west coastal region of Bangladesh has been suffering severe biomass fuel crisis for domestic cooking since 90's. Since the traditional fuels almost or fully disappeared from the study area, majority of the community people were found fully or partially dependent on SRF for availing their biomass fuel materials. Nevertheless, this study indentified several alternatives to forest biomass fuel for FDCs that might contribute to the diminution of fuel crisis as well as their fuel dependency on adjacent SRF.

The study traced out several factors such as widespread shrimp farming, frequent natural disasters, unproductive homegarden and saltwater based landuse-cum-economic activities responsible for creating local fuel shortage and making communities more forest dependent. These factors drove away traditional fuel such as homegarden fuel, cowdung, and agriculture residues from the study area, though people felt fascination with these biomasses for household cooking. Hence, the majority of the respondents were found to be engaged in illegal collection of biomass from forest. However, the study result demonstrated conflict in respondents' attitude towards forest conservation and illegal collection of forest fuel biomass under the prevailing context. Respondents were also much informed of traditional biomass

alternatives such as homegarden fuel, cowdung, agriculture residues and some other alternatives like fuel efficient stoves, LPG, kerosene. Though alternatives like biogas and solar cooker were reported very new energy options to the majority of them, evidences of very limited use of homegarden fuel and cowdung were also recorded. No respondents traced out to be using agriculture residues in the study area. According to the respondents' opinions, lack of government initiatives was identified as the main issue for generating extreme situation that created barrier for respondents to accepting fuel alternatives.

With respect to the availability of the alternatives being accessible to fuel alternatives for respondents in future socio-economic as well as environmental context, the study suggests biomass fuel from homegarden (bamboo, tree parts etc), agriculture practices (agriculture residues) and livestock (cowdung, buffalo dung, poultry litter etc) in combination with certain type of fuel efficient smokeless stoves as potential alternatives to existing forest fuel biomass for FDCs. This finding contradicts apparently promising result published in 2012 where Rashid (2012) recommended biogas and solar energy as potential renewable energy options for the same study area.

Under the prevailing circumstances, it is recommended for the management and use of affordable and legally as well as locally available fuel resources, restoration of agro-ecological environment through appropriate policy or community interventions and enabling respondents through awareness creation, technology transfer and marketing interventions in order to ensure the sustainable supply of affordable and legally available energy for household cooking. Besides, the study discourages all sorts of brackish water based land use as well as economic activities in and around the FDCs. However, further empirical research is required to investigate on how to plan and sustainably manage the ever increasing household energy demand for next few decades with declined land and local biotic resources. Related

studies in connection with application of governance without government approach might be fruitful under the context of least developing countries.

REFERENCES

Agoramoorthy, G., and Hsu, M. J. 2012.The significance of cows in Indian society between sacredness and economy.*Anthropological Notebooks*, 18(3): 5-12.

Agricultural Services Innovation and Reform Project (ASIRP). 2003. *Agricultural Extension in Bangladesh: An Entitlement of All Farmers?The result of a national extension coverage survey*.ASIRP.Accessed online at: http://www.lcgbangladesh.org/Agriculture/reports/The%20Results%20of%20a%20National%20Extension%20Coverage%20Survey.pdf. Accessed date: July 12, 2015.

Akther, S., Miah, M. D., and Koike, M. 2010.Domestic use of biomass fuel in the rural Meghna floodplain areas of Bangladesh.*iForest*, 3: 144-149.

Alam, S. M. N., and Chowdhury, S. J. 2010. Improved earthen stoves in coastal areas in Bangladesh: Economic, ecological and socio-cultural evaluation. *Biomass and Bioenergy*, 34:1954–1960.

Ali, A. M. S. 2006. Rice to shrimp: Land use/land cover changes and soil degradation in Southwestern Bangladesh. *Land Use Policy*, 23: 421-435.

Asante, F. A., Essel, A., Addai, P.,andAidoo. 2010.*National environmental, economic and development study (needs) for climate change: Ghana country report*. Accessed online at: https://unfccc.int/files/adaptation/application/pdf/ghananeeds.pdf. Accessed date: July 12, 2015.

Atikullah, S. M., and Eusuf, M. 2002. Biomass crisis and improved stoves in Bangladesh.*Bangladesh Renewable Energy Newsletter*, 1 (2):1. Accessed online at: http://bdresearch.org/home/attachments/article/502/Biomass%20Crisis%20and%20Improved%20Stoves%20in%20Bangladesh2003-8.pdf. Accessed date: July 11, 2015.

Badola, R. 1998. Attitude of local people towards conservation and alternatives to forest resources: A case study from lower Himalayas. *Biodiversity and Conservation*, 7: 1245-1259.

Bangladesh Bank (BB). 2015. *Exchange Rate of Taka.*Accessed online at: https://www.bb.org.bd/econdata/exchangerate.php . Accessed date: June 24, 2015.

Bangladesh Bureau of Statistics (BBS). 2012. *Population and Housing Census 2011:Community Report SatkhiraZila.*Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh. Accessed online at: http://www.bbs.gov.bd/Census2011/Khulna/Satkhira/Satkhira%20at%20a%20glance.pdf. Accessed date: July 12, 2015.

Bangladesh Bureau of Statistics (BBS). 2013. *District Statistics 2011 Satkhira*. Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh. Accessed online at: http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/District%20Statistics/Satkhira.pdf. Accessed date: July 12, 2015.

Bangladesh Bureau of Statistics (BBS). 2014. *Statistical Pocket Book of Bangladesh-2013*.Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh. Accessed online at: http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/LatestReports/PB2013.pdf. Accessed date: July 11, 2015.

Bangladesh Power Development Board (BPDB). 2015a. *Demand Forecast*. Accessed online at: http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=12&Itemid=126. Accessed date: July 11, 2015.

Bangladesh Power Development Board (BPDB). 2015b. *Four Years Achievement of Government in Power Sector*. Accessed online at: http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=12&Itemid=126. Accessed date: July 11, 2015.

Bangladesh Resource Centre for Indigenous Knowledge (BARCIK). 2009. *National Adaptation Programme of Action (NAPA) and People's Adaptation Plan.* BARCIK.Dhaka.Accessed online at: http://www.klima-und-gerechtigkeit.de/fileadmin/upload/Dialogforen/summary_NAPA_study.pdf Accessed date: June 24, 2015

Barlow, A. C. D. 2009. *The Sundarbans tiger adaptation, population status, and conflict management* (PhD thesis*)*.The University of Minnesota, USA.Accessed online at:http://www.carnivoreconservation.org/files/thesis/barlow_2009_phd.pdf . Accessed date: July 12, 2015.

Bekele, M. 2001. *Forestry Outlook Studies in Africa (FOSA).*Food and Agriculture Organization (FAO).Accessed online at: http://www.fao.org/3/a-ab582e.pdf . Accessed date: July 12, 2015.

Beyene, A. D. 2010. *Property right and choice of fuel wood sources in rural Ethiopia.* Contributed paper prepared for presentation at the 3rd conference of African Association of Agricultural Economists (AAAE) and the 48th Agricultural Economics Association of South Africa (AEASA), Cape Town, South Africa. Accessed online at: http://ageconsearch.umn.edu/bitstream/96171/2/PROPERTY%20RIGHTS%20AND%20CHOICE%20OF%20FUEL%20WOOD%20SOURCES%20(for%20AEASA%20conf).pdf Accessed date: July 12, 2015.

Braun, M., Saroar, M. 2012.Participatory Action Research on Climate Risk Management, Bangladesh.WorldFish, Penang, Malaysia. Studies & Reviews: 2012-39.

Department of Energy and Climate Change (DECC). 2013.*Fuel Poverty: A Framework for Future action – Analytical Annex*. Crown (Publishing Group). Accessed online at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/211137/fuel_poverty_strategic_framework_analytical_annex.pdf . Accessed date: July 12, 2015.

Dhanai, R., Negi, R. S., Parmar, M. K., and Singh, S. 2014. Fuelwood and fodder consumption pattern in Uttarakhand Himalayan watershed.*International Journal of Environmental Biology*, 4(1): 35-40.

Edinbvrgh. 2012. *Housing and Fuel Poverty* (Report No. HSC&H/12/12-13/SfC).Edinbvrgh-The City of Edinburgh Council.Accessed online at: http://www.edinburgh.gov.uk/download/meetings/id/17824/edinburgh_standards_for_sustainable_buildings.Accessed date: July 12, 2015.

Energy UK. 2015. *Fuel Poverty*. Accessed online at: http://www.energy-uk.org.uk/policy/fuel-poverty.html. Accessed date: June 24, 2015.

European Union (EU).2011. *Expert group report: Alternative fuels could replace fossil fuels in Europe by 2050* [Press Release]. Accessed online at: http://europa.eu/rapid/press-release_IP-11-61_en.htm . Accessed date: July 12, 2015.

Forest Department (FD). 2010. *Integrated Resources Management Plans for Sundarbans (2010-2020)*. Ministry of Environment and Forest, Government of the People's Republic of Bangladesh.

Four-year tiger conservation project starts in 2014. 2013, November 20. *Dhaka Tribune*.Accessed online at: http://www.dhakatribune.com/environment/2013/nov/20/four-year-tiger-conservation-project-starts-2014 . Accessed date: July 12, 2015.

Gaudreau, K., and Gibson, R. B. 2015.Sustainability Assessment of the Agricultural and Energy Systems of Senegal.*Energies,* 8: 3503-3528.

Getzner, M., and Islam, M. S. 2013, Natural resources, livelihood and reserve management: A case study from Sundarbans mangrove forests Bangladesh. *International Journal of Sustainable Development and Planning*, 8(1): 75–87.

Ghosh, M. K., Falk, G.C., and Ahmed, R. 2014. *Environmental impact of land-use change in the southwest coastal zone of Bangladesh.* Paper presented at the International conference on environment and development, University of Rajshahi, Bangladesh. Accessed online: http://dept.ru.ac.bd/geography/Procedings_Int_Conf_2014.pdf. Accessed date: July 11, 2015.

Gitonga, S. 2003. Responding to Climate Change, Generating Community Benefits: A Review of Community Initiatives supported by the Global Environment Facility's Small Grants Program 1992-2003. GFE small grant program (SGP).Accessed online at: https://sgp.undp.org/index.php?option=com_docman&task=doc_download&gid=269&Itemid=222 . Accessed date: July 12, 2015.

Global Administrative Areas.2015. University of California, Berkely. [country shape file]. Accessed online at: http://www.gadm.org Accessed date: July 18, 2015.

Geographic Information System for Biodiversity Research. 2015. National Aeronautics and Space Administration[Administrative division shape file and land cover map]. Accessed online at: www.diva-gis.org Accessed date: July 18, 2015

Haider, M. Z., and Hossain, M. Z. 2013. Impact of salinity on livelihood strategies of farmers, *Journal of Social Science and Plant Nutrition*, 13(2):417-431.

Halder, P. K., Paul, N., and Beg, M. R. A. 2014. Assessment of biomass energy resources and related technologies practice in Bangladesh. *Renewable and Sustainable Energy Reviews*, 39: 444-460.

Hill, J. 2011. *Fuel Poverty: The Problem and Its Measurement (*Case Report 69). Crown (Publishing Group). Accessed online at: http://sticerd.lse.ac.uk/dps/case/cr/CASEreport69.pdf. Accessed date: July 12, 2015.

Hoanh, C. T., Tuong, T. P., Gowing, J.W., and Hardy, B. 2006.Land and water management in coastal zones: Dealing with agriculture–aquaculture–fishery conflicts. In C. T. Hoanh, T. P. Tuong, J. W. Gowing, and B. Hardy (eds), *Environment and livelihoods in tropical coastal zones* (pp. 1-16). Oxon and Cambridge: CAB International.

Hossain, E. 2011, May 26. Shrimp farming deals major blow to south. *The Daily Star*.Accessed online at: http://archive.thedailystar.net/newDesign/news-details.php?nid=187242. Accessed date: July 11, 2015.

International Food Safety Authorities Network (INFOSAN). 2005. *"Food Safety in Natural Disasters"* INFOSAN Information Note No. XXX/2005 - "Topic". Accessed online at: http://www.searo.who.int/entity/emergencies/documents/food_safety_in_disasters.pdf?ua=1 Accessed date: July 11, 2015.

International Network of Alternative Financial Institutions (INAFI) Bangladesh., and PROCASUR Corporation. 2014. *Crab culture value chain development under FEDE: The case of crab in Satkhira, Bangladesh.* International Fund for Agriculture Development (IFAD).Accessed online athttp://asia.procasur.org/wp-content/uploads/2014/10/FEDEC-Crab-Culture-VCD_Case-Study.pdf . Accessed date: June 24, 2015.

International Union for Conservation of Nature (IUCN).1997. *Sundarbans Wildlife Sanctuaries Bangladesh: World Heritage Nomination-IUCN Technical Evaluation*. IUCN.Accessed online at: http://whc.unesco.org/archive/advisory_body_evaluation/798.pdf.Accessed date: July 12, 2015.

Islam, M. S., Rahman, M. A., Sultana, N., Nath, B., and Paul, A. 2012.Using geospatial techniques to assess the salinity impact on agricultural landuse: A study on ShyamnagarUpazilaSatkhira.*JAEID (Journal of Agriculture and Environment for International Development),* 106 (2): 157-169.

Jashimuddin, M., Masum, K. M., and Salam, M. A. 2006. Preference and consumption pattern of biomass fuel in some disregarded villages of Bangladesh. *Biomass and Bioenergy*, 30: 446–451.

Karim, M. R. 2006. Brackish-water shrimp cultivation threatens permanent damage to coastal agriculture in Bangladesh. In C. T. Hoanh, T. P. Tuong, J. W. Gowing, and B. Hardy (eds), *Environment and livelihoods in tropical coastal zones* (pp. 61-71). Oxon and Cambridge: CAB International.

Khan, M. M. H. 2012.*Effects of changes in land-use and natural disasters on social-ecological resilience and vulnerabilities in coastal Bangladesh (*Master's thesis).Norwegian University of Life Sciences, Norway.

Klasen, Stephan. 2013. Is it time for a new international poverty measure? In OECD, *Development Co-operation Report 2013: Ending Poverty (pp. 35-42).* Paris: OECD Publishing. Accessed online at: http://dx.doi.org/10.1787/dcr-2013-6-en . Accessed date: July 12, 2015.

Mahajan, H. K. 2014. Child rights in Bangladesh. *Journal of Social Welfare and Human Rights*, 2(1):207-238.

Miah, M. G., Bari, M. N., and Rahman, M. A. 2003.Agricultural activities and their impacts on the ecology and biodiversity of the Sundarbans area of Bangladesh.*Journal of Natural Science Foundation Sri Lanka*, 31(1& 2): 175-199.

Miah, M. D., Rashid, H. A., and Shin, M. Y. (2009) Wood fuel use in the traditional cooking stoves in the rural floodplain areas of Bangladesh: A socio environmental perspective. *Biomass and Bioenergy*, 33 (1) : 70-78.

Mukul, S. A., Tito, M. R., and Munim, S. A. 2014. Can homegardens help save forests in Bangladesh?Domestic biomass fuel consumption patterns and implications for forest conservation in south-central Bangladesh.*International Journal of Research on Land-use Sustainability*, 1: 18-25.

Oyekale, A .S., Dare, A. M., and Olugbire, O. O. 2012. Assessment of rural households 'cooking energy choice during kerosene subsidy in Nigeria: A case study of Oluyole Local Government Area of Oyo State, *African Journal of Agricultural Research*, 7(39): 5405-5411.

Paul, B. G., and Vogl, C. R. 2011. Impacts of shrimp farming in Bangladesh: Challenges and alternatives. *Ocean and Coastal Management*, vol. 54: 201-211.

Rahman, M. H., Lund, T., and Bryceson, I. 2011.Salinity impact on agro-biodiversity in the three coastal rural villages of Bangladesh. *Ocean and Coastal Management*, 54: 455-468.

Rahman, M. M., Hasan, M. M., Paatero, J. V., and Lahdelma, R. 2014. Hybrid application of biogas and solar resources to fulfill household energy needs: A potentially viable option in rural areas of developing countries. *Renewable Energy*, 30: 1-11.

Rashid, M. J. 2012. *Renewable and Informal Energy of South-Western Part of Bangladesh*.LAP LAMBERT Academy Publishing. Accessed online at: http://www.bip.org.bd/SharingFiles/j6XQkLp020130530124639.pdf. Accessed date: July 12, 2015.

Sarwar, M. G. M. 2015. *SundariProtecting the Biodiversity of the Sundarbans by Reducing Human Pressure.*Concern Worldwide.Accessed online at: https://www.concern.net/sites/default/files/media/resource/sundari_-_protecting_the_biodiversity_of_the_sundarbans_by_reducing_human_pressure.pdf. Accessed date: July 12, 2015.

South Asian Disaster Knowledge Network (SADKN). 2013. Areas Prone to Each Disaster Type [map]. Accessed online at: http://www.saarc-sadkn.org/countries/bangladesh/hazard_profile.aspx Accessed date: July 12, 2015.

Stone, D., Cole, E., and Wroe-Street, G. 2008. Assessing the effectiveness of fuel-efficient stove programming: A Darfur wide review. ProAct Network.Accessed online at: http://postconflict.unep.ch/humanitarianaction/documents/02_02-04_02-09.pdf . Accessed date: July 12, 2015.

Swapan, M. S. H., and Gavin, M. 2011. A desert in the delta : Participatory assessment of changing livelihoods induced by commercial shrimp farming in Southwest Bangladesh. *Ocean and Coastal Management*, 54: 45-54.

Solidarity International and Uttaran. 2013. *Chronic Poverty in the Southwest Coastal Belt of Bangladesh.* Solidarity International. Retrieved through http://www.eldis.org/go/topics&id=64272&type=Document#.VazlNfmqqko onJuly 11, 2015.

Tabrig, M. S. U., Shamim, A. H. M., Rahman, M. A., Islam K. M. M., &Akae, T. 2013, Impacts of salinity problems on livelihood in Bangladesh: A case study, International *Journal of Experimental Agriculture*, 3(1): 13-21.

Tutu, A. 2005. River management in Bangladesh: A people's initiative to solve water-logging. *Participatory Learning and Action*, 51: 117-121.

Uddin, M.S. 2011. *Economic valuation of Sundarbans mangrove ecosystem services: A case study in Bangladesh* (Master thesis). UNESCO-IHE Institute for Water Education, Netherlands.

UKPower.co.uk. 2015.*Fuel Poverty*.Accessed online at: https://www.ukpower.co.uk/home_energy/fuel_poverty. Accessed date: July 12, 2015.

United Nations Conference on Trade and Development (UNCTAD). 2013. *The Least Developed Countries Report 2013: Growth with employment for inclusive and sustainable development.*United Nations.Accessed online at: http://unctad.org/en/PublicationsLibrary/ldc2013_en.pdf . Accessed date: July 11, 2015.

United Nations Educational, Scientific and Cultural Organization (UNESCO). 2012. *UN System Task Team on the Post-2015 UN Development Agenda: Education and skills for inclusive and sustainable development beyond 2015.*UNESCO.Accessed online at:http://www.un.org/millenniumgoals/pdf/Think%20Pieces/4_education.pdf . Accessed date: July 12, 2015.

United Nations Environmental Protection Agency (UNEPA).2013. *Renewable and Alternative Fuels.* Accessed online at:http://www.epa.gov/oms/fuels/alternative-renewablefuels/. Accessed date: July 12, 2015.

World Bank (WB)., and Bangladesh Centre for Advanced Studies (BCAS). 1998. *Bangladesh. 2020—A Long-run Perspective Study.Bangladesh Development Series.* Dhaka, Bangladesh: University Press Limited

APPENDIXES

Appendix A: Questionnaire for household survey

1. General Information

1.1 Name of the respondents:

1.2 Father/Husband name:

1.3 Address:

a) Village

b) Union

c) Upazila (Sub-district)

d) District:

1.4 Age

1.5 Gender

1.6 Education

1.7 Household Size

1.8 Occupation and Income

a) Family head/leading earning member:

b) Other working member if any:

c) Total family income and expenditure (average):

1.9 Asset

a) Land: (Homestead....., Other than homestead....., total.....)

b) House (Kaccha/Semi-pacca/Pacca)

c) No Livestock (Cow....., Goat....., Buffalo....., Poultry.....)

2. Attitudes towards forest and conservation

2.1 What are the benefits you derive from the forest?

a) Food b) Fuel wood c) Cash (selling wood) d) Timber (for house/furniture making)

e) Thatching f) Recreation Materials g) Religious h) Others:

2.2 Is the conservation of plants and animals a good thing and you support it?

a) Yes b) No c) I don't know

Why? .....

2.3 There is a need to protect Sundarbans forest. What extent do you support this statement?

a) Strongly Disagree b) Disagree c) Neither agree nor disagree d) Agree e) Strongly agree f) I don't know

3. FDC's fuel wood use and their attitudes towards alternatives

3.1 Sources and uses of fuel for household consumption

Source	Amount per day	Price per unit	Cost per day	No of days in a year	Total
Homestead Garden					
Forest (Permitted)*					
Forest (Illegal)*					
Agri. Residue					
Market (Home Garden)**					
Market (Forest-Permit)**					
Market (Forest-illegal)**					

* Fuel collected by themselves **Fuel bought from local market

3.2 Cash income of the household through wood fuel selling

Sources	Amount per day	Price per unit	Cost per day	No of days in a year	Total
Homestead Garden					
Forest (Permitted)*					
Forest (Illegal)*					
Agri. Residue					

3.3 Frequency of fuel wood collection from forest

Sources	Don't go inside forest	Daily	How many times a week	How many times a month	How many times a year
Forest (Permitted)					
Forest (Illegal)					

3.4 Reasons for using wood fuel

a) Can't afford anything else | b) Improper supply of LPG/Kerosene | c) Available free of cost | d) Available easily at cheap | e) Wood-the only option | e) Other sources are not sufficient | f) Others if any ……

3.5: Why dependent on current fuel sources?

Sources	Reasons							
	Only available	Easily available	Affordable (low cost)	Available free of cost	No home gardens	No agri. residue	No dung cake available	Others if any
Homestead Garden								
Forest (Permitted)*								
Forest (Illegal)*								
Agri. Residues								
Market (Home Garden)**								
Market (Forest-Permit)**								
Market (Forest-illegal)**								

3.6 Trend of fuel use by FDCs (Mention the names of fuel options in the respective space)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Present (2014)												
10 Years Back (2004)												
20Years Back (1994)												

3.7 What are the factors that made you reliant on the present sources of fuel?

a) Natural calamities | b) Shrimp culture in lieu of agri. practice | c) Destruction of home garden | d) Salinity intrusion | e) Improper management | f) I don't know | g) Others if any

3.8 Reactions to unavailability of wood from the forest

Options	Immediate priority (Single Choice)	All Choices	Reasons/Remarks
Buy from market			
Steal from the forest			
Agitate			
Grow fuel wood			
Switch over to other fuel sources			
Don't know			

3.9 Do you know about the following fuel sources?

Fuel Sources	First time I hear the name	I heard the name, but I didn't know the benefit	I knew the use and benefit of it
Biogas			
Fuel efficient stove			
Solar cooker			
LPG/Kerosene			
Dung cakes			
Agri. residue			
Homestead garden			

3.10 Suppose no wood is available, you switch to alternative sources. Which do you prefer to choice?

Fuel Sources	Immediate priority (Single Choice)	All Choices	Reasons/remarks for ranking
Biogas			
Fuel efficient stove			
Solar cooker			
LPG/Kerosene			
Dung cakes			
Agri. residue			
Homestead garden			

3.11 Adoption status of alternative fuel sources?

Fuel Sources	Past		Present		Future		
	Yes	No	Yes	No	Yes	No	If yes, under which conditions?
Biogas							
Fuel efficient stove							
Solar cooker							
LPG/Kerosene							
Dung cakes							
Agri. residue							
Homestead garden							

3.12 Reasons stated by the respondents for not using alternatives i.e. fuel sources other than forest

Sources	Due to unavailability	Insufficient for the family	Can't afford	Knew but costly	Heard but not aware of benefit	I didn't know it	Face difficulties and discomfort	Others if any
Biogas								
Fuel efficient stove								
Solar cooker								
LPG/Kerosene								
Dung cakes								
Agri. residue								
Homestead garden								

3.13 What are the potential barriers for not accepting alternative fuel sources?

SN		Response/Explanations
1	No marketing channel for supplying devices	
2	Poor quality of devices (stoves/cookers)	
3	Lack of awareness of FDCs	
4	Insufficient income of FDCs	
5	Lack of government initiatives	
6	Lack of policy support	
7	Other if any	

3.14 How we can eliminate above mentioned barriers?

a)		d)	
b)		e)	
c)		f)	

Appendix B: Topics of group discussion and fuel alternatives assessment framework

1. Overall discussion topics

a) Socio-economic and demographic characteristics of the community;

b) Community's forest dependency especially for biomass fuel (background, causes, trend etc.);

c) Attitudes towards forest biomass fuel alternatives and sustainability of forest resources;

d) Potential barriers to accepting those forest fuel alternatives by them; and

e) Potential alternatives to forest fuel biomass fuel for community.

2. Fuel alternatives assessment framework

Fuel Alternatives	Previous User or Prior Knowledge	Intention to Use in Future	Affordability	Feasibility	Legal Barrier	Type
1	2	3	4	5	6	7
Agri. Residues					Since they are mostly illiterate, it is not for group discussion. Rather, it can be explore through reviewing policy documents	
Homegarden Fuel						
Cowdung						
Fuel Effi. Stove						
LPG/Kerosene						
Solar Cooker						
Biogas						

Remarks:

	Column 2	Column 3	Column 4	Column 5	Column 7
Degree of Choices	Previous User or Prior Knowledge	Intention to Use in Future	Affordability	Feasibility	**A. Highly potential** ('No' with at-least++++ in each of column 2-5) **B. Potential** ('No' with at-least +++ in each of column 2-5) **C. Non-potential** (except A & B)
+	No	Never thought	No	No	
++	Little	Not interested	Low	Some extent	
+++	Better	Thinking	Moderate	Better	
++++	Enough	Determined	High	Best	