Sustainability of Changing Agricultural Systems in the Coastal Zone of Bangladesh

By

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A thesis submitted to the School of Environmental Studies in conformity with the requirements for the degree of Master of Environmental Studies

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Transformations of the various agricultural systems have been taking place in the coastal zone of Bangladesh. While some farmers continue to follow traditional practices, in recent years, others have become involved in massive shrimp cultivation, shrimp-rice cultivation, a rice-based improved agricultural system or a shrimp-rice-vegetable integrated system. All these types of agriculture are being practiced under highly vulnerable environmental conditions. The long-term livelihood, food security and adaptation of the coastal people largely depend on the sustainability of these agricultural practices. In this context, assessing the level of sustainability is extremely important and will be essential for developing future policy options in Bangladesh.

This study attempts to examine the sustainability of agricultural practices in the coastal region of Bangladesh. A field study was carried out in 2011 in five villages of five upazilas in the mature and active delta areas of the country. The data were collected through in-depth questionnaire surveys, focus groups discussions, field observation, key informants and secondary materials. A comprehensive suite of indicators was developed considering productivity, efficiency, stability, durability, compatibility and equity of the coastal agriculture. The categories and the indicators were weighted using Multi-Criteria Decision Analysis (MCDA) to measure the sustainability level of five study sites.

The integrated agricultural system (shrimp-rice-vegetable) of Dumuria appeared to be the most sustainable system among agricultural practices, and other integrated systems (rice-based improved agricultural system) of Kalaroa were also found to show a good level of sustainability. The massive shrimp cultivation system of Shyamnagar and Kaliganj appears to be least sustainable. A traditional agriculture system with some improved methods followed in Bhola Sadar...
also performed in a satisfactory manner, but there were limitations in terms of its location in the active delta. The level of the sustainability measured in this study allows for a comparison among agricultural practices of the five study sites. The information generated from the study may be used in formulating policies for this part of the country. Measuring agricultural sustainability in this way produces a useful summary of sustainability issues and also provides some vital learning experiences.

A holistic and interdisciplinary approach is attempted in this study for assessing and comparing the sustainability level of coastal agricultural systems. It has the potential to become useful as one of the frameworks for sustainability assessment.
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1.0 Introduction

Agriculture is the most important livelihood option for the coastal people of Bangladesh (GoB and UNDP, 2009). It has a key role to play in tackling the challenges of the growing population, poverty alleviation, maintaining food security and adapting to climate change (BCCAAP, 2010; BPRSP, 2005). It has been identified as being of prime importance for achieving development goals in coastal areas (BPRSP, 2005). About 40 million people of the coastal areas of Bangladesh depend on agriculture (BBS, 2011).

The area under study in this thesis is highly vulnerable due to causes that are both natural and human (UNEP and GoB, 2001). Cyclones, tidal surges, high wave interactions, sea level rise, global climate change impacts, floods, withdrawal of upstream river water, salt water intrusion, erosion and saline water-logging are all affecting the agricultural systems in the coastal areas (GoB, 2010). Along with disasters, the agriculture practices of this area are always under threat as it is one of the depressed regions of Bangladesh and it has suffered from sluggish growth partly due to longstanding administrative negligence (BPRSP, 2005).

At present, however, the coastal agricultural of Bangladesh is transforming, in spite of the many problems and constraints (Islam, 2006a). Embankments in particular have played a crucial role in transformation of traditional agriculture. After the introduction of surge-protecting embankments/polders in the 1960s some parts of the coastal region started to enjoy high yields in traditional crop cultivation (Ali, 2002; Nishat, 1988). However, later on due to the effects of frequent cyclones and storm surges and poor management of the embankment, some parts of the coastal areas have become water logged and saline (Rahman, 1995). This makes these areas unsuitable for traditional cropping (Rahman, 1995) and in this situation, in the 1970s some farmers started
commercial shrimp cultivation to mitigate the loss in traditional agriculture to maintain their livelihood (Karim, 1986).

From the 1980s to the present, shrimp cultivation has created a substantial economic and social transformation in those coastal areas where it has been taken up (DoF, 2010; Hamid and Alauddin, 1998). Furthermore, in recent years, shrimp has become a significant foreign exchange earner for Bangladesh (DoF, 2010; Mahmood, 2006). However, shrimp farming is a subject of criticism since it can damage the local ecology by increasing the salinity of the water and soil, change the composition of the soil and bring about rapid changes in land use and land cover (Deb, 1998; Hagler, 1997; Haque, 2004; Islam et al. 1999; Kori, 1996; Karim and Stellwagen, 1998). There are also claims that it has led to disintegration of economic and social conditions of coastal rural communities (Ali, 2006; Ali, 2004; Islam and Koudstaal, 2003; Mohmood, 2006).

Because of environmental and social impacts associated with shrimp cultivation, farmers of some parts of the coastal areas are incorporating vegetables and domestic animals into existing farming practices, integrating shrimp or prawn and fish with rice and vegetables. As a whole the people of the coastal areas are trying different agricultural practices to cope with the changing environment (Mohmood, 2006). This transformation of agriculture has many positive effects and has reduced some risks in farming. However, there is a growing concern on how this transforming agriculture is coping with the existing physical and social economic environment, how it is supporting people of the area and how beneficial it is in comparison with shrimp cultivation or traditional agricultural practices. In fact, these changes in livelihood have raised several issues, all of which can be summarized under the following research question.
What are the sustainability features of adaptive agricultural systems that are practised for pursuing livelihoods, especially in comparison with different farming systems that are followed in different parts of the coastal areas? This can be answered by measuring the sustainability of agricultural practices.

1.1 Agricultural Sustainability

The word ‘sustainability’ is often used interchangeably with ‘sustainable development’ in spite of perhaps having different meanings (Sarah et al., 1999). The words sustainable development have been at the center of the environment and development debate since the Conference on Human Environment in Stockholm in 1972 (Richard and Emmerij, 2009). The best known definition of sustainable development that of the Brundtland Commission of the United Nations on March 20, 1987: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (UN, 1987).

Sustainable Development or sustainability must involve many interconnected factors (vanLoon et al., 2005). There is broad consensus that these factors should incorporate three elements: environmental, economical and, social (Figure 1.1).

On the basis of the above basic concept, the sustainability of any human activity can be assessed. Agriculture is one of the human activities that is a major concern in the present world due to the global food crisis and environmental problems. Interest in the sustainability of agricultural and food systems can be traced to environmental concerns that began to appear in the 1950s–1960s
Sustainability of Changing Agricultural Systems in the Coastal Zone of Bangladesh

(Pretty, 2008). The interest has evolved over the last 20 years, now appearing in the political agenda at the international and national levels, with particular emphasis on ecological concerns (Häni et al., 2006).

Agriculture profoundly affects many natural ecological systems and, in its relation with economics and society, also affects the life of humans around the world (Figure 1.2). Agro-ecosystems can be conceived as social-ecological systems that combine human actors with other biological and physical elements in the process of food and fiber production (Waltner-Toews et al., 2004).

The social element of agricultural sustainability mainly derives from the fact that each of us is involved directly or indirectly in all aspects of agriculture (vanLoon et al., 2005). In most definitions of agricultural sustainability, the need to maintain resilience in environmental and social systems by meeting a complex array of interacting environmental, social and economic conditions is central (Swart et al., 2004). According to DFID (2004) "agriculture is sustainable when current and future food demands can be met without unnecessarily compromising economic, ecological, social and..."
political needs. Feenstra and Campbell (2011) also emphasize that sustainable agriculture integrates three main goals—environmental health, economic profitability, and social and economic equity.

There are different views regarding how to assess the sustainability of agriculture. According to Lynam and Herdt (1989), agricultural sustainability can be assessed by examining the changes in yields and total factor productivity. Conway (1987, 1985) measured agricultural sustainability through studying its yields, social acceptability and biophysical sustainability. Biological and physical scientists have tended to focus on biophysical measures of sustainability, such as crop yields on the output side, and indicators of soil and water quality on the input side (Barnett et al., 1995; Pieri et al., 1995). According to Ceyhan (2010), to assess agricultural sustainability data used to create indicators of sustainability should be collected within economic, social, environmental and bio-physical groupings.

Due to its multidimensional nature, a variety of philosophies, policies and practices have contributed to measure the goals of sustainable agriculture. Those who study and practice sustainable agriculture come from diverse backgrounds, academic disciplines, and farming practices (Gold, 2007) and their opinions vary on what features are suitable or not suitable in its assessment (Table 1.1).

A detailed and multidimensional investigation is needed to assess sustainability of any agricultural system. In assessing sustainability, setting objectives should be the first step followed by a careful selection and application of indicators. An indicator is a number or other descriptor that is representative of a set of conditions and indicates or points to aspects of an issue (vanLoon et al., 2005). Another fairly simple definition of indicator is something that quantifies and simplifies phenomena and helps us to understand complex realities; in other words it acts as a proxy or
simplification of more complex information (EC, 2007). Sustainability indicators for agriculture are being developed all over the world to measure the effects of agriculture on economic, environmental and social issues. Sustainability indicators need to be easy to measure, overlapping in time and diverse so that the indicators can capture the main effects of agriculture on the economy, environment and socio-economic make-up of a community.

Table 1.1: Classification of scholars’ emphasis and their tendency toward three components of agricultural sustainability according to a review of literatures

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameters</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td>The education level of the household members</td>
<td>Herzog and Gotsch (1998); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Housing facilities</td>
<td>Herzog and Gotsch (1998)</td>
</tr>
<tr>
<td></td>
<td>Work study</td>
<td>Herzog and Gotsch (1998)</td>
</tr>
<tr>
<td></td>
<td>Nutritional/health status of the family members</td>
<td>Herzog and Gotsch (1998); Rasul and Thapa (2003); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Improved decision Making</td>
<td>Ingels et al. (1997); Pannell and Glenn (2000); Horrigan et al. (2002); Rasul and Thapa (2003)</td>
</tr>
<tr>
<td></td>
<td>Improved the quality of rural life</td>
<td>Karami (1995); Ingels et al. (1997); Rezaei-Moghaddam (1997); Norman et al. (1997); Lyson (1998); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Working and living Conditions</td>
<td>Ingels et al. (1997); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Participation/social capital</td>
<td>Becker (1997); Ingels et al. (1997); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Social equity, social or community well-being</td>
<td>Becker (1997); Rigby et al. (2001); Rasul and Thapa (2003); Rasul and Thapa (2004); Lowrance et al. (1986); Gliessman (1998); DFID, 2002</td>
</tr>
<tr>
<td></td>
<td>Food sufficiency</td>
<td>Lowrance et al. (1986)</td>
</tr>
<tr>
<td></td>
<td>Consumer safety</td>
<td>NRCS (2009)</td>
</tr>
<tr>
<td>Economic</td>
<td>Average of crop production</td>
<td>Hayati (1995); Nambiar et al. (2001); Rasul and Thapa (2003)</td>
</tr>
<tr>
<td></td>
<td>Expenses for input</td>
<td>Becker (1997); Herzog and Gotsch (1998)</td>
</tr>
<tr>
<td></td>
<td>Monetary income from outside the farm</td>
<td>Herzog and Gotsch (1998); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Monetary income from the farm</td>
<td>Herzog and Gotsch (1998); Pannell and Glenn (2000); Nijkamp and Vreeker (2000); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Economic efficiency</td>
<td>Becker (1997); Herzog and Gotsch (1998); Nijkamp and Vreeker (2000); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Profitability</td>
<td>Karami (1995); Herzog and Gotsch (1998); Lyson (1998); Smith and McDonald (1998); Comer et al. (1999); Pannell and Glenn (2000); Rigby et al. (2001); Koeijer et al. (2002); Rasul and Thapa (2003); Van Passel et al. (2006); Gafsi et al. (2006)</td>
</tr>
<tr>
<td></td>
<td>Salaries paid to workers</td>
<td>Herzog and Gotsch (1998)</td>
</tr>
<tr>
<td></td>
<td>Employment opportunities</td>
<td>Herzog and Gotsch (1998); Rasul and Thapa (2003)</td>
</tr>
<tr>
<td></td>
<td>Market availability</td>
<td>Smith and McDonald (1998); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Land ownership</td>
<td>Karami (1995); Nijkamp and Vreeker (2000); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td>Component</td>
<td>Parameters</td>
<td>Sources</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Economic</strong></td>
<td>Soil management</td>
<td>Hayati (1995); Becker (1997); Ingels et al. (1997); Bouma and Droogers (1998); Pannell and Glenn (2000); Sands and Podmore (2000); Bosshard (2000); Nambiar et al. (2001); Horrigan et al. (2002); Rasul and Thapa (2003); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Long-term stability of the agricultural enterprise</td>
<td>NRCS (2009)</td>
</tr>
<tr>
<td></td>
<td>Crop productivity</td>
<td>Giessman (1998); DFID, 2002</td>
</tr>
<tr>
<td></td>
<td>Improve water resource management</td>
<td>Hayati (1995); Ingels et al. (1997); Gafsi et al. (2006); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Usage of pesticides, herbicides and fungicides</td>
<td>Hayati (1995); Rezaei-Moghaddam (1997); Ingels et al. (1997); Norman et al. (1997); Pannell and Glenn (2000); Rasul and Thapa (2004)</td>
</tr>
<tr>
<td></td>
<td>Usage of animal/organic manure</td>
<td>Saltiel et al. (1994); Hayati (1995); Norman et al. (1997); Bosshard (2000)</td>
</tr>
<tr>
<td></td>
<td>Usage of green manure</td>
<td>Senanayake (1991); Saltiel et al. (1994); Hayati (1995)</td>
</tr>
<tr>
<td></td>
<td>Crop diversification</td>
<td>Senanayake (1991); Saltiel et al. (1994); Ingels et al. (1997); Comer et al. (1999); Praneetvatakul et al. (2001); Nambiar et al. (2001); Horrigan et al. (2002); Rasul and Thapa (2003)</td>
</tr>
<tr>
<td></td>
<td>Crop rotation</td>
<td>Saltiel et al. (1994); Rasul and Thapa (2003) • Use of alternative crop</td>
</tr>
<tr>
<td></td>
<td>Cropping pattern</td>
<td>Nijkamp and Vreeker (2000); Rasul and Thapa (2003); Rasul and Thapa (2004)</td>
</tr>
<tr>
<td></td>
<td>Trend of change in climatic conditions</td>
<td>Smith and McDonald (1998); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Usage of chemical fertilizer (no/minimum tillage)</td>
<td>Hayati (1995); Ingels et al. (1997); Rezaei-Moghaddam (1997)</td>
</tr>
<tr>
<td></td>
<td>Conservational tillage</td>
<td>Hayati (1995); Ingels et al. (1997); Comer et al. (1999); Horrigan et al. (2002);</td>
</tr>
<tr>
<td></td>
<td>Control erosion</td>
<td>Hayati (1995); Ingels et al. (1997); Rasul and Thapa (2003); Gafsi et al. (2006); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Energy</td>
<td>Senanayake (1991); Pannell and Glenn (2000) • Microbial biomass with in the soil Senanayake (1991); Ingels et al. (1997); Norman et al. (1997); Nambiar et al. (2001); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Cover crop/Mulch</td>
<td>Ingels et al. (1997); Norman et al. (1997); Comer et al. (1999); Horrigan et al. (2002); Rasul and Thapa (2003)</td>
</tr>
<tr>
<td></td>
<td>Depth of groundwater Table</td>
<td>Pannell and Glenn (2000); Sands and Podmore (2000); Van Cauwenbergh et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Integrated pest Management</td>
<td>Pannell and Glenn (2000); Protein level of crops Comer et al. (1999); Praneetvatakul et al. (2001); Orrigan et al. (2002); Rasul and Thapa (2003)</td>
</tr>
<tr>
<td></td>
<td>Decline in the quality of the natural environment</td>
<td>McIsaac and Edwards (1994)</td>
</tr>
<tr>
<td></td>
<td>Adverse environmental impact</td>
<td>Rasul and Thapa (2003)</td>
</tr>
</tbody>
</table>
Sustainability of Changing Agricultural Systems in the Coastal Zone of Bangladesh

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameters</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecological</td>
<td>Stewardship of natural resources</td>
<td>Lowrance et al. (1986)</td>
</tr>
<tr>
<td></td>
<td>Environmental protection</td>
<td>NRCS (2009)</td>
</tr>
<tr>
<td></td>
<td>Balances environmental soundness</td>
<td>Gliessman (1998)</td>
</tr>
<tr>
<td></td>
<td>Capacity of systems to buffer shocks and stresses (Resilience)</td>
<td>DFID, (2002)</td>
</tr>
</tbody>
</table>

Source: Hayati et al., 2010; Literature survey, 2012

1.2 Conceptual Framework of the Thesis

In any assessment, indicators should be chosen only after first developing and clearly expressing a conceptual overview (Figure 1.3) of the situation and objectives of the measurement process. For our study in Bangladesh sustainable agriculture is defined as “producing food in a productive and economically efficient manner, using practices that maintain or enhance the quality of the local and surrounding environment—soil, water, air and all living things. It is also sustainable in supporting the health and quality of life of individual farmers, their families and the community as a whole” (based on the definition in vanLoon et al., 2005).

Assess Agricultural Sustainability

Steps to Assess Agricultural Sustainability

Figure 1.3: Conceptual framework to assess agricultural sustainability, Concept adapted from vanLoon et al., 2005
After setting out a conceptual statement a second step is to further refine and expand the overview to establish specific areas that require investigation. These areas are called categories. To draw a description of the total situation of any agriculture system, it is then necessary as third step to select appropriate indicators that allow assessment within these categories. Recognizing that agriculture is a process of food production as well as a way of life, six categories are chosen so as to reflect its various dimensions. These categories are based on issues of sustainable development. The categories (modified from vanLoon et al., 2005) are:

**Productivity**: For the needs of the farm family as well as to satisfy national and global requirements, sustainable agriculture must be capable of producing high yields. For this study, standard measures of crop yield, shrimp/fish harvest, etc. will be used, and also comparisons will be made on the basis of economic value of the harvested product.

**Stability**: For sustainable agriculture it is necessary that the high level of productivity be maintained over an indefinite period of time. This requires that the quality of the resources on which production is based also be maintained and even enhanced. For this study an examination of the long-term prospects of traditional and altered agriculture systems will be carried out based on data of land, soil, water, climate and other related issues.

**Efficiency**: To be sustainable, all resources required for agriculture - human, animal and material - should be used in a way that is not wasteful, but maximizes output per unit input. This is especially true of non-renewable resources. For this project the measures will be the ratio of product output to input of various resources, primarily non-renewable resources, including measures of energy output/input ratios.
**Durability:** Any crop production process is from time to time subject to stresses of various types, such as those due to water, pests or finance. Sustainable systems should be intrinsically resilient in the face of such stress. For this study, durability issues are the frequency of stress encounters in the study area – financial and environmental, and ways of relieving stress and what are the sustainability measures that can be taken to cope with regular stresses?

**Compatibility:** Sustainable agriculture should fit in with the human, social and natural environments where it is located, maintaining and enhancing health of these environments. For this study, it will be observed how the traditional and modified agricultural systems fit in with the unique natural surroundings of the coastal area. Also, how compatible are the agricultural practices with human health?

**Equity:** Agriculture should promote a good quality of life among the various individuals involved in the farming activities and within families. This includes having consideration for the standard of living, health and education of all people in the community. For this study the comparison of some issues of education, economics, health and gender of the traditional and altered agricultural system will be followed in terms of equity.

Having set out categories to be assessed, indicators are chosen, modified or often developed afresh. The careful choice of indicators is critical in order to achieve the desired goals of the investigation.

The overviews of the assessment suggested here are meant to provide a comprehensive picture of agricultural sustainability in coastal areas of Bangladesh. Other workers in this field have developed different, but usually similar, frameworks that can be used as scaffolding for the construction of indicators. For example, Rasul and Thapa (2003) in their study for sustainability
assessment of agricultural systems in Bangladesh used ecological, economic and social dimension categories for the evaluation of conventional and ecological agricultural systems.

While sustainability of agriculture has become an important issue in developed countries, there are few studies in Bangladesh that have addressed the issue. Sustainable agriculture has only recently been directly addressed through policy initiatives, although the term sustainability has often been mentioned. Most of the policies have indicated the need of sustainable development in agriculture by ensuring good environmental management, increasing economic activities and development the society (GoB, 2006). The draft National Agriculture Policy of Bangladesh (2010) broadly aims at "creating an enabling environment for sustainable growth of agriculture for reducing poverty and ensuring food security through increased crop production and employment opportunity as envisaged in National Strategy for Accelerated Poverty Reduction (NSAPR), Millennium Development Goals (MDGs) and SAARC Development Goals (SDGs)" (MoA, 2010). In fact, to achieve these aims agriculture will have to be managed on the basis of a broad view of sustainability. Recently the national strategy of sustainable development of Bangladesh recognized sustainable development in agriculture through formulating a sustainable agricultural strategy for crops, fisheries and livestock sectors.

1.3 Research Objectives

Based on empirical data obtained from primary observation and other sources, the present study attempts to examine the sustainability of agricultural practices in the coastal Bangladesh. Specific objectives of the research are:
1. To understand and draw a profile of traditional and changing agriculture systems in coastal areas of Bangladesh;

2. To develop a set of representative indicators, in order to analyze agricultural sustainability;

3. Using these indicators, to measure the level of agricultural sustainability in various categories and to aggregate them using a Multiple-Criteria Decision Analysis technique

4. To give some recommendations based on the findings that support best agriculture practice for sustainable agriculture in coastal regions of Bangladesh.

1.4 Scope of the Study

An understanding of agricultural sustainability is indispensable for designing coastal agricultural policies. Different studies have revealed that, due to transformation of practices in this area, the natural resource base has potentially been damaged but at the same time there have been some positive impacts on coastal society (Alam et al., 1990; DoE, 2005; Firoze, 2003; Haque, 2004).

While many aspects of the present agricultural systems appear to be attractive, there is no conclusive evidence about the long term benefits to individuals and the wider community. In this situation, it is expected that the study will assist farm families and policy makers in understanding the features of coastal agricultural sustainability

In order to do this assessment, a supporting goal is to identify and develop communicable indicators for productivity, stability, efficiency, durability, compatibility and equity. For this, there is a need to apply a variety of multidisciplinary methods in gathering and analyzing information.
1.5 Brief Profile of Bangladesh

Bangladesh is a low-lying deltaic country in the tropical zone of South Asia (NPDM, 2007; Rashid, 1991). The physiography of the country consists of floodplains (79.1%), some terraces (8.3%) and hilly areas (12.6%) (FAO, 2007). A network of 230 rivers with their tributaries and distributaries crisscross the country, and among them 57 are trans-boundary rivers (Suvedi, 2005). Being the downstream and deltaic portion of a vast watershed, it is naturally vulnerable to the water quality and quantity that flows into it from upstream.

The United Nations Development Program (UNDP) in 2004 and Global Climate Risk Index (CRI)-2010 (Harmeling, 2010) recognized Bangladesh as a highly vulnerable country in terms of natural calamities. It is also widely recognized to be one of the most vulnerable countries to the potential effects of climate change. The country could lose 17% of its land by 2050 because of rising sea level by 1 m (IPCC, 2007). In the coming decades therefore, the rising sea level could create more than 20 million climate refugees in Bangladesh (PBS, 2008; Walker, 2010). Along with many natural calamities, Bangladesh is grappling with the largest mass poisoning of a population in history because of groundwater used for drinking that has been contaminated with naturally occurring inorganic arsenic (Smith et al., 2000); up to 77 million people are exposed to toxic arsenic from drinking water (BBC, 2010).

Bangladesh has a typical monsoon climate. The average annual rainfall is about 2000 mm, of which approximately 70% occurs during the monsoon season. The relative humidity is persistently high, varying from 70% in March to 89% in July. The average annual temperature is 26°C (BMD, 2011).
The total land area of Bangladesh is about 14.4 million ha (BBS, 2011). Depending on the flooding depth, land is categorized as highland (20%), medium highland (35%), medium lowland (20%), lowland (8%) and very lowland (1%) (Kashem, 2006). Based on the features of the physical environment that are relevant to land use, the land is divided into 30 agro-ecological zones and 88 sub-regions (FAO/UNDP, 1999).

The population of 142.32 million ranks Bangladesh 7th in the world and the population density is more than 964 people per km$^2$ (BBS, 2011). About 80% of the total population are living in rural areas, and among them, 53% are classified as poor (WB, 2011). Rural population is made up of mostly marginal and small farmers along with a sizeable fraction of rural landless labourers all of whom are fully dependent on agriculture (BBS, 2006). The number of farmer families is 10 million; among them 2 million are in the marginal and landless categories (BBS, 2008). At present the average household size is 4.4 persons per family (BBS, 2011).

Bangladesh has 8.44 (56.87% of total land area) million ha of cultivable land among which about 2.85 (19%) million ha is devoted to single cropped area; 3.98 (26.82%) million ha is double cropped area and 0.94 (6.54%) million ha is triple cropped area (BBS, 2006; MoA, 2006). The total number of farm holdings is 15,089,000 with 0.56 ha being the average size of a holding and 0.06 ha per capita cultivated area (BBS, 2006). Agricultural land is fragmented into small pieces because of the large number of farm holdings and division of land among family members over the generations (Uddin and Haque, 2007). Over 30 to 40 years, the arable land of the country is decreasing by 1% per year due to the absence of proper land use policies, and the building of new houses, industrialization, and urbanization (NFPCSP, 2008).
Despite many constraints, Bangladesh has made substantial progress in enhancing food security and recently achieved food autarky in rice at the national level (FPMU, 2008). Among different crops, rice is overwhelmingly dominant in terms of area planted and importance; it is the staple food and accounts for about 75% of the cropping area of the country (Gumma, 2012). Although production of rice is largely sufficient, self-sufficiency in other food items is yet to be achieved (Mainudden et al., 2011). In Bangladesh half of the population are below the absolute poverty line defined in terms of a minimum calorie intake of 2122 kcal/day (WFP, 2005) and approximately one fourth of the population are the hard-core poor consuming less than 1805 kcal/day (MoA and FAO, 2010).

The national economy of Bangladesh is significantly dependent on agricultural production (ICID, 2000). The rural population is directly or indirectly engaged in a wide range of agricultural activities for employment, livelihoods and nutrition - including grain crops, fruit and vegetables, fisheries, livestock and forestry (Rahman et al., 2002). In 2007-08, the agricultural sector accounted 20.16% of the national GDP, of which crops made up 11.70%, fisheries 4.64%, livestock 2.79% and forestry 1.75%. Agriculture provides more than 60% of the national employment (BBS, 2008).

In 2011, Bangladesh ranked 146 among 172 countries in the Human Development Index (HDI) with an index value of 0.566 (UNDP, 2011). The per capita GDP of Bangladesh stood at USD 664 per annum (PC, 2010). Households spend 59% of their income on food. Bangladesh has, however, achieved remarkable progress in some areas of MDGs such as primary schooling, girls' education, immunization, micro-credit, female economic participation, birth control, physical mobility and safety nets (GoB and UNDP, 2005). In universal primary education, Bangladesh is on its way to meet the MDG 2 by 2015 (GoB and UNDP, 2005). Although relevant indicators of other MDGs
have moved toward their 2015 targets, their performances have been uneven (GoB and UNDP, 2005). Bangladesh is in the process of completing its first Poverty Reduction Strategy Papers (PRSP), which has taken into account the MDGs. The PRSP is addressing the issues of pro-poor growth and human development, and when implemented, will accelerate the achievement of the MDGs (GoB and UNDP, 2005).

1.6 Brief Profile of the Coastal Areas

The coastal zone of Bangladesh covers 47,201 (32%) km² land area of the total geographical area of the country (Shamsuddoha and Chowdhury, 2007; MoWR, 2005). The entire zone is low lying with 62% of land have an elevation of less than 3 metres and 86% less than 5 metres (Islam et al., 2006). Depending on elevation and other factors, the defined coastal area can reach from 37 to 195 km from the shore (MoWR, 2005). The whole coast runs along the northern border of the Bay of Bengal, forming a 710 km long coastline (MoWR, 2005).

Physiographically most of the coastal zone consists of extensive flat coastal and deltaic land of the Ganges-Brahmaputra Delta, which is crossed by large tidal rivers discharging into the Bay of Bengal (Rashid and Kabir, 1998). In general, much of the western part of the coastal zone is a moribund or mature delta; the middle part is an active delta; and the eastern part is a stable landmass (Ahmed, 2003) (Figure 1.4). Continuous accretion and deposition are taking place in active delta of the coastal regions due to strong river and tidal currents (Chowdhury and Hossain, 2006). In this project study areas were selected from the active delta (Bhola Sadar) and the mature delta (the other four sites).
The coastal region covers 19 administrative districts encompassing 153 upazilas (sub-districts, formerly called thanas) and the Exclusive Economic Zone (MoWR, 2005). Out of these 19 districts, 12 meet the sea or lower estuary directly (MoWR, 2005). Among the upazilas, 51 from 12 districts face the coast or lower estuary and these areas are known as exposed coast (Islam et al., 2006; PDO-ICZMP, 2003). The remaining 102 upazilas that are further inland from the exposed coast are within what is termed the interior coast (MoWR, 2005). The upazilas in the exposed coast have already met or crossed the threshold limit tidal movement, salinity, cyclone risk - and the upazilas in interior coast have met or exceed any two or one of the three parameters (PDO-ICZMP, 2003).

In the coastal zone, 62% of land has an elevation of 3 m or less and 86% is less than 5 m above sea level (Islam et al., 2006). Since the 1960s, the southeast coast of Bangladesh is protected by implementing cross dams (Wheeler and Gravgaard, 2010). The coastal people pursue their livelihoods in a unique environment with a combination of natural disasters and man-made changes (WRPO, 2006).

The National Strategy for Accelerated Poverty Reduction (BPRSP, 2005) acknowledges the Coastal Zone as a special focus area that is distinct in many respects and requiring of special attention acknowledging the fact that “there is considerable interface between the persistence of chronic poverty and unfavorable agricultural environments, (e.g. salinity-prone, flood-prone, river-erosion prone, drought-prone areas)”. Later on, the Government of Bangladesh formulated Coastal Zone Policy, 2005 and Coastal Development Strategy, 2006 and adopted an Estuary Development Programme along with other initiatives to address coastal vulnerabilities.
According to 2011 Population Census, the coastal zone comprises 6.85 million households with a population of 35.1 million (BBS, 2011). In the coastal zone the net cultivable area is 1.95 million ha.
indicating that the average landholding per household is half the already small national average. The net-cropped area of coastal zone in Bangladesh has been decreasing over the years due to various causes that are soil-related or associated with climate risk and socio-economic problems; the most common one is land inundation and salinity intrusion by tidal water. A comparative study of Bangladesh Soil Resource Development Institute (SRDI) shows that from 1973 to 2000 about 0.170 million ha (20.4%) land of coastal areas is affected by salinity (SRDI, 1997; SRDI, 2001).

One of the main economic activities in the coastal zone is aquaculture (Islam and Ahmad, 2004). The significance of shrimp farming has grown rapidly over the last 30 years (Alam and Phillips, 2004). Shrimp areas have expanded from 51 812 ha in 1983 to 137 996 ha in 1994 and 218 649 ha in 2004 (DoF, 1995 and 2005). At present, Bangladesh supplies around 2.5% of the global shrimp trade (DoF, 2004).

1.7 Organization of the thesis

This thesis is comprised of five chapters that contribute to fulfilling of the research objectives. Chapter One sets out the context of the research and the research question, the framework of the research, research objectives and scope. Chapter Two describes the methodologies with a focus on description of different approaches used for data collection and analysis. It also reflects on the research plan, the process adopted for the selection of study areas and a view of the techniques of data analysis. Chapter Three describes the study areas. Chapter Four analyses the data, through qualitative, quantitative and MCDA methods. It explores different indicators, their measurement and, finally, the level of agricultural sustainability in the five study areas. This chapter also
synthesizes the key findings and contributions of the research. Chapter Five concludes the thesis with some recommendations related to coastal agricultural sustainability of Bangladesh.
2.0 Introduction

Assessment of agricultural sustainability is a complex task, involving many factors. Developing a comprehensive suite of indicators is one useful way of assessing sustainability. Indicators can be qualitative or quantitative; they are often relative in terms of time and space and are influenced by the socioeconomic and agro-ecological conditions of the area (Hayati et al., 2011). In this study, an indicator-based procedure is used to assess agricultural sustainability in the coastal zones of Bangladesh; supported by descriptive data obtained by various types of primary and secondary data.

Ethical approval was obtained from the General Research Ethics Board (GREB) to conduct this research through the Office of Research Services, Queen’s University, Kingston, Ontario. After ethical approval, the research methodology of the study advanced in three main phases (Figure 2.1). In the first phase, issues of sustainability relevant to the adapted agriculture of the study area were identified through literature survey, brainstorming and discussion with experts. On the basis of the identified issues, a questionnaire was established. In this phase, correspondence was carried out with a local university of Bangladesh for selection of study areas, pre-test of the questionnaire, and arranging for students to assist with data collection.

Phase two dealt with primary and secondary data collection. Farmers were the source of primary data. General discussions were held with them to monitor the situation. Various documents of the Government and NGOs were acted as major sources of secondary data. Ensuring full participation of the sampled farmers at all stages was the main strategy of primary data collection.
In phase three, both primary and secondary data were summarized and tabulated. After tabulation, both qualitative and quantitative techniques were applied to assess the sustainability of agricultural systems.

2.1 Literature Review

A literature review was carried out to collect available data related to sustainability of coastal agriculture in Bangladesh. At the same time literature was sought that would assist in
understanding appropriate qualitative and quantitative techniques for data analysis. Documents, policy reports, presented papers, articles, academic journals, books and related websites of government and non-government bodies were reviewed. The literature also assisted in identifying gaps in current knowledge and targeting the types of data needed for the assessment. The source organizations of secondary data are listed in Table 2.1.

Table 2.1: List of sources of the secondary information and data

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the Source Organization</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Government Organizations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Bangladesh Statistical Bureau</td>
<td>BBS</td>
</tr>
<tr>
<td>2.</td>
<td>Department of Agriculture Extension</td>
<td>DoAE</td>
</tr>
<tr>
<td>3.</td>
<td>Department of Fisheries</td>
<td>DoF</td>
</tr>
<tr>
<td>4.</td>
<td>Department of Livestock Services</td>
<td>DoLS</td>
</tr>
<tr>
<td>5.</td>
<td>Bangladesh Water Development Board</td>
<td>BWDB</td>
</tr>
<tr>
<td>6.</td>
<td>Bangladesh Agricultural Research Council</td>
<td>BARC</td>
</tr>
<tr>
<td>7.</td>
<td>Soil Resources Development Institute</td>
<td>SRDI</td>
</tr>
<tr>
<td>8.</td>
<td>Bangladesh Meteorological Department</td>
<td>BMD</td>
</tr>
<tr>
<td>9.</td>
<td>Department of Environment</td>
<td>DoF</td>
</tr>
<tr>
<td>10.</td>
<td>Comprehensive Disaster Management Programme</td>
<td>CDMP</td>
</tr>
<tr>
<td><strong>NGOs (Non-Government Organizations)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Bangladesh Resource Center on Indigenous Knowledge</td>
<td>BARCIK</td>
</tr>
<tr>
<td>2.</td>
<td>Coastal Environment Conservation Center</td>
<td>CECC</td>
</tr>
<tr>
<td>3.</td>
<td>Bangladesh Centre for Advanced Studies</td>
<td>BCAS</td>
</tr>
<tr>
<td>4.</td>
<td>Bangladesh Rural Advancement Centre</td>
<td>BRAC</td>
</tr>
<tr>
<td>5.</td>
<td>Sushilon</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Centre for Policy Dialog</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Bangladesh Institute for Development Studies</td>
<td>BIDS</td>
</tr>
<tr>
<td><strong>International Organizations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>International Union for Conservation of Nature</td>
<td>IUCN</td>
</tr>
<tr>
<td>2.</td>
<td>United States Agency for International Development</td>
<td>USAID - Bangladesh</td>
</tr>
<tr>
<td>3.</td>
<td>Asian Development Bank</td>
<td>ADB</td>
</tr>
<tr>
<td>4.</td>
<td>World bank</td>
<td>WB</td>
</tr>
<tr>
<td>5.</td>
<td>United Nations</td>
<td>UN</td>
</tr>
<tr>
<td>6.</td>
<td>Food and Agriculture Organization</td>
<td>FAO</td>
</tr>
<tr>
<td>7.</td>
<td>Intergovernmental Panel on Climate Change</td>
<td>IPCC</td>
</tr>
<tr>
<td>8.</td>
<td>World Health Organization</td>
<td>WHO</td>
</tr>
<tr>
<td>9.</td>
<td>Canadian International Development Agency</td>
<td>CIDA</td>
</tr>
</tbody>
</table>

Source: Literature review, 2011
2.2 Establishing Linkage with a Local University

An informal linkage was established involving two academicians at the Department of Geography and Environment, Jahangirnagar University, Savar, Dhaka, Bangladesh and the School of Environmental Studies, Queen’s University, Kingston, Canada. Professor Dara Shamsuddin and Lecturer Md. Saifuzzaman of Jahangirnagar contributed immensely to the work by sharing their ideas, and assisting in data collection and analysis. In addition, a group consisting of six students was selected through interviews and they were given training on the research topic and data collection methods. After training, they worked under supervision for data collection.

2.3 Questionnaire Development

A 35-page questionnaire was developed to collect field level primary data (Appendix A). The questionnaire was pre-tested through 5 interviews, and after pretest needed improvements were made. The questionnaire was in English, but interviews were conducted in the local language, Bangla. The issues of sustainability of agriculture were kept in mind during development of the questionnaire, and it was designed to be comprehensive, but also simple enough to allow for appropriate collection and interpretation of information (Rattray and Jones, 2007).

2.4 Selection of Study Areas

Five villages from five coastal upazilas were selected for study areas. Several criteria were considered during their selection: farmers doing intensive shrimp farming with little rice; farmers doing intensive shrimp and rice with the same weight; farmers growing traditional crops but using modern methods; farmers doing integrated shrimp, rice and vegetable farming; and farmers doing mostly traditional agriculture. The criteria and locations were selected through literature review and consultation with local experts. Here, traditional agriculture means growing crops and following...
practice that have been used over many years. Five maps from Google imagery were produced to
get an idea about the environs of the study areas before undertaking the field study.

A number of matrixes (Table 2.2) were used in order to enable optimum choices of the study areas.
The five selected study villages were Munshiganj from Shyamnagar Upazila in Satkhira District,
Nalta from Kaliganj Upazila in Satkhira District, Tarulia from Kalaroa Upazila in Satkhira District,
Banda from Dumuria Upazila in Khulan District and Kunja Patti from Bhola Sadar Upazila in Bhola
District. Among study villages Munshiganj, Nalta, Jogikhali and Banda are located in the moribund
delta, whereas Kunja Putti is located in the active delta. The village data and secondary data
related to the surrounding areas represents a broad picture of agriculture in the five upazilas in this
part of the coastal agricultural system.

Table 2.2: Matrixes for selection of the study areas

<table>
<thead>
<tr>
<th>Sl.</th>
<th>Matrixes</th>
<th>Study Areas</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Khulna</th>
<th>Bhola</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Location in Moribund Delta</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Location in Active Delta</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>3.</td>
<td>Exposed to sea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Unexposed to sea</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Mostly intensive shrimp + other fish cultivation</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Mostly intensive shrimp + other fish + rice cultivation</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Mostly semi traditional agriculture</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Mostly integrated agriculture (shrimp+ rice+ vegetable)</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Mostly traditional agriculture</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Livelihood dependency on local agriculture</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>11.</td>
<td>Diversity of livelihood through agricultural activities</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>12.</td>
<td>Time tested knowledgeable farmers</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>Community cohesiveness</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>Positive attitude of the community</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Community eagerness to take part in FGD</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>Support from local NGOs and administration</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Literature review and discussion with local experts, 2011
2.5 Events in Field Study

The field study was carried out from May to August, 2011. First step of the field study was to visit and observe the selected study areas to understand the agricultural activities and environment inform helpers about the objectives of the research and contact key informants. The second step was to establish contact with different organizations as sources of secondary information and to arrange logistic support for data collection activities. After this, approximately three months were spent in carrying out the various components of the survey. The major events of field study over a period of four months are presented in Table 2.3.

<table>
<thead>
<tr>
<th>Tools/methods</th>
<th>2011</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground truthing of the selected study areas, informing local helper about the objectives of the research.</td>
<td>May</td>
<td>Visit selected study areas with Google images and understand the agricultural practices and associate environ.</td>
</tr>
<tr>
<td>Second pretesting of the questionnaire.</td>
<td>June</td>
<td>Pretesting of the questionnaire in the selected villages.</td>
</tr>
<tr>
<td>Field observation.</td>
<td>July</td>
<td>Field visit on foot to interact with farmers to understand the agricultural practices fully.</td>
</tr>
<tr>
<td>Household questionnaire survey.</td>
<td>August</td>
<td>Sustainability issues of agricultural systems.</td>
</tr>
<tr>
<td>FGD with farmers.</td>
<td></td>
<td>Identify the sustainability issue of agricultural practices.</td>
</tr>
<tr>
<td>Interview with key informants.</td>
<td></td>
<td>Collect the key information related to coastal agriculture.</td>
</tr>
<tr>
<td>Collecting of secondary data.</td>
<td></td>
<td>Various secondary data on six categories of sustainability of agriculture.</td>
</tr>
</tbody>
</table>

Table 2.3: Major events of field study over a period of four months

Source: Field study, 2011

2.6 Verification of the Study Areas

Philosophy of ground-truthing techniques was applied to verify the nature of the agricultural systems and associate environments of the elected study areas. This was especially pertinent in order to relate satellite image data (Google) to real features and material on the ground. Prior to
ground-truthing field visits, checklists were prepared for the issues which needed to be verified. Examples of some activates of ground-truthing are presented in Picture 2.1.

![Picture 2.1: Activities for verification of the study areas. (A) Verification of agricultural system and surrounding environs of Kaliganj with local people, (B) Verification of agricultural system and surrounding environs of Kalaroa with key informants, (C) Verification of agricultural system and surrounding environs of Shyamnagar with local people and (D) Returning field station after verifying the study area of Shyamnagar.](image)

### 2.7 Field Observation

Field observation was used to collect information on the agricultural system and people involved with emphasis on issues of sustainability. Advantages of the use of direct observation as a research method have been emphasized by many researchers (Robson, 1993). Simpson and Tuson (1995) noted that there is almost no research strategy to which data collection by observation cannot contribute. In the present situation, a detailed examination of the agricultural
settings was important as background for carrying out the farmers’ survey as well as the interviews of various stakeholders.

2.8 Selection of Sample Size

Five different categories of farmer were considered from selected study areas and the plan was to select at least five farmers from each category. In the end, 211 households were covered which represent 6.71% of the total 3141 households. The numbers of surveyed households in different categories of the farmer are presented in Table 2.4.

<table>
<thead>
<tr>
<th>Categories of Farmer</th>
<th>Study Areas</th>
<th>Shyamnagar</th>
<th>Kaligonj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
<th>Total Farmer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landless farmer</td>
<td></td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td>Marginal farmer</td>
<td></td>
<td>5</td>
<td>12</td>
<td>15</td>
<td>4</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>Small farmer</td>
<td></td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>6</td>
<td>6</td>
<td>63</td>
</tr>
<tr>
<td>Medium farmer</td>
<td></td>
<td>12</td>
<td>9</td>
<td>11</td>
<td>4</td>
<td>5</td>
<td>41</td>
</tr>
<tr>
<td>Large farmer</td>
<td></td>
<td>7</td>
<td>12</td>
<td>8</td>
<td>3</td>
<td>5</td>
<td>32</td>
</tr>
<tr>
<td><strong>Total farmer</strong></td>
<td></td>
<td><strong>45</strong></td>
<td><strong>60</strong></td>
<td><strong>59</strong></td>
<td><strong>22</strong></td>
<td><strong>26</strong></td>
<td><strong>211</strong></td>
</tr>
</tbody>
</table>

Note: Farmers are categorized according to operated land. Landless: <0.01 acres, Marginal: 0.01 - <0.50 acres, Small: 0.50 - < 2.5 acres, Medium: 2.5 - < 5.0 acres, Large: > 5.0 acres (Source: BBS, 2010)

2.9 Household Questionnaire Survey

Before conducting each household survey, informed consent was obtained from the participants. Stratified purposeful sampling was applied during household questionnaire survey. Stratification illustrates characteristics of particular subgroups of interest and facilitates comparisons. The household questionnaire was related to agricultural production, input and output, education, equity, occupation, assets, awareness, marketing system, health situation and care, sanitation and other related aspects of agricultural sustainability.

Surveys based on structured questionnaires are an orthodox but useful tool for data collection in social research (Bassey, 1999; Cohen et al., 2002). Although large scale questionnaire surveys are sometimes criticized for their high costs, errors and other defects (Bleek, 1987; Gill, 1993; Inglis,
for one-off investigations or longitudinal studies, but they remain one of the most widespread and sustainable methods of rural research (Guijt, 1992). DFID (2000) and Ellis (1998) suggested that using questionnaire surveys can provide reliable data on livelihoods strategies and outcomes.

Data gathered by questionnaires provide an opportunity to compare across cases and wealth groups on the basis of wealth categories (Islam, 2002). A summary of target groups, settings and questionnaire types is presented in Table 2.5.

Table 2.5: Target groups and data collection methods

<table>
<thead>
<tr>
<th>Target Groups</th>
<th>Study Area Location</th>
<th>Main Farming System</th>
<th>No. of Surveyed Household</th>
<th>Data Collection Method</th>
<th>Information Gathered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagda Farmers</td>
<td>Moribund Delta-west south</td>
<td>Bagda monoculture with little rice</td>
<td>45</td>
<td>Questionnaire interviews, observation</td>
<td>Sustainability issues of Bagda based farming system</td>
</tr>
<tr>
<td>Bagda + Rice Farmers</td>
<td>Moribund Delta–west south</td>
<td>Bagda, rice with other crops (Note: spatial variation)</td>
<td>60</td>
<td>Questionnaire interviews, observation</td>
<td>Sustainability issues of Bagda and Rice based farming system</td>
</tr>
<tr>
<td>Traditional Farmers</td>
<td>Moribund Delta–west south</td>
<td>Rice monoculture with others crops</td>
<td>59</td>
<td>Questionnaire interviews, observation</td>
<td>Sustainability issues of Rice based farming system</td>
</tr>
<tr>
<td>Galda + Rice + Vegetable Farmers</td>
<td>Moribund Delta–west south</td>
<td>Galda + Rice + Vegetable-mixed farming (Note: temporal variation)</td>
<td>22</td>
<td>Questionnaire interviews, observation</td>
<td>Sustainability issues of Galda + Rice + Vegetable based farming system</td>
</tr>
<tr>
<td>Traditional Farmers</td>
<td>Active Delta-middle</td>
<td>Rice monoculture with others crops</td>
<td>26</td>
<td>Questionnaire interviews, observation</td>
<td>Sustainability issues of Rice based farming system</td>
</tr>
<tr>
<td>FGD (participants were from five categories of farmers)</td>
<td>Active Delta + Moribund Delta</td>
<td>All types of farming from all study areas</td>
<td>120 (5 events)</td>
<td>Cross-checking</td>
<td>Discussion on various issues of Agricultural Sustainability</td>
</tr>
<tr>
<td>Key Informants (Upazila Agriculture Extension Officers, Fisheries Officers and Animal Resource Officers and local people of all study areas)</td>
<td>Active Delta + Moribund Delta</td>
<td>All types of farming in all study areas</td>
<td>20</td>
<td>Cross-checking through discussion, structured and unstructured interviews</td>
<td>Validation of collected information (Each Key Informants interview were 2/3 hours long)</td>
</tr>
</tbody>
</table>

Source: Field study, 2011
2.10 FGD (Focus Group Discussion)

Focus group discussion (FGD) is one of the most widely used participatory methods in PRA (Guijt, 1992). Focus group discussions were used to enable different categories of people, including disadvantaged groups to identify their priorities and interests. In this study, FGDs were conducted in all study areas with different farmers groups to understand and collect information related to issues of sustainability (Picture 2.3).
Picture 2.3: Activities of FGDs during field study. (A) FGD in Shyamnagar, (B) FGD in Kaliganj, (C) FGD in Dumuria and (D) FGD in Bhola Sadar.

The household questionnaire was used as a checklist in conducting the FGDs but different issues were also discussed. FGDs were carried out for 1.5-2 hours, at farm sites, at farmers’ homesteads and in community settings. In totality, approximately 120 participants attended five FGDs. Audio recordings of FGDs were made.

Under FGDs, the participants were permitted to discuss among themselves and even argue in order to reach a consensus of an issue. The main limitation of FGDs was dominance by one individual as a leader type person which often influenced other participants. However, in the informal environment of the FGD, many of the respondents shared a wide variety of opinions while answering the questions which proved to be an effective technique.
2.11 Key Informant Interviews

Key informant interviews were carried out to verify information from household questionnaire surveys and focus groups. A key informant is anyone who has significant knowledge on a particular topic (Faruk, 2009). The key informant survey is a method of obtaining information from persons whose professional and/or organizational roles imply that they have knowledge about specific characteristics of the population being studied as well as potential pathways and constraints for community change (Eyler et al., 1999).

In order to efficiently develop agriculture, there is an agricultural extensions office, a fisheries office and a livestock office in each upazila. Through unstructured and informal discussions, varieties of information were collected from the key informants employed in these offices. The experts were encouraged to speak in their minds. A total of 20 key informant interviews were conducted.

Picture 2.4: Key informant interview during field study. (A) Interview with key informant in Kalaroa and (B) Interview with key informant in Dumuria.
2.12 Summarizing and Tabulating Collected Data

Collected data were compiled, edited, and summarized. For easy modification and refinement of information, five databases for each of the study area were prepared in Excel format.

2.13 Quantitative Data Analysis

Preliminary quantitative methods such as percentage, weighted average, mean etc. were used to prepare tables and graphs. Normality of quantitative data was checked by visual observation.

2.14 Qualitative Data Analysis

From qualitative data, simple percentages of various issues of sustainability of agriculture were calculated. The collected qualitative data were coded before entering to the computer.

2.15 Selection of Indicators

For the present study, agricultural sustainability was defined in terms of the six categories – productivity, stability, efficiency, durability, compatibility and equity - defined above (vanLoon et al., 2005). In order to assess sustainability within these categories, a suite of indicators was selected from standard sources or developed for the particular situation in coastal Bangladesh. Indicators are an aggregation of information that indicates the change or determines the status of particular issues (UN, 2007). Indicators are most often based on quantifiable data but may also be based on qualitative data depending on the purpose of the indicator (Miller, 2001). The indicators were developed on the basis of being policy-relevant, practical, available in standardized measurements and related to a reference level (Hardi and Zdan, 1997; Meadows, 1998; vanLoon et al., 2005). Although it was difficult for every indicator to conform to all of these requirements, it was important that they be adhered to as far as possible. It was also important that indicators be selected according to their ability to describe some aspect of sustainability of agriculture in its broadest sense. A literature review (OECD, 2001; Vander Werf and Petit, 2002; vanLoon et al., 2005) and
discussions with experts and farmers were carried out before creating the final set of indicators. The selected indicators were designed in a way that allowed for easy collection of good quality information. The indicators and their corresponding justification are described in Table 2.6.

<table>
<thead>
<tr>
<th>Category</th>
<th>Attribute</th>
<th>Selected Indicators</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>Rice</td>
<td>Primary productivity: Weighted average yield (t/ha)</td>
<td>Rice is the most important agricultural product as both food and income.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Net income yield ($/ha)</td>
<td>Farmers’ income largely depends on the income from rice.</td>
</tr>
<tr>
<td></td>
<td>Agro-Ecosystem</td>
<td>Net income yield ($/hectare)</td>
<td>Income from the agro-ecosystem determines the economic conditions of a framer.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Protein yield (kg/hectare)</td>
<td>Productivity of protein is important for the depended population of the agro-ecosystem.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy yield (j/ha)</td>
<td>Productivity of food energy is important for the dependent people of the agro-ecosystem.</td>
</tr>
<tr>
<td>Stability</td>
<td>Land</td>
<td>Land types</td>
<td>Land use for agricultural activities is determined by land types.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mobility of water on land surface</td>
<td>Mobility of water in land surface determines agriculture practice.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crop production intensity</td>
<td>Increasing crop production intensity increases agricultural production.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land surface exposure to saline water</td>
<td>Saline water causes an unfavorable environment that restricts normal crop production throughout the year.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land exposure to cyclone</td>
<td>Lands that are exposed to cyclones are potentially unstable in terms of agricultural activities.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land affected by cyclone</td>
<td>Almost every year some parts of the coastal regions of Bangladesh are subject to damaging of cyclones.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land affected by drought in kharif to rabi season</td>
<td>Periods of drought can have significant environmental, agricultural, health, economic and social consequences.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Irrigation facilities of the land</td>
<td>Irrigation facilities play a significant role in enhancing crop production.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Existence of river bank erosion</td>
<td>Riverbank erosion causes setbacks for village agriculture. Along with homestead settlements, it erodes farmland, infrastructure and the communication system.</td>
</tr>
<tr>
<td>Soil</td>
<td>Organic materials</td>
<td>Soil organic matter affects the chemical and physical properties of the soil and its overall health</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil texture</td>
<td>Soil texture is an important soil characteristic that drives crop production and field management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chemical properties</td>
<td>Balance of chemical properties in soil is important for plants growth and production of crops.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Salinity</td>
<td>Soil salinity is a significant factor in reducing crop productivity.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pH</td>
<td>Soil pH plays important role in controlling availability of plant nutrients to crops.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mineral nutrients</td>
<td>Mineral nutrients are required for the growth and reproduction of plants.</td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>Attribute</td>
<td>Selected Indicators</td>
<td>Justification</td>
</tr>
<tr>
<td>----------------</td>
<td>--------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Soil</td>
<td>Macronutrients (N, P, Ca, K, and Mg)</td>
<td>Soil macronutrients, nitrogen (N), phosphorus (P), and potassium (K), are essential elements for crop growth</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Micronutrients (B, Cu, Fe, Mn, Mo, Zn and Cl)</td>
<td>Soil micronutrient controls crop yield, quality, plant morphological structure (such as fewer xylem vessels of small size), widespread infestation of various diseases and pests, low activation of phytosiderophores, and lower fertilizer use efficiency.</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Surface water salinity</td>
<td>Too much salt can reduce or even prohibit crop production.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Groundwater salinity</td>
<td>Too much salt can reduce or even prohibit crop production.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Arsenic concentration</td>
<td>Reduced agricultural productivity due to arsenic toxicity which is harmful to humans and possibly to animals when high arsenic rice straw is used for feed</td>
<td></td>
</tr>
<tr>
<td>Stability</td>
<td>Current temperature (CT)</td>
<td>Current temperature and trend of temperature affects the yield of various crops.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trend of temperature (TT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Current rainfall (CR)</td>
<td>Agricultural production in coastal areas of Bangladesh is very much dependent upon adequate and timely rainfall.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trend of rainfall(TR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others issues</td>
<td>Withdraw of upstream water</td>
<td>Withdrawal of upstream water creates a severe stress on soil moisture, soil salinity, and non-availability of fresh groundwater, thus affecting agricultural productivity in the long term.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drying of river</td>
<td>Drying river has a profound negative impact on hydrological cycle, ecosystem and agricultural activities.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stability of embankment</td>
<td>Coastal embankments provide safeguard against the intrusion of saline water and devastation associated with repeated attacks of tidal surges and cyclonic storms.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Condition of transport system</td>
<td>Effective transport helps to develop agriculture.</td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>Hectare wise efficiency ($/ha)</td>
<td>Rice production dominates the farming system, so maximizing gain (income per unit of land) from rice is important for farmers.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall energy efficiency (Ratio of energy output and input)</td>
<td>Rice production dominates the farming system, so energy efficiency (energy out/energy in) is important for the efficiency of rice cultivation system.</td>
<td></td>
</tr>
<tr>
<td>Efficiency</td>
<td>Ratio ($output/$ input)</td>
<td>Profit gained per unit area is important from the farmers' economic point of view.</td>
<td></td>
</tr>
<tr>
<td>Agro-Ecosystem</td>
<td>Overall energy efficiency (Ratio of energy output and input)</td>
<td>Overall energy efficiency of an agro-ecosystem determines the efficiency of the agricultural practices.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-renewable energy efficiency</td>
<td>Efficiency in terms of non-renewable energy sources is especially important for the sustainability of an agro-ecosystem.</td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>Attribute</td>
<td>Selected Indicators</td>
<td>Justification</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Durability</td>
<td>Pest stress</td>
<td>Non-Chemical Response to Pest Stress</td>
<td>Pest control by non-chemical means ensures a healthy environment and ecosystem.</td>
</tr>
<tr>
<td></td>
<td>Water availability</td>
<td>Water availability at transplanting stage of rice</td>
<td>Availability of water at the transplanting stage is important for crops growth.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water availability at flowering stage of rice</td>
<td>Availability of water at the flowering stage is important for crops growth.</td>
</tr>
<tr>
<td></td>
<td>Seed</td>
<td>Seeds preservation</td>
<td>Proper preservation of seeds ensures the quality of seeds.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Availability of seeds</td>
<td>Availability of seeds ensures smooth agricultural activities.</td>
</tr>
<tr>
<td></td>
<td>Economics</td>
<td>Product price</td>
<td>Good price of the agricultural products motivates farmers to employ good agricultural practices.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Availability of market</td>
<td>Availability of markets ensures the sale of the agricultural products.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Livelihood diversity</td>
<td>Livelihood diversity ensures additional sources of income and provides an outlet for some secondary agricultural products.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Years of economic hardship</td>
<td>Economic hardship stops farmer of doing agricultural activities all the year round.</td>
</tr>
<tr>
<td></td>
<td>Agriculture Knowledge</td>
<td>Agricultural training</td>
<td>Block Supervisor provides efficient and effective need-based extension services to all categories of farmers, to enable them to optimize their use of resources, in order to promote sustainable agricultural and socioeconomic development.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Advices from suggestion from Block Supervisor</td>
<td>Awareness of climate change impacts on agriculture helps farmers to adopt their agricultural systems.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil test</td>
<td>Improved farm management/soil test is necessary to enhance production of crops.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Climate change awareness</td>
<td>Training on agriculture helps farmers to employ better agricultural practices.</td>
</tr>
<tr>
<td></td>
<td>Human</td>
<td>Illness from drinking water</td>
<td>Concentration of As in drinking water affects the health of farmers.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Protected water supply</td>
<td>Drinking-water related illness indicates the quality of drinking water in the agro-ecosystem.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arsenic concentration in drinking water supply</td>
<td>Protected water supply ensures safe drinking water.</td>
</tr>
<tr>
<td>Compatibility</td>
<td>Biophysical Surroundings</td>
<td>Overall biodiversity condition</td>
<td>Diversity of agro-ecosystem ensures better agricultural practices and maintains ecosystem health.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percentage of Non-crop area</td>
<td>Non-crop area helps in sustainable pest control.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Condition of ecosystem services</td>
<td>Sustainable agricultural depends on the conditions of ecosystem services.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall environmental conditions</td>
<td>Overall environmental conditions determines the sustainability of the agriculture</td>
</tr>
</tbody>
</table>
### Equity

<table>
<thead>
<tr>
<th>Category</th>
<th>Attribute</th>
<th>Selected Indicators</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Education</strong></td>
<td>Education status of farmers</td>
<td>Education of farmers is beneficial for promoting sustainable agriculture.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Education status of farmers' male</td>
<td>Education of farmers’ male children also helps the sustainable practise of agriculture.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>children</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Education status of farmers' female</td>
<td>Female children’s education indicates the openness of a community.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>children</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Access to electronic media</td>
<td>Access to electronic media indicates farmers’ access to information in an agro-ecosystem.</td>
<td></td>
</tr>
<tr>
<td><strong>Economic</strong></td>
<td>Average income from agro ecosystem</td>
<td>Average income of an agro-ecosystem provides information about economic status and wellbeing of the area.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average value of the assets of the</td>
<td>Farm assets value indicates the economic status of a farm.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>farm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>People above extreme poor</td>
<td>Percentage of extremely poor people indicates is a measure of economic equity.</td>
<td></td>
</tr>
<tr>
<td><strong>Economic</strong></td>
<td>Average daily wage of farm labourer</td>
<td>Average wage of farm labour indicates the economic status of the farm labourer.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender based wage differentials</td>
<td>Gender based wage differences is an indication the status of women in the labour market.</td>
<td></td>
</tr>
<tr>
<td><strong>Economic</strong></td>
<td>Electricity connection</td>
<td>Electricity connection in the household indicates opportunities for better health, more education, and more time for other activities than basic household chores.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Status of production of own staple</td>
<td>Status of production of owns staple food indicates the availability of food within the agro-ecosystem.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>food</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average calorie intake by each family member from staple food</td>
<td>Average calorie intake by each family member from staple food indicates the calorie intake status of the household.</td>
<td></td>
</tr>
<tr>
<td><strong>Health</strong></td>
<td>Settings where treatment is taken</td>
<td>A setting where treatment is taken indicates the health care facilities in the agro-ecosystem.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Toilet facilities</td>
<td>Toilet facilities are a measure of a healthy environment for humans in the agro-ecosystem.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cooking facilities</td>
<td>Cooking facilities indicate indoor air quality and use of agricultural by products.</td>
<td></td>
</tr>
<tr>
<td><strong>Decision Making</strong></td>
<td>Women participation in agricultural activities</td>
<td>Women’s participation supports diversification and sustainable development of agriculture.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender based governance difference</td>
<td>Gender based governance difference indicates the women participation in decision-making in an agro-ecosystem.</td>
<td></td>
</tr>
</tbody>
</table>

Source: Literature review, Expert opinion, FGD, Key informants, Questionnaire survey, and observation, 2011

### 2.16 Multi Criteria Decision Analysis

The indicator data obtained in the five study areas was assessed by Multi-Criteria Decision Analysis (MCDA). MCDA is a set of methods and procedures by which multiple criteria can be formally incorporated into a management planning process (Dantsis et al., 2010; Mustajoki et al., 2010).
There is extensive literature describing application of multi-criteria analysis or multi-criteria decision making in environmental studies (Dantsis et al., 2010; DFCALG, 2009; Miranda, 2001; Tiwari et al., 1999). Dantsis et al. in 2010; Hayashi in 2000 and Marttunen and Hamalainen in 1995 have reviewed the application of the methodology in natural resource management, agricultural resource management and agricultural sustainability assessment.

In this study, MCDA was carried out using web-based Web-HIPRE (Hierarchical PREference Analysis) shareware. Web-HIPRE is a web-version of the HIPRE3+ implementation software for analytic problem structuring, multi-criteria evaluation and prioritization (Hämaäinen and Lauri, 1995). It is also capable of considering a large collection of criteria and is able to produce comparisons for different situations. In the present case, it was used to rank sustainability in the six chosen categories for the five study sites.

This software supports multi-attribute value theory (MAVT) based methods (Keeney and Raiffa, 1976). Multi-Attribute Value Theory (MAVT) is a rigorous framework for pursuing the logic of computing an overall score for each alternative (Dias and Antunes, 2012). In this study, MAVT approach was used as it has the ability to analyze situations and conduct an assessment (Scholz and Tietje, 2002).

An attribute tree was developed in data analysis by MAVT. A set of attribute trees summarize the indicators that were chosen to assess sustainability. In the comprehensive tree (Figure 2.6), agricultural sustainability (overall goal) is divided hierarchically into six individual sustainability categories. Similarly, lower level trees tabulate and correlate indicator data with that category.
In MAVT, the alternatives are evaluated with respect to each attribute and the attributes are weighted according to their relative importance (Mustajoki et al., 2003). An additive value function can be used to aggregate the component values, assuming mutually preferentially independent attributes (Mustajoki et al., 2003). The overall value of the alternative “x” is

$$ n \sum_{i=1}^{n} w_{i} v_{i}(x) $$

Where,

- $n$ = The number of attributes,
- $w_{i}$ = The weight of attribute $i$, and
- $v_{i}(x)$ = The rating of an alternative $x$ with respect to an attribute $i$. 

Figure 2.2: Example of the attribute tree of agricultural sustainability in Web-HIPRE window
The sum of the weights is normalized to one, and the component value functions \( v(\cdot) \) has values between 0 and 1. The weights \( w_i \) indicates the relative importance of attribute \( i \), changing from its worst level to its best level, compared to the changes in the other attributes (Mustajoki et al., 2003). The words attribute and criterion are often used synonymously in the literature on MCDA. Attribute is also sometimes used to refer to a measurable criterion. In this study, the identified category of sustainability of agriculture is first attribute. Subdivisions of the categories are second attributes and the indicators that are identified under each subcategory are third attributes.

Weight attributes can be elicited by different procedures. For weighting of attributes in this study, “Direct” and “SMART” weighting procedures were used. In “Direct weight”, points are given directly whereas in “SMART”, 10 points are first given to the least important attribute. Then, more points are given to the other attributes depending on the relative importance of their ranges (Häma“la”inen and Lauri, 1995). The relative spacing between the levels of the attribute reflects the strength of preference of one level compared with another (Hostmanna et al., 2005).

To give weighting values that estimate the relative importance of the different attributes of sustainability of agriculture multiple judgment methods were employed based on field observation, literature survey and discussion with farmers and local experts (Table 2.7). The values for different indicators were assessed as shown in Table 2.8. It was difficult to set the optimum value for some of the indicators as indicators of sustainable agriculture are time and space relative. However, in this study the actual range is determined by the alternatives with the largest and smallest values of each indicator based on the results of the questionnaire, secondary information and accepted standard values of some of the indicators.
Table 2.7: Weighting judgment of selected attributes to measure value of sustainability of agricultural systems by MCDA

<table>
<thead>
<tr>
<th>Code</th>
<th>Selected Attributes</th>
<th>Weight</th>
<th>Weighting Judgment</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Productivity</td>
<td>30</td>
<td>Rice dominates the cropping pattern in study areas’ agro-ecosystem and it is also the staple food of the study areas' people.</td>
</tr>
<tr>
<td>P1</td>
<td>Rice</td>
<td>30</td>
<td>Among many types of productivity of rice, yield is very important as it related self-sufficiency of rice.</td>
</tr>
<tr>
<td>P1.1</td>
<td>Primary productivity: Weighted average yield(t/ha)</td>
<td>40</td>
<td>Net income yield of rice is very important to the farmers as farmers' economic condition is largely determined by it. It is also the most important strategic commodity in the economy of Bangladesh.</td>
</tr>
<tr>
<td>P1.2</td>
<td>Net income yield($/ha)</td>
<td>60</td>
<td>Food security and entire agro-economics of the farmers depend on the productivity of whole agro-ecosystem including crops and aquatics foods.</td>
</tr>
<tr>
<td>P2</td>
<td>Agro-Ecosystem</td>
<td>70</td>
<td>Economic condition of farmers of the study areas’ agro-ecosystem is determined by hectare wise net income of the agro-ecosystem.</td>
</tr>
<tr>
<td>P2.1</td>
<td>Net income ($/ha)</td>
<td>50</td>
<td>Hectare wise protein yield of agro-ecosystem determines supply of this essential nutrient for the people.</td>
</tr>
<tr>
<td>P2.2</td>
<td>Protein (kg/ha)</td>
<td>25</td>
<td>Energy intake by the people is related with the hectare wise kilocalorie yield of the agro-ecosystem.</td>
</tr>
<tr>
<td>S</td>
<td>Stability</td>
<td>20</td>
<td>Land in terms of appropriate location, availability of water and protected from disasters is a fundamental requirement for establishing an agricultural system.</td>
</tr>
<tr>
<td>S1</td>
<td>Land</td>
<td>20</td>
<td>Farmers of the study areas determine cultivation of crops according to land types (elevation).</td>
</tr>
<tr>
<td>S1.1</td>
<td>Land types</td>
<td>20</td>
<td>Mobility of water over the land surface determines the time of crop establishment.</td>
</tr>
<tr>
<td>S1.2</td>
<td>Mobility of water</td>
<td>10</td>
<td>Crop production intensity ensures year round agricultural activities and land’s health.</td>
</tr>
<tr>
<td>S1.3</td>
<td>Crop production intensity</td>
<td>10</td>
<td>Saline water diminishes the biological productivity of land.</td>
</tr>
<tr>
<td>S1.4</td>
<td>Exposure to saline water</td>
<td>10</td>
<td>Cyclone damages the agriculture of cyclone exposed lands.</td>
</tr>
<tr>
<td>S1.5</td>
<td>Exposure to cyclone</td>
<td>10</td>
<td>The persistent of damage to land by cyclone varies at different study sides.</td>
</tr>
<tr>
<td>S1.6</td>
<td>Land affected by cyclone</td>
<td>10</td>
<td>Drought damages crops and reduce productivity in some coastal areas due to inadequate and poorly distributed rainfall.</td>
</tr>
<tr>
<td>S1.7</td>
<td>Land affected by drought</td>
<td>10</td>
<td>Surface and ground water are important aspects for rice cultivation when salinity and/or drought problem occur.</td>
</tr>
<tr>
<td>S1.8</td>
<td>Irrigation facilities</td>
<td>10</td>
<td>River bank erosion hampers agricultural activities in coastal regions.</td>
</tr>
<tr>
<td>S2</td>
<td>Soil</td>
<td>40</td>
<td>Soil is the fundamental component of crop production. Healthy soil is the foundation of the food system. Its produce crops that in turn nourish people.</td>
</tr>
<tr>
<td>Section</td>
<td>Topic</td>
<td>Score</td>
<td>Note</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------</td>
<td>-------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>S2.1</td>
<td>Salinity</td>
<td>50</td>
<td>Higher concentrations of salt in soil slowdowns the movement of water from the soil to the root which affects crop growth.</td>
</tr>
<tr>
<td>S2.2</td>
<td>Organic materials</td>
<td>20</td>
<td>Organic materials perform many vital functions including converting dead and decaying matter as well as minerals to plant nutrients.</td>
</tr>
<tr>
<td>S2.3</td>
<td>Soil texture</td>
<td>10</td>
<td>Soil texture is an important soil characteristic that drives crop production and field management.</td>
</tr>
<tr>
<td>S2.4</td>
<td>Chemical properties</td>
<td>20</td>
<td>Soil chemical properties directly or indirectly influence nutrient dynamics of soil in agriculture production.</td>
</tr>
<tr>
<td>S2.4.1</td>
<td>pH</td>
<td>20</td>
<td>Plants grown in acid soils can experience a potential nutrient deficiency of calcium (Ca) and magnesium (Mg).</td>
</tr>
<tr>
<td>S2.4.2</td>
<td>Mineral nutrients</td>
<td>80</td>
<td>Balance mineral nutrients ensure higher productivity of crops.</td>
</tr>
<tr>
<td>S2.4.2.1</td>
<td>Macronutrients (N, S, P, Ca, K, and Mg)</td>
<td>70</td>
<td>Large quantity macronutrients are needed for crop growth.</td>
</tr>
<tr>
<td>S2.4.2.2</td>
<td>Micronutrients (B, Cu, Fe, Mn, Mo, Zn and Cl)</td>
<td>30</td>
<td>Micronutrients are essential for crops growth, but are required in much smaller amounts than macronutrients.</td>
</tr>
<tr>
<td>S3</td>
<td>Water</td>
<td>30</td>
<td>Water (surface and ground) is essential for the survival of all crops.</td>
</tr>
<tr>
<td>S3.1</td>
<td>Surface water salinity</td>
<td>60</td>
<td>Surface water salinity degraded land and it reduces agricultural productivity.</td>
</tr>
<tr>
<td>S3.2</td>
<td>Groundwater salinity</td>
<td>30</td>
<td>Groundwater salinity restrains land from irrigation facilities from ground water.</td>
</tr>
<tr>
<td>S3.3</td>
<td>Arsenic concentration</td>
<td>10</td>
<td>Arsenic concentration restrains farmers from ground water irrigation as there is generally a significant positive correlation between soil arsenic and crops arsenic concentrations. The farmers of Bangladesh start to realize the contamination of arsenic in crops.</td>
</tr>
<tr>
<td>S4</td>
<td>Climate</td>
<td>0</td>
<td>Climatic condition controls agricultural activities with soil and water. Therefore, as fundamental components of agriculture climate scores 10 in 10-100 weighting scale.</td>
</tr>
<tr>
<td>S4.1</td>
<td>Temperature</td>
<td>0</td>
<td>Temperature variation affects agriculture.</td>
</tr>
<tr>
<td>S4.2</td>
<td>Rainfall</td>
<td>0</td>
<td>Most of the crops in Bangladesh require at least some rain water to survive and to some extend agriculture in Bangladesh is largely rain dependent.</td>
</tr>
<tr>
<td>S5</td>
<td>Others issues</td>
<td>10</td>
<td>Without main stability issues there are some other issues those have some impacts on agricultural activities in coastal areas.</td>
</tr>
<tr>
<td>S5.1</td>
<td>Withdraw of upstream water</td>
<td>25</td>
<td>Withdraw of upstream water disrupts irrigation system in coastal areas as well as helps in saline intrusion.</td>
</tr>
<tr>
<td>S5.2</td>
<td>Drying of river</td>
<td>25</td>
<td>Drying rivers have significant impacts on total agro-ecosystem.</td>
</tr>
<tr>
<td>S5.3</td>
<td>Stability of embankment</td>
<td>40</td>
<td>Stability of embankment largely determines the agricultural practices in coastal areas.</td>
</tr>
<tr>
<td>S5.4</td>
<td>Condition of transport system</td>
<td>10</td>
<td>Transport system allows farmers to sell their products outside the agro-ecosystem.</td>
</tr>
<tr>
<td>E</td>
<td>Efficiency</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>E1</td>
<td>Rice</td>
<td>30</td>
<td>Rice is the main crop of the study areas’ agro-ecosystem. The efficiency issues of rice are very...</td>
</tr>
<tr>
<td></td>
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<tr>
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<td>---</td>
</tr>
<tr>
<td><strong>E1</strong></td>
<td>Profit ($/ha)</td>
<td>60</td>
<td>Profit ($/hectare) from main crops is very important to farmers economic point of view.</td>
</tr>
<tr>
<td><strong>E1.2</strong></td>
<td>Overall energy efficiency</td>
<td>40</td>
<td>Ratio of energy output and input of rice production indicates how efficiently rice is produced.</td>
</tr>
<tr>
<td><strong>E2</strong></td>
<td>Agro-Ecosystem</td>
<td>70</td>
<td>Total income and food security depend on agro-ecosystem.</td>
</tr>
<tr>
<td><strong>E2.1</strong></td>
<td>Ratio ($input/$output)</td>
<td>50</td>
<td>Ratio of $input and $output of agro-ecosystem is very important to maintain the farmers overall economic conditions.</td>
</tr>
<tr>
<td><strong>E2.2</strong></td>
<td>Overall energy efficiency</td>
<td>25</td>
<td>Ratio of energy input and output in producing of biomass indicates how efficient the total agro-ecosystem in term of energy use.</td>
</tr>
<tr>
<td><strong>E2.3</strong></td>
<td>Non-renewable energy efficiency</td>
<td>25</td>
<td>Use of non-renewable primary energy in producing primary products is very important from sustainable energy use in agro-ecosystem.</td>
</tr>
<tr>
<td><strong>D</strong></td>
<td>Durability</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>D1</strong></td>
<td>Pest stress</td>
<td>10</td>
<td>Non-Chemical Response to Pest Stress improve environmental conditions of agro-ecosystem.</td>
</tr>
<tr>
<td><strong>D2</strong></td>
<td>Water availability</td>
<td>10</td>
<td>Water is an essential production factor in agriculture.</td>
</tr>
<tr>
<td><strong>D2.1</strong></td>
<td>Water availability at transplanting stage of rice</td>
<td>50</td>
<td>Availability of water in transplanting stage ensures proper growth of rice.</td>
</tr>
<tr>
<td><strong>D2.2</strong></td>
<td>Water availability at flowering stage of rice</td>
<td>50</td>
<td>Availability of water in flowering stage ensures sustainability of rice.</td>
</tr>
<tr>
<td><strong>D3</strong></td>
<td>Seeds</td>
<td>10</td>
<td>Seeds are foundation of agriculture.</td>
</tr>
<tr>
<td><strong>D3.1</strong></td>
<td>Seeds preservation</td>
<td>50</td>
<td>Improve seed preservation system ensures good quality of seeds which help better production of crops.</td>
</tr>
<tr>
<td><strong>D3.2</strong></td>
<td>Availability of seeds</td>
<td>50</td>
<td>Availability of seeds through different channels ensures timely establishment of crops</td>
</tr>
<tr>
<td><strong>D4</strong></td>
<td>Economics</td>
<td>50</td>
<td>Economic related durability issues have influence on sustainability of agriculture.</td>
</tr>
<tr>
<td><strong>D4.1</strong></td>
<td>Product price</td>
<td>25</td>
<td>Good price of agricultural products ensures farmers return from agricultural activities. This eventually helps farmer to do next year agriculture properly.</td>
</tr>
<tr>
<td><strong>D4.2</strong></td>
<td>Availability of market</td>
<td>25</td>
<td>Availability of market ensures the sale of agricultural products</td>
</tr>
<tr>
<td><strong>D4.3</strong></td>
<td>Livelihood diversity</td>
<td>25</td>
<td>Diversity of livelihood ensures income from different sources which maintain stability to the economic status of the farmers.</td>
</tr>
<tr>
<td><strong>D4.4</strong></td>
<td>Years of economic hardship</td>
<td>25</td>
<td>Years of economic hardship hampers agricultural activities.</td>
</tr>
<tr>
<td><strong>D5</strong></td>
<td>Agricultural Knowledge</td>
<td>20</td>
<td>Knowledge related to agricultural issues has positive influence on better practices of agriculture.</td>
</tr>
<tr>
<td><strong>D5.1</strong></td>
<td>Agricultural training</td>
<td>40</td>
<td>Agricultural training is very important for extension of improved farm methods.</td>
</tr>
<tr>
<td><strong>D5.2</strong></td>
<td>Advices from Block Supervisor</td>
<td>20</td>
<td>Block supervisor’s suggestions help farmers for improving agricultural practices.</td>
</tr>
<tr>
<td><strong>D5.3</strong></td>
<td>Soil test</td>
<td>20</td>
<td>Soil test ensures better practices of crop production.</td>
</tr>
<tr>
<td><strong>D5.4</strong></td>
<td>Climate change awareness</td>
<td>20</td>
<td>Awareness of climate change impacts on agriculture helps farmers to adapt their agriculture in changing environment.</td>
</tr>
<tr>
<td>C</td>
<td>Compatibility</td>
<td>10</td>
<td></td>
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<td>-----</td>
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<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>C1</td>
<td>Human</td>
<td>50</td>
<td><strong>C1.1</strong> Illness from drinking water 50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>C1.2</strong> Protected water supply 30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>C1.3</strong> Arsenic concentration in drinking water supply 20</td>
</tr>
<tr>
<td>C2</td>
<td>Biophysical Surroundings</td>
<td>50</td>
<td><strong>C2.1</strong> Overall biodiversity condition 30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>C2.2</strong> Percentage of non-crop area. 20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>C2.3</strong> Condition of ecosystem services 20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>C2.4</strong> Crop richness 20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>C2.5</strong> Overall environmental condition 10</td>
</tr>
<tr>
<td>E</td>
<td>Equity</td>
<td>15</td>
<td><strong>E1</strong> Education 20</td>
</tr>
<tr>
<td>E1</td>
<td>Education</td>
<td>20</td>
<td><strong>E1.1</strong> Education status of farmers 20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>E1.2</strong> Education status of male children 35</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>E1.3</strong> Education status of female children 35</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>E1.4</strong> Access to electronic media 10</td>
</tr>
<tr>
<td>E2</td>
<td>Economics</td>
<td>35</td>
<td><strong>E2</strong> Economics 35</td>
</tr>
<tr>
<td>E2.1</td>
<td>Farmer income</td>
<td>45</td>
<td><strong>E2.1.1</strong> Income from agro ecosystem 50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>E2.1.2</strong> Average value of the assets of farm 25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>E2.1.3</strong> Percentage of people above extreme poor 25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>E2.2</strong> Labourer income 45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>E2.2.1</strong> Average wage of farm labourer 60</td>
</tr>
</tbody>
</table>
|     |               |    | **E2.2.2** Gender based labourer wage 40 | Gender based wage different indicates the status of...
<table>
<thead>
<tr>
<th></th>
<th>differentials</th>
<th>women labour in the society.</th>
</tr>
</thead>
<tbody>
<tr>
<td>E2.3</td>
<td>Electricity connection in household</td>
<td>Electricity supply indicates the advancement of the society.</td>
</tr>
<tr>
<td>E3</td>
<td>Health</td>
<td>25</td>
</tr>
<tr>
<td>E3.1</td>
<td>Production of own staple food</td>
<td>Status of health is an important issue of equity. It indicates circumstances in which farmers grow, live, work, and age, and the systems put in place to deal with illness.</td>
</tr>
<tr>
<td>E3.2</td>
<td>Average calorie intake by each family member from staple food</td>
<td>Production of won staple food indicates some sorts of stability of food security.</td>
</tr>
<tr>
<td>E3.3</td>
<td>Settings where treatment taken</td>
<td>10</td>
</tr>
<tr>
<td>E3.4</td>
<td>Toilet facilities</td>
<td>Toilet facilities indicate the status of healthy environment in agro-ecosystem.</td>
</tr>
<tr>
<td>E3.5</td>
<td>Cooking facilities</td>
<td>10</td>
</tr>
<tr>
<td>E5</td>
<td>Gender issue</td>
<td>20</td>
</tr>
<tr>
<td>E5.1</td>
<td>Women’s participation in the agricultural activities of the household</td>
<td>Gender equality is, first and foremost, a human right. Women are entitled to live in dignity and in freedom from want and from fear. Empowering women is also an indispensable tool for advancing development and reducing poverty.</td>
</tr>
<tr>
<td>E5.2</td>
<td>Gender-based governance difference</td>
<td>50</td>
</tr>
</tbody>
</table>

Source: Developed after discussions with respondents, both farmers and experts, 2011
Table 2.8: List of methods/software for measuring different indicators

<table>
<thead>
<tr>
<th>Code</th>
<th>Purpose</th>
<th>Methods/Software</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Productivity</td>
<td>ArcGIS</td>
<td>Identification of study areas</td>
</tr>
<tr>
<td>P1.1</td>
<td>Primary productivity of rice: Weighted average yield (t/ha)</td>
<td>PP(Y)=Mₚ/A</td>
<td>Where, PP(Y)= Primary productivity (Yield), Mₚ=Total mass of crop, A=Total area of crop</td>
</tr>
<tr>
<td>P1.2</td>
<td>Income yield from rice ($/ha)</td>
<td>IY=Iₙ/A</td>
<td>Where, IY= Income yield, Iₙ = The net income, A=Total area of crop</td>
</tr>
<tr>
<td>P2.1</td>
<td>Income yield from agro-ecosystem ($/ha)</td>
<td>IYAE=∑(Iₙ X Aₙ)/A</td>
<td>Where, IYAE= Income yield from agro-ecosystem, Iₙ = The net income per hectare for each crop grown, A=Area of each crop, Aₙ = Total land area of agro-ecosystem</td>
</tr>
<tr>
<td>P2.2</td>
<td>Protein yield from agro-ecosystem (kg/ha)</td>
<td>PYAE = ∑Pₙ/AT</td>
<td>Where, PYAE= Protein yield from agro-ecosystem, Pₙ = Total protein from different crops of agro-ecosystem, A = Total land area of agro-ecosystem</td>
</tr>
<tr>
<td>P2.3</td>
<td>Energy yield from agro-ecosystem (kcal/ha)</td>
<td>EYAE = ∑Eₙ/AT</td>
<td>Where, EYAE= Energy yield from agro-ecosystem, Eₙ = Total energy from different crops of agro-ecosystem, A = Total land area of agro-ecosystem</td>
</tr>
</tbody>
</table>

Note: Stability data has been collected from secondary information

<table>
<thead>
<tr>
<th>E</th>
<th>Efficiency</th>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1.1</td>
<td>Profit (gain from rice) ($/ha)</td>
<td>GR=TV/A</td>
<td>Where, GR= Dollar gain from per ha of rice, TV = Total value of the total production of rice, A = Total land area for rice</td>
</tr>
<tr>
<td>E1.2</td>
<td>Overall energy efficiency in rice</td>
<td>OEER= TECR/ TEI</td>
<td>Where, OEER= Overall energy efficiency of rice, TECR=Total energy content of total production of rice, TEI=Total energy input for total rice production.</td>
</tr>
<tr>
<td>E2.1</td>
<td>Ratio ($input/$output)</td>
<td>R=TVI/TVO</td>
<td>Where, R= Ratio of $input to $output in agro-ecosystem, TVI = Total value of the total input in $, TVO= Total value of the total output in $</td>
</tr>
<tr>
<td>E2.2</td>
<td>Overall energy efficiency in agro-ecosystem</td>
<td>OEEAE=TECAE/TEO</td>
<td>Where, OEEAE= Overall energy efficiency of agro-ecosystem, TECR=Total energy content of total production of crops of agro-ecosystem, TEI=Total energy input for total all crops production.</td>
</tr>
<tr>
<td>E2.3</td>
<td>Non-renewable primary energy efficiency in agro-ecosystem</td>
<td>NREFAE= ECPR/NEEI</td>
<td>Where, NREFAE= Non-renewable primary energy efficiency of agro-ecosystem, ECPR=Energy content of primary product, NEEI=Non-Renewable energy input for total all crops production.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D</th>
<th>Durability</th>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Non-chemical response to pest stress</td>
<td>NCRPS=P*10</td>
<td>Where, NCRPS=Non-chemical response to pest stress, P= Percentage of farmers using non-chemical pest control, 10 indicates height value of non-chemical response to pest stress by converting percentage of farmers in 0 to 10 scale.</td>
</tr>
<tr>
<td>D2.1</td>
<td>Water availability at transplanting stage of main crops (t. Aman)</td>
<td>WATS=P*10</td>
<td>Where, WATS= Water availability at transplanting stage of rice, P= Percentage of farmers reported availability of water, 10 indicates height value of water availability reported by farmers by converting percentage of farmers in 0 to 10 scale.</td>
</tr>
<tr>
<td>D2.2</td>
<td>Water availability at flowering stage of rice</td>
<td>WAWS=P*10</td>
<td>Where, WATS= Water availability at flowering stage of rice, P= Percentage of farmers reported ...</td>
</tr>
<tr>
<td>D3.1</td>
<td>Seeds preservation</td>
<td>( SPS = P \times 10 )</td>
<td>Where, ( SPS ) = Seeds preservation, ( P ) = Percentage of farmers apply modern methods for seed preservation, 10 indicates height value of farmers who preserved seeds by converting percentage of farmers in 0 to 10 scale.</td>
</tr>
<tr>
<td>D3.2</td>
<td>Availability of seeds</td>
<td>( AS = P \times 10 )</td>
<td>Where, ( AS ) = Availability of seed, ( P ) = Percentage of farmers reported of availability of seed, 10 indicates height value of farmers who said seeds are available by converting percentage of farmers in 0 to 10 scale.</td>
</tr>
<tr>
<td>D4.1</td>
<td>Products price</td>
<td>( PP = P \times 10 )</td>
<td>Where, ( PP ) = Product price, ( P ) = Percentage of reported about good product price, 10 indicates height value of farmers who get good price of the agricultural products by converting percentage of farmers in 0 to 10 scale.</td>
</tr>
<tr>
<td>D4.2</td>
<td>Availability of market</td>
<td>( AMAP = P \times 10 )</td>
<td>Where, ( AMAP ) = Availability of market, ( P ) = Percentage of farmers reported availability of market, 10 indicates height value of farmers who said availability of market by converting percentage of farmers in 0 to 10 scale.</td>
</tr>
<tr>
<td>D4.3</td>
<td>Livelihood diversity</td>
<td>( LD = P \times 10 )</td>
<td>Where, ( LD ) = Livelihood diversity, ( P ) = Percentage of farmers reported secondary occupation other than agricultural activities, 10 indicates height value of farmers reported livelihood diversity by converting percentage of farmers in 0 to 10 scale.</td>
</tr>
<tr>
<td>D4.4</td>
<td>Years of economic hardship</td>
<td>( YEH = 10 - N )</td>
<td>Where, ( YEH ) = Year of economic hardship, ( N ) = Number of year of economic hardship out of 10 years.</td>
</tr>
<tr>
<td>D5.1</td>
<td>Agricultural training</td>
<td>( AT = P \times 10 )</td>
<td>Where, ( AT ) = Agricultural training, ( P ) = Percentage of farmers reported about receiving agricultural training, 10 indicates height value of farmers received agricultural training by converting percentage of farmers in 0 to 10 scale.</td>
</tr>
<tr>
<td>D5.2</td>
<td>Advices from block supervisor</td>
<td>( AFBS = P \times 10 )</td>
<td>Where, ( AFBS ) = Advices from block supervisor, ( P ) = Percentage of farmers reported about taking suggestion from block supervisor for agricultural activities, 10 indicates height value of farmers reported take suggestion from block supervisor by converting percentage of farmers in 0 to 10 scale.</td>
</tr>
<tr>
<td>D5.3</td>
<td>Soil test</td>
<td>( ST = P \times 10 )</td>
<td>Where, ( ST ) = Soil test, ( P ) = Percentage of farmers do soil test in farm management, 10 indicates height value of farmers who follow soil test in farm management by converting percentage of farmers in 0 to 10 scale.</td>
</tr>
<tr>
<td>D5.4</td>
<td>Climate change awareness</td>
<td>( CCA = P \times 10 )</td>
<td>Where, ( CCA ) = Climate change awareness in agriculture, ( P ) = Percentage of farmers reported about awareness of climate change impacts on agriculture, 10 indicates height value of farmers reported have awareness about climate change impacts by converting percentage of farmers in 0 to 10 scale.</td>
</tr>
<tr>
<td>Compatibility</td>
<td>Formula</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
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<td></td>
</tr>
<tr>
<td><strong>C1.1</strong> Illness from drinking water</td>
<td>IFDW=(20-P)/2</td>
<td>Where, IFDW= Illness from drinking water, P=Percentage of people how have experienced illness and required treatment in past year, 20 per cent is the poorest goalpost and 0 is the best goalpost.</td>
<td></td>
</tr>
<tr>
<td><strong>C1.2</strong> Protected water supply</td>
<td>PWS=P/10</td>
<td>Where, PWS=Protected water supply, P=Percentage of people with access to protected water. “10” is the best score in 0 to 10 scales.</td>
<td></td>
</tr>
<tr>
<td><strong>C1.3</strong> Arsenic concentration in drinking water supply</td>
<td>AsCDWS = (10mg/L-(C_{As}))/5</td>
<td>Where, AsCDWS= Arsenic concentration in drinking water supply, (C_{As})=mg/L As concentration in drinking water, 10 mg/L is the WHO upper limit guideline.</td>
<td></td>
</tr>
<tr>
<td><strong>C2.1</strong> Overall biodiversity condition[Shannon Diversity Index]</td>
<td>OBC = -(\sum A_i \cdot \ln A_i) SOBC=10XOBC/2</td>
<td>Where, OBC=Overall biodiversity condition, (A_i) = Fractional area occupied by an individual crop or land use, (\ln A_i) = natural logarithm (ln) of (A_i). SOBC= Scaling overall biodiversity condition, OBC=Overall biodiversity condition, “10” is the best score in 0 to 10 scale.</td>
<td></td>
</tr>
<tr>
<td><strong>C2.2</strong> Percentage of non-crop area</td>
<td>PONCA = TNCA/TA*100</td>
<td>Where, PONCA = Percentage of non-crop area, TNCA= Total non-crop area, TA=Total area</td>
<td></td>
</tr>
<tr>
<td><strong>C2.3</strong> Condition of ecosystem services</td>
<td>COES=TSESAS/HS*10</td>
<td>Where, ES=Ecosystem services, TSESAS=Total score of ecosystem services of an agricultural system, HS=Possible highest score of the agricultural system, “10” is the best score in 0 to 10 scale.</td>
<td></td>
</tr>
<tr>
<td><strong>C2.4</strong> Crop richness</td>
<td>CR=N</td>
<td>Where, CR= Crop richness, N=Number of different crops grown</td>
<td></td>
</tr>
<tr>
<td><strong>C2.5</strong> Overall environmental condition</td>
<td>OEC=QRFFAE</td>
<td>Where, OEC = Overall environmental condition, QRFFAE=Overall qualitative ranking of environment by farmers</td>
<td></td>
</tr>
<tr>
<td><strong>E1.1</strong> Education status of farmers</td>
<td>ES=((\sum XN/Ni))*10</td>
<td>Where, ES=Education status, (N_i) = Individuals have a score of (X), (N)=Total number, “10” is the best score in 0 to 10 scale.</td>
<td></td>
</tr>
<tr>
<td><strong>E1.2</strong> Education status of male children</td>
<td>As above</td>
<td>As above</td>
<td></td>
</tr>
<tr>
<td><strong>E1.3</strong> Education status of female children</td>
<td>As above</td>
<td>As above</td>
<td></td>
</tr>
<tr>
<td><strong>E1.4</strong> Access to electronic media</td>
<td>AEM=P*10</td>
<td>Where, AEM=Access to electronic media, P=Percentage of farmer have access to electronic media, “10” is the best score in 0 to 10 scale.</td>
<td></td>
</tr>
<tr>
<td><strong>E2.1.1</strong> Income from agro ecosystem</td>
<td>IAE=(\sum TE/N)</td>
<td>Where, IAE= Income from agro-ecosystem in a year, TE=Total income from the whole agro-ecosystem, N=Number of farmer surveyed.</td>
<td></td>
</tr>
<tr>
<td><strong>E2.1.2</strong> Average value of the assets of farm</td>
<td>AVAF=(\sum CA/N)</td>
<td>Where, AVAF= Average value of the assets of farm, (CA_i) = Value of capital assets of an individual farmer, (N) = Number of farmer surveyed.</td>
<td></td>
</tr>
<tr>
<td><strong>E2.1.3</strong> Percentage of people above extreme poor</td>
<td>PPAEP=P</td>
<td>Where, PPAEP=Percentage of people above extreme poor, P=Number of percentage of people above extreme poor in the agro-ecosystem</td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
<td>Formula</td>
<td>Notes</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>E2.2.1</td>
<td>Average wage for farm labour</td>
<td>( AWFL = \frac{\sum TW}{N} )</td>
<td>Where, ( AWFL ) = Average wage for farm labour, ( TE ) = Total wage, ( N ) = Number of farmer respondent.</td>
</tr>
</tbody>
</table>
| E2.2.2  | Gender based wage differentials | \( GBWD = \frac{(30-D)}{3} \) | Where, \( GBWD \) = Gender based wage differentials, \( D \) = Wage difference in percentage term between men and women labour, “30” is the per cent differential as the poorest value.
| E2.3    | Electricity connection in household | \( ECH/H = P \times 10 \) | Where, \( ECH/H \) = Electricity connection of household, \( P \) = Percentage of household connected by electricity, “10” is the best score in 0 to 10 scale. |
| E3.1    | Production of own staple food | \( POSF = P \times 10 \) | Where, \( SPOSF \) = Production of own staple food, \( P \) = Percentage of farmer reported produce own staple food, “10” is the best score in 0 to 10 scale. |
| E3.2    | Average calorie intake by each family member from staple food | \( ACIEFMFSF = \frac{TCIBEFMO}{A(CR)} \times RIOC \times 10 \) | Where, \( ACIEFMFSF \) = Average calorie intake by each family member from staple food, \( TCIBEFMO \) = Total calorie intake by each family member on average (considering rice), \( RIOC \) = Recommended intake of calorie, “10” is the best score in 0 to 10 scale. |
| E3.3    | Settings where treatment taken | \( ST = \sum xN_i/N_t \) | Where, \( ST \) = Settings where treatment is taken, \( N_i \) = Treatment attain a score \( x \) and these are summed and averaged for all treatments, \( N_t \) = Total number of individuals. |
| E3.4    | Toilet facilities | \( TF = \sum xN_i/N_t \) | Where, \( TF \) = Toilet Facilities, \( N_i \) = Number of Toilet facilities attain a score \( x \), \( N_t \) = Total number of toilet facilities |
| E3.5    | Cooking facilities | \( CF = \sum xN_i/N_t \) | Where, \( CF \) = Cooking Facilities, \( N_i \) = Number of cooking units attain a score \( x \), \( N_t \) = Total number of cooking units |
| E5.1    | Women’s participation in agricultural activities of the household | \( WPAA = P \times 10 \) | Where, \( WPAA \) = Women participation in agricultural activities of the household, \( P \) = Percentage of women participate in agricultural activities, “10” is the best score in 0 to 10 scale. |
| E5.2    | Gender based governance difference | \( GBDG = P \times 10 \) | Where, \( GBDG \) = Gender based governance difference, \( P \) = Percentage of women in governance, “10” is the best score in 0 to 10 scale. |

Finally, using MCDA the relative sustainability values within each category was evaluated, and then those values were combined in MCDA again to evaluate overall sustainability of the study areas.
Chapter-III: Study Area

3.0 Introduction

A brief description of the study areas is given in this chapter. The selected study areas (upazilas, counties) are located in the coastal zone of Bangladesh as shown in Figure 3.1. The study included primary information obtained from a selected village within each upazila as well as secondary information from the upazila and broader district.

Figure 3.1: Location of the study areas in Bangladesh (Source: CGIS, 2010)
3.1 Description of Munshiganj Village of Shyamnagar Upazila

Location and Area: Munshiganj Village lies between latitudes of 22°11’ and 22°24’N, and longitudes 89°0’ and 89°19’E in Shyamnagar Upazila of Satkhira District. The total area of Munshiganj is 2470 ha whereas total area of Shyamnagar is 1968 km² including 32.20 km² occupied by the river (BBSa, 2001; SRDIa, 2001).

Physiography: Shyamnagar is located in the tidal floodplain of the Ganges delta and is influenced by diurnal tidal cycles. The area is characterized by flat land and smooth relief created by the deposition of sediment from the Ganges distributaries. Within the area there is a tidal river and a close network of interconnected creeks. In general, river banks of the area are elevated about a metre or less above the water level. Most parts of the region are less than 500 m from a tidal river or creek. The natural drainage, other than the main river channel, is impeded by extensive embankments and polders (SRDIa, 2001).

Climate: Like other parts of Bangladesh, this area experiences tropical monsoon climate with a hot and rainy summer and a pronounced dry season in the cooler months. Annual average rainfall of the area is about 1682 mm and annual average temperature is 25.8°C (SRDIa, 2001). The rainy season is characterized by hot and humid winds blowing from the Bay of Bengal during April to September, resulting in heavy rainfall with about 80% of the total rainfall occurring in this period. November to March is cool and dry (Mahmood et. al., 1994; SRDIa, 2001).

Land and Soil Type: About 78% land of the area is classified as medium high land. The soil is mostly grey or dark grey, noncalcareous, heavy silty clay. There is a general pattern of grey, slightly calcareous loamy soils in the river banks. Organic matter content is medium. Extremely acidic soils (acid sulfate soils) occur in patches throughout the area (SRDIa, 2001).
Water Resources: The region abounds in water resources; however most of these are rich in salt content. High salinity is also noticed in ground water under near-surface aquifers (SRDIa, 2001).

Present Land Use: Transplanted ‘Aman’ rice is the principal crop during and after the rainy season (the kharif season), a time when water salinity is low. ‘Aus’ rice and rabi (dry, winter) season crops may grow in non-saline upland areas. In homestead areas betelnut, coconut, vegetables, local fruits can be grown. However, most of the land is devoted to Bagda (a type of saltwater shrimp) cultivation (Field Study, 2011).

Salinity: Salinity in soil and water is a common feature of the area. The salinity is dominated by the presence of a prolonged low saline regime during the monsoon and post-monsoon seasons. Tidal waves play an important role in salinity intrusion and drainage congestion/inundations in this area. Salinity dominates agriculture, ecosystems and human activities (SRDIa, 2001).

Population: The total population is 17,692 with 9,079 males and 8,613 females. According to the population census of 2001 the population growth rate is 1.77% per annum. The population density is 1024/km². Average literacy rate is 44% with male literacy rate at 54% and female literacy rate at 33%. The average household size is 5.2 persons (BBSa, 2001).

Livelihood: Most people of the area are involved in agriculture or related activities either on their land or as workers for other people. Besides agriculture some people are also involved in fishing, fish business, transport, shopkeeping and a variety of other occupations. The staple food is rice and most people are accustomed to consuming fish and vegetables as part of their daily diet (Field Study, 2011).
3.2 Description of Nalta Village of Kaliganj Upazila

Location and Area: Nalta Village lies between latitudes of 22°19' and 22°34'N, and longitudes 89°58' and 89°10'E in Kaliganj Upazila of Satkhira District. The total area of Nalta is 480 ha whereas the total area of Kaliganj is 334 km² inclusive of 8 km² for the river (BBSa, 2001; SRDlb, 1997).

Nalta is also a part of tidal floodplain of the Ganges Delta, and has similar physiographic features - climate, soil type, water resource, salinity, land use and livelihood pattern - as does Shyamnagar (SRDlb, 1997). However, the land use pattern of more expansive homesteads is somewhat different than that of Munshiganj. Usually, the homestead area is used for growing rice as well as rabi crops and vegetables both for personal consumption and for commercial purposes.

Population: The total population is 7900 among which males make up 4084 and females 3816. Population density is 768/km². Population growth rate is 1.19% per annum. Average literacy rate is 47% with 53% male literacy rate and 40% female literacy rate. Total number of household is 1605. The average household size is 4.9 persons (BBSa, 2001).

3.3 Description of Tarulia Village of Kalaroa Upazila

Location and Area: Tarulia Village lies between latitudes of 23°48' and 23°57'N, and longitudes of 88°54' and 89°09'E in Kalaroa Upazila of Satkhira District. The total area of Tarulia is 546 ha whereas the total area of Kalaroa is 231.5 km² (BBSa, 2001; SRDlc, 1991).

Physiography: Like Munshiganj and Nalta, Kalaroa is also part of the tidal floodplain of the Ganges Delta. Most parts have a complex relief of ridges and inter-ridge depressions. Upper parts of high ridges remain above flood level, and lower parts are seasonally flooded to a shallow depth.
Like other parts of Satkhira District, the natural drainage system is impeded by embankments and polders (SRDIc, 1991).

**Climate:** Kalaroa also has a tropical monsoonal climate. There is no difference in the average annual rainfall and temperature for Munshiganj and Nalta areas (SRDIc, 1991).

**Land and Soil Type:** Most of the land is medium high land. Soils are silty loam and silty clay loam in ridges, and dark grey clay soils in basins. Most ridge soils are calcareous while basin soils are non-calcareous. Organic matter content in ridges is low (<1.5%), but higher (2-5%) in the dark grey basin soils. Soil reaction ranges from neutral to strongly acidic (SRDIc, 1991).

**Water Resources:** In some parts of this area, water is pumped from the river channel in order to irrigate *kharif* crops. In other parts, only limited amounts of surface water are available from small rivers and oxbow lakes. However, groundwater is used extensively for irrigation (Filed study, 2011; SRDIc, 1991).

**Salinity:** Water is substantially fresh, little influenced by the sea, therefore playing a dominating role in agriculture, ecosystems and livelihood (SRDIc, 1991).

**Present Land Use:** Rice, jute, pulses, oilseeds, wheat, sugarcane, tobacco, potato, turmeric, vegetables, banana and mango are important crops (Field study, 2011).

**Population:** Total population is 3166 with 1648 males and 1518 females. Population density is 953/km². Population growth rate is 1.67 persons per annum. Total literacy rate is 43 % with males at 48 % and female at 37 %. Total number of household is 708 with an average household size of 4.4 persons (BBSa, 2001).

**Livelihood:** Like Munshiganj and Nalta, a most of the people are involved in agricultural activities on their own land or for other people. Some people are involved in other activities including transportation, service, business and shopkeeping (Field study, 2011).
3.4 Description of Banda Village of Dumuria *Upazila*

**Location and Area:** Banda Village lies between latitudes 22°39' and 22°56'N, and longitudes 89°15' and 89°32'E (Figure 3.5 and 3.6) in Dumuria *Upazila* of Khulna District. The total area of Banda is 229 ha whereas total area of Dumuria is 448 km² of which the river occupies 19.5 km² (BBSb, 2001; SRDId, 2008).

**Physiography:** Like Munshiganj, Nalta and Tarulia it is also a part of tidal floodplain of the Ganges Delta and has been created by deposition of sediment. Most parts are located in a flat low-lying basin. The area is characterized by low relief and is influenced by diurnal tidal cycles. Like other study areas of Satkhira its natural drainage system is impeded by embankments and polders (SRDId, 2008).

**Climate:** Dumuria also belongs to the tropical monsoonal climatic system. The average annual rainfall is 1693 mm and annual average temperature is 26°C. Eighty percent of the total rainfall occurs in the rainy season from May to September (Mahmood et. al., 1994; SRDId, 2008).

**Land Type and Soil:** Most of the land is classified as medium high land. On basin margins, grey and dark grey acidic heavy clay overlies peat and muck to a depth of 25 to 100 cm. Soft peat and muck occupy perennially wet basin centres. Organic matter content is medium from 1.7% to 3.4% (SRDId, 2008).

**Water Resources:** Surface water is used for irrigation purpose. Rivers and creeks are tidal in the dry season. Ground water is sweet in northern and eastern areas but saline in the south-west. Along with surface water, rain plays an important role in agricultural activities (SRDId, 2008).

**Salinity:** The surface water is slightly saline but the concentration of salinity can be high in the ground water. Farmers use rainwater for agricultural activities as well as in Galda farming. The
farmers of the area are careful not to allow saline water into their agricultural fields (SRDld, 2008; Field study, 2011).

**Present Land Use:** Transplanted *Aman* rice or HYV *Boro* rice are grown in the *kharif* season. *Rabi* crops are grown on high river bank soils. Many of the fields are characterized by an integrated system of *Galda* (a type of fresh water prawn), rice and vegetables; the latter are often grown on the dikes of the *gher* (Field study, 2011).

**Population:** Total population is 1828 with 922 males and 906 females. Population density is 616/km². The population growth rate at 0.88 % per annum is lower than in the other areas. Total literacy rate is 62% with 72% male literacy rate and 52% female literacy rate. Total number of households is 426. The average household size is 4.9 persons (BBSb, 2001).

**Livelihood:** Like other study areas of Satkhira District the people of Banda are involved in agricultural activities. Other livelihood activities include agricultural labour, services, shopkeeping, business and trading (Field study, 2011).

### 3.5 Description of Kunja Patti Village of Bhola Sadar *Upazila*

**Location and Area:** Kunja Patti Village lies between latitude 22°32’ and 22°52’ N, and longitude 90°32’ and 90°44’ E in Bhola Sadar *Upazila* of Bhola District. The total area of Kunja Patti is 458 ha, whereas the total area of Bhola Sadar is 314 km² within which the river occupies 10 km² (BBSc, 2001; SRDIe, 1993).

**Physiography:** Bhola Sadar is located in the discharge area of the Ganges- Brahmaputra-Meghna River (GBM) system. It is occupied by flat land with very low ridges and broad depressions. Here, shifting channels constantly erode land and deposits sediment in other places to create new island formations. The area is highly influenced by tidal interactions and the consequential backwater
effect. The heavy sediment inputs from the rivers make it a morphologically dynamic coastal zone (SRDIe, 1993).

**Climate:** Like other study areas it is also within the tropical monsoon climate system. The annual mean rainfall is about 2000 mm and annual average temperature is 25.6°C. In the early summer (April and May) and late in the monsoon season (September to November) wind is variable and unstable causing frequent cyclones and tidal surges (SRDIe, 1993).

**Land type and Soil:** Medium high land makes up about 45% of all land types. Soils of the area are mainly grey to olive deep silt loams and silty clay loams, and organic matter content is medium (SRDIe, 1993).

**Water Resources:** Surface water is fresh. Sweet water is also found at a shallow depth in floodplain ridges and this is required for domestic use. Deeper water is more saline, especially in the southern part. Salinity gradually progresses northward in the dry season (SRDIe, 1993).

**Salinity:** Surface fresh water plays a lead role in agriculture, ecosystem and human activities of the area. On the other hand, salinity found in deep groundwater renders it unusable for most purposes (SRDIe, 1993).

**Present Land Use:** The dominant crop is transplanted *Aman* rice followed by *kheshari* and lentils. *Aus* or *Aman* rice is also grown in some parts. *Rabi* crops including many vegetables like chilli, eggplant, water gourd, amaranths etc. and multi-season crops like coconut, betel nut and sugarcane are also grown (Field study, 2011).

**Population:** Total population is 5235 with 2712 males and 2523 females. Population density is 988/km² with population growth at 1.50 % per annum. Literacy is very low at 26% in totality with 30% male literacy rate and 23% female literacy rate. The total number of households is 1028 and average household size is 5.1 persons (BBSc, 2001).
Livelihood: Like other study areas, most people are farmers and involved in agricultural activities. Some other occupations for the local people include labour, transport, shopkeeping and fishing (Field study, 2011).
4.0 Introduction

Data analysis was carried out in response to the objectives set out in Chapter One. The overall goal was to compare the levels of agricultural sustainability in the five study areas.

4.1 Profile of the Respondent Households

A total of 211 households were surveyed, based on interviews with one of the senior household members; among them only 6 were female respondents. A profile of the respondent households is presented in Table 3.1. It was found that the average age of the respondents was between 40 and 50 years.

<table>
<thead>
<tr>
<th>Items</th>
<th>Study areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Total number of respondents</td>
<td>45</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>44</td>
</tr>
<tr>
<td>Female</td>
<td>1</td>
</tr>
<tr>
<td>Family size (Average family member)</td>
<td>6</td>
</tr>
<tr>
<td>Average age</td>
<td>40</td>
</tr>
<tr>
<td>Literacy level (%)</td>
<td></td>
</tr>
<tr>
<td>Illiterate (No schooling)</td>
<td>18</td>
</tr>
<tr>
<td>Primary schooling</td>
<td>24</td>
</tr>
<tr>
<td>Secondary schooling</td>
<td>42</td>
</tr>
<tr>
<td>Tertiary schooling (SSC and HSC equivalent and above)</td>
<td>16</td>
</tr>
<tr>
<td>Occupation status (%)</td>
<td></td>
</tr>
<tr>
<td>Agricultural (Primary)</td>
<td>100%</td>
</tr>
<tr>
<td>Others (Secondary)</td>
<td>33%</td>
</tr>
<tr>
<td>Land holding (Ha/HH)</td>
<td>2.25</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

Educational status of the sample households was considered under the following categories: illiterate, completed primary schooling, high schooling and tertiary schooling. Among respondents, illiteracy rate is highest in Kalaroa and Bhola Sadar. Thirty to fifty years ago the number of primary school going students was unusually low in rural areas of Bangladesh. As a result, the illiteracy rate remains high among adults in many parts of the country. In Kalaroa, the average age of the...
respondents is about 50 years and illiteracy is high among them. Most of the aged respondents did not have access to primary education. Because of this reason, in Bhola Sadar too illiteracy is also high among respondents. In the case of Dumuria, although the age of the farmers is around 50 years, the illiteracy rate is lower as it was near a large urban area and primary education started here during the British period. The average family size of the respondent households of about 6 persons is close to the national average of 4.4 persons (BBS, 2011). The family size has been defined as the number of persons living together under the control of one head and taking meals from the same kitchen. The term family includes wife, sons, unmarried daughters, father, mother, and brothers etc. (BBS, 2001). The highest family size was found in Bhola Sadar. Average land holdings ranged from 1.12 ha/HH in Kalaroa to 3.50 ha/HH in Kaliganj. Land use varied from shrimp farming in the near-coast areas of Shyamnagar and Kaliganj, to field crops in Kalaroa and Bhola Sadar while there is extensive use of land for both shrimp and agriculture in Dumuria.

All the respondents of the study areas are doing agriculture as primary activities. In all study areas, apart from agriculture, about one third to one half of respondents held secondary occupations like fishing, small business, shop keeping, transport and a variety of services. The highest numbers of respondents involved in activities other than agriculture were found in Kaliganj while Kalaroa had the lowest number of respondents in non-agricultural occupations.

4.2 Agricultural Profile of the Study Areas

**Shyamnagar:** The Black Tiger shrimp (*Penaeus monodon*), locally called *bagda chingri* (DoF, 2005) is intensively cultivated in the tidally inundated low-lying flat lands of Shyamnagar. Most of the shrimp farmers include several types of fish in their *gher* to reduce their risks (Field study, 2011). The cultivation methods supporting production of *bagda* are mostly traditional with low
inputs and low yield per hectare (UFO, 2011). The activities of bagda shrimp cultivation start from January and continue up to November. General characteristics of the traditional bagda cultivation are presented in Table 4.2.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Traditional shrimp farming</th>
<th>Integrated prawn farming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farming system</td>
<td>Traditional aquaculture with some modified practices</td>
<td>Integrated aquaculture</td>
</tr>
<tr>
<td>Stocking density</td>
<td>In general High (3-5 post larvae/m²)</td>
<td>In general Medium (2-3 post larvae/m²)</td>
</tr>
<tr>
<td>Name of the species</td>
<td>Bagda (P. monodon)</td>
<td>Galda (M. rosenbergii )</td>
</tr>
<tr>
<td>Feeding</td>
<td>Mainly natural and supplementary</td>
<td>Supplementary and natural</td>
</tr>
<tr>
<td>Use of organic fertilizer (cow dung)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Use of synthetic fertilizer (urea)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Use of pesticide</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Use of antibiotic</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sources of post larvae</td>
<td>Wild and hatchery</td>
<td>Mainly hatchery, sometimes from wild</td>
</tr>
<tr>
<td>Uses of species</td>
<td>Native and exotic</td>
<td>Native and exotic</td>
</tr>
<tr>
<td>Mode of water exchange</td>
<td>Sluice gate and pump</td>
<td>Sluice gate and pump</td>
</tr>
</tbody>
</table>

Source: Field study and local experts, 2011

Ghers are enclosed by dykes that are normally low and often have holes in them that allow easy entry of pest animals. Most ghers are connected to creeks and waterway networks through sluice gates that allow farmers to manage the flow of brackish tidal water. The sluice gates are reinforced concrete and often imperfectly constructed. Normally, the water control systems are not based on local hydrography. Usually, the ghers do not have proper inlet screens; as a result heterogeneous species of highly predatory fish and crabs can therefore enter the ghers. At the same time, along with tidal water entry some desirable species including mullets, white shrimp (*Penaeus indicus*) and brown shrimp (*Metapenaeus monoceros*), also enter the pond freely (Field study, 2011). Most farmers use dry cow dung to grow algae in the gher while some use fish feed made of rice bran, wheat bran and fish meal. The algae serve as a food supply for both fish and bagda. While shrimp farming has the potential to be very lucrative, in recent years white spot syndrome disease has been causing mass mortality of bagda in this part of Bangladesh. White spot syndrome is a viral
infection of shrimp. The disease is highly lethal and contagious, killing shrimps quickly. Outbreaks of this disease can wipe out the entire populations of a gher within a few days. According to farmers and upazila fisheries officers there is no available treatment for this disease. However, farmers occasionally use “Aqua Fresh” to prevent the disease. According to the farmers it cleans gher water. Upazila fisheries officers opined that, it is a natural and safe solution for prevention and control of ammonia in aqua culture ponds.

In Shyamnagar, farmers grow rice in relatively higher areas and lands that are protected by secondary embankments or roads. The rice-growing areas are never more than 1 m above sea level and are therefore susceptible to flooding from river water during periods of heavy rain, or by sea water as a consequence of tidal surges or typhoons. Where rice is grown, two crops are possible. Aman rice is grown in the period from July to December while boro rice follows in the period from December to April. In general, farmers in Shyamnagar do not cultivate any crops in rabi season. Rabi season starts from November and extends up to the end of March. The season is characterized by dry sunny weather, warm at the beginning and end but cool in December-February. Livestock, poultry rearing and open water fishing continue throughout the year. The general seasonal characteristics, agricultural activities, transect of agricultural system and agricultural practices of Shyamnagar are shown in Table 4.3 and 4.4; Figure 4.1.

Table 4.3: General seasonal calendar of the study areas

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Note: “+” means increase of magnitude; “-” decrease of magnitude. Source: Field study, 2011
Table 4.4: Agricultural activities of Shyamnagar based on general crop calendar

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Source: FGD and Field study, 2011.

Figure 4.1: Large-scale transect of agricultural system of Shyamnagar. Source: Field study, 2011.
Kaliganj: As in Shyamnagar, bagda is also cultivated intensively in low lying tidal flats in Kaliganj upazila. For the most part, bagda cultivation is carried out in the same way as in Shyamnagar, but during the high salinity period from February to July, in some elevated fields whitefish are cultured along with shrimp in the same gher. Some farmers have excavated their relatively high lands to make the level lower and allow tidal inundation for aquaculture purposes. During the low-salinity period from August to December a salt-resistant type of aman rice is cultivated in the same elevated parts of the fields. In a limited number of cases, in lowlands during periods of low salinity, rice along with shrimp and fish are also grown in some ghers. In this system, some farmers even combine freshwater shrimp (Macrobrachium rosenbergii) and fish, like tilapia (Oreochromis niloticus niloticus), carp (Cyprinus carpio) or Thai sharpunti (Barbodes gonionotus), with the euryhaline species. Like Shyamnagar, rice, rabi crops and some vegetables are grown in relatively high land and lands that are protected by secondary embankments/roads. Livestock and poultry rearing are supporting activities as in Shyamnagar. Table 4.5 and Figure 4.2 illustrate the agricultural activities and agricultural system of Kaliganj.

Table 4.5: Agricultural activities of Kaliganj based on general crop calendar

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<th>Season</th>
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Source: FGD and Field study, 2011.
**Figure 4.2**: Large-scale transect of agricultural system of Kaliganj. Source: Field study, 2011

**Kalaroa**: In contrast to the farmers in Shyamnagar and Kaliganj, those in Kalaroa are in a position to follow a more diverse farming pattern. The agricultural system in this inner coastal area depends on the monsoonal climate bracketed by a hot-humid summer and a dry, mild winter. Rice is widely cultivated and is mostly rain-based where summer *aus* rice and *kharif aman* rice require little or no irrigated water. During the winter season, *boro* rice is grown extensively with irrigation. In the *kharif* season apart from rice, jute (*Corchorus*), sugarcane (*Saccharum*), and sesame (*Sesamum indicum*) are also grown (Field study, 2011). In summer, in general farmers grow many vegetables including okra (*Abelmoschus esculentus*), red amaranth (*Amaranthus gangeticus*), stem amaranth (*Amaranthus lividus*), Indian spinach (*Basella alba* L.), sweet gourd (*Cucurbita maxima*), bottle gourd (*Lagenaria siceraria*), wax gourd (*Benincasa hispida*), ribbed gourd (*Luffa acutagula*), sponge gourd (*Luffa cylindrica*), bitter gourd (*Momordica charantia*), snake gourd (*Trichosanthes anguina*), palwal (*Trichosanthes dioica*), cucumber (*Cucumis sativus*), squash (*Cucurbita pepo*),
brinjal (*Solanum melongena*) and summer tomato (*Lycopersicon esculentum*). In the *rabi* season farmers grow *boro* rice, wheat, oilseeds and pulses. Some farmers also grow spices and other supporting crops like green chillies (*Capsicum annuum*), ginger (*zingiber officinale*), onion (*Allium cepa*) and turmeric (*Curcuma longa*) in different seasons. As in Kaliganj, livestock and poultry rearing are continued throughout the year. Table 4.6 and Figure 4.3 illustrate the agricultural activities and agricultural system of Kalaroa.

**Table 4.6: Agricultural activities of Kalaroa based on general crop calendar**

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*Livestock & poultry*

All the year round

Source: FGD and Field study, 2011

**Figure 4.3: Large-scale transect of agricultural system of Kalaroa. Source: Filed study, 2011**
**Dumuria:** The farmers of Dumuria are mostly involved in an agricultural system where farmers hope to get a substantial output but with minimum supply of inputs of seeds, urea, TSP, gypsum, and pesticide. Through the questionnaire survey it was observed that, in comparison with other study areas, farmers of Dumuria are using less input for agricultural activities. Most of the farmers are involved in rice, fresh water prawn (*Macrobrachium rosenbergii*) and fish and vegetables cultivation in the same *gher*. This approach has been uniquely developed by the local farmers. In the *gher*, dikes are raised above normal flood level with an excavated canal 1 to 2 m deep and 3 to 6 m wide; alternatively, a small shallow pond is excavated in the middle or corner inside the *gher* periphery as a shelter for prawns and fish during the dry season (Field study, 2011). In this *gher* the rice is cultivated during the *kharif* season. Figure 4.4 illustrates the integrated *gher* system of Dumuria.

This fresh water prawn is known as the giant river/freshwater prawn worldwide while in Bangladesh it is commonly known as ‘*galda chingri*’ (*Macrobrachium rosenbergii*) (FAO, 1980). Farmers are growing *galda* along with carp, tilapia and other fish culture after harvesting rice. In this technique, *galda* and fish (usually carp and grass carp (*Ctenopharyngodon idella*)) are stocked in the paddy field after harvesting rice from the land. Fish rearing for six to seven months is possible until rice plantation begins in the next season. Vegetables are planted on dikes or by constructing frames using available materials (bamboo sticks, branches of trees and shrubs). In this way, farmers are able to produce both summer and winter vegetables commercially. Particularly in summer, the cultivated vegetables include eggplant, amaranth, bitter gourd, cucumber, tomato, water gourd, coneflower, radish and bean. In some relatively high lands, farmers are cultivating only rice and *rabi* crops like, potato, pulses, onion. The livestock and poultry are reared throughout the year. Table 4.7, Figure 4.4 and 4.5 illustrate the agricultural activities and agricultural system in Dumuria.
Table 4.7: Agricultural activities of Dumuria based on general crop calendar

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<th>Season</th>
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</tr>
</tbody>
</table>

Livestock & poultry: All the year round

Source: FGD and Field study, 2011.

Figure 4.4: Large-scale transect of agricultural system of Dumuria. Source: Field study, 2011
Bhola Sadar: Bhola Sadar is located on an evolving depositional island and is accessible from the mainland only by boat. Being isolated and unconnected to local physical and social infrastructure, agricultural practices are mostly traditional and based on the monsoon climate. Aus, aman and boro rice are cultivated in sequence throughout the year. Pulses such as grass pea, beans, lentils, groundnuts, and mustard are important components of the agricultural system. Recently boro rice, potato and watermelon cultivation and productivity have increased. Some farmers are practicing intercropping such as chili, okra plus sweet gourd or potato plus bitter gourd. The least productive season is the early kharif due to drought and higher salinity. There is no cultivation of fresh or marine aquatic species, although farmers support their own diet by fishing in the open water. Table 4.8 and Figure 4.6 illustrate the agricultural activities and agricultural system of Bohol Sadar.
Table 4.8: Agricultural activities of Bhola Sadar based on general crop calendar

<table>
<thead>
<tr>
<th>Crops</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<tr>
<td>Aus rice</td>
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<td>Showing and Harvesting</td>
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<tr>
<td>Aman rice</td>
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<td></td>
<td></td>
<td>Showing and Harvesting</td>
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<tr>
<td>Boro rice</td>
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<td>Rabi crops</td>
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<tr>
<td>Summer vegetables</td>
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<td></td>
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<tr>
<td>Winter vegetables</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livestock &amp; poultry</td>
<td>All the year round</td>
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</tr>
</tbody>
</table>

Source: FGD and Field study, 2011.

4.3 Sustainability Assessment

To assess sustainability of agriculture in the five study areas, indicators within six categories were calculated as outlined in Chapter 3.Employing MCDA methodology, the indicator data were then scored within the different categories and finally in terms of overall agricultural sustainability. The goal of this work was to compare various aspects of agricultural sustainability followed in the coastal region of Bangladesh using the results obtained.
4.3.1 Productivity

Productivity of the agricultural system is extremely important in order to provide for individual farmers’ livelihood and to feed the wider population. Without good productivity, it would be a challenge in the future to feed people in the coastal area as well as the population of the whole country from an increasingly vanishing and degraded natural resource base. Productivity is therefore the first prerequisite necessary to meet food security for both the farmer’s family as well as for the nation. It is an intrinsic component of agricultural sustainability.

In measuring productivity, the fundamental issues centre around how much crop or crops can be produced on a given area of land and this can be measured by several different indicators. Keeping in mind the importance of rice as the principal agricultural crop throughout the area, two indicators that focus on rice were considered essential – the average yield (t/ha) and the net income ($/ha) from a given area obtained by farmers. Clearly, these indicators overlap but in addition to yield, the second one also takes into account the important economic issue of cost in achieving a certain level of production. Three other indicators were also chosen to account for the variety of other agricultural and marine products produced within the total area available to farmers - net income ($/ha), protein yield (kg/ha) and energy yield (J/ha), all considering the entire agro-ecosystem (Table: P1). These indicators were selected to take into account the main goals of agriculture, as a source of income and to produce protein and food energy (kcal). Again, there is overlap in what is measured in each of these three indicators since all of them depend on the yield of various commodities, but no single indicator is able to account for issues like the varying economic value, protein and energy content of different products. Assigning a weight to each indicator was then done in a way to take into account this overlap. For example, because rice yield
influences all five productivity indicators, productivity of rice (P1.1) was assigned a lower weighting than if it had been the single indicator used to describe productivity alone.

Of the five study areas, the weighted average yield of overall seasons (6.51 t/ha) of rice was found to be highest in the integrated agricultural system of Dumuria. This high yield is considerably above the Bangladesh average (2.8 t/ha) and can be attributed in part to the lower salinity of both water and soil during the rice cultivation period and also to the supply of a significant amount of soil organic matter and soil nutrients from waste associated with galda prawn cultivation prior to planting rice were other contributing factors towards the higher yield (Barmon et al., 2007). Yield (2.28 t/ha) is lowest in the bagda shrimp dominated agricultural system of Shyamnagar because prolonged shrimp farming diminishes the soil quality of the rice fields adjacent to the ghers (Ali, 2004; 2006). Furthermore, the storm surge from the recent, 2009 cyclone ‘Aila’ over Shyamnagar brought saline water into the rice fields. This has created profound negative impacts on the soil and water for rice cultivation. While 2009 was the most recent such event, this highly exposed coastal region has been subject to other such surges over the past decades. The yield (2.86 t/ha) of rice in Bhola Sadar was also found to be low about the same as the national average of Bangladesh, however the farming systems are basically subsistence in nature, and rice is cultivated under input-starved conditions. Moreover, natural hazards like cyclones, heavy rainfall and drought have been affecting the rice production systems of this area at different levels almost every year. Kalaroa (5.25 t/ha) and Kaliganj (4.41 t/ha) experience good yield of rice every year because of improved methods and irrigation facilities. The rice marketing chain is very fragmented in Bhola Sadar and for this reason the farmers get a lower price, US$ 0.18 per kg, for their rice compared to the other three areas. In other study areas the price of per kg rice varies from US$ 0.25 to US$ 0.30. The net income from rice is very high in Dumuria because wholesalers purchase there and send the rice to
commission agents in the very accessible urban wholesale markets in Khulna, Dhaka and elsewhere. Some rice is sold to local processors.

Table P1: Productivity indicators of the agricultural systems

<table>
<thead>
<tr>
<th>Productivity</th>
<th>Indicators</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>Productivity: Weighted average yield (t/ha)</td>
<td>2.26</td>
<td>4.41</td>
<td>5.23</td>
<td>6.51</td>
<td>2.86</td>
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<tr>
<td></td>
<td>Net income yield ($/ha)</td>
<td>206.98</td>
<td>495.40</td>
<td>890.39</td>
<td>1487.66</td>
<td>262.38</td>
</tr>
<tr>
<td>Agro-</td>
<td>Net Income ($/ha)</td>
<td>311.15</td>
<td>1020.37</td>
<td>1585.81</td>
<td>1806.04</td>
<td>544.01</td>
</tr>
<tr>
<td>Ecosystem</td>
<td>Protein yield (kg/ha)</td>
<td>68.42</td>
<td>147.23</td>
<td>552.00</td>
<td>373.01</td>
<td>318.87</td>
</tr>
<tr>
<td></td>
<td>Energy yield (j/ha)</td>
<td>7.6X10^9</td>
<td>2.1X10^10</td>
<td>1.2X10^11</td>
<td>7.2X10^10</td>
<td>6.4X10^10</td>
</tr>
</tbody>
</table>

Note: (1) actual value derived from questionnaire survey (2) For reference tables please see appendix. Source: Based on questionnaire survey, 2011

In general the agro-ecosystem of Dumuria is productive and lucrative compared with the others as varied crops and galda prawn are cultivated there. Although galda is not produced in Kalaroa, the net income from the agro-ecosystem is high as the farmers grow various crops, some of high value, all the year round. In Shyamnagar, net income from the agro-ecosystem is low as the area is dominated by bagda shrimp which gets poor yields and there is little diversity in crops. Although the farmers of Bhola Sadar are involved with diverse cropping, their net income is low as often they do not get a good price for the agricultural products, being isolated from the main transport and supply chain networks of the country. Net income from the agro-ecosystem in Kaliganj is moderate with the farmers growing bagda shrimp as well as a somewhat diverse range of crops, such as til (sesame), potato and bringal. Protein and energy yield are high in Kalaroa. Protein and energy contents vary from crop to crop and there are some high protein and/or energy containing crops, like, masoor dhal (Lens culinaris), wheat (Triticum spp.), mustard, potato, turmeric, kachur mukhi
(Colocasia esculenta), garlic, oal kachu (Colocasia esculenta), onion, indian spinach, sweet pumpkin, bitter gourd, betel nut (Areca catechu) and mango in Kalaroa. The protein and energy indicator values are lowest in Shyamnagar because of less diverse crops while they are moderate in Dumuria and Bhola Sadar. In Bhola Sadar respondents are growing many pulse and vegetable crops - masoor dhal, kesari dhal (lathyrus sativus), mung dhal (vigna radiata), palen dhal, boot dhal, sesame, mustard, chilli, garlic, onion, sweet pumpkin, kumra (pumpkin), water melon (Citrullus lanatus), ladies finger and betel nut.
Table 4.3.1: Productivity values after combining weightings and normalized results of indicators

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td>0.013</td>
<td>0.025</td>
<td>0.030</td>
<td>0.037</td>
<td>0.016</td>
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<tr>
<td>Net income</td>
<td>0.011</td>
<td>0.027</td>
<td>0.048</td>
<td>0.080</td>
<td>0.014</td>
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<tr>
<td>Agro-Ecosystem</td>
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</tr>
<tr>
<td>Net income</td>
<td>0.021</td>
<td>0.068</td>
<td>0.105</td>
<td>0.120</td>
<td>0.036</td>
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<tr>
<td>Protein yield</td>
<td>0.008</td>
<td>0.018</td>
<td>0.066</td>
<td>0.045</td>
<td>0.038</td>
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<tr>
<td>Energy yield</td>
<td>0.005</td>
<td>0.013</td>
<td>0.074</td>
<td>0.044</td>
<td>0.039</td>
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<tr>
<td>Overall</td>
<td>0.057</td>
<td>0.150</td>
<td>0.323</td>
<td>0.326</td>
<td>0.144</td>
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</table>


Combining all the productivity indicators and weighting as described in the methodology chapter (Table 2.8), MCDA analysis (Figure 4.3.1 and Table 4.3.1) shows that the productivity score is high in Dumuria and Kalaroa, both areas showing good yields of rich agro-biodiversity. On the other hand, the score for productivity is very low in Shyamnagar, an area where most food production is limited to repetitive farming of bagda shrimp in lowlands and rice in slightly elevated areas.

4.3.2 Stability

Stability in crop production describes the ability to maintain a good level of productivity over an extended period of time (vanLoon et al., 2005). It is generally not possible to measure stability directly in a predictive sense but it can be assessed indirectly by examining the quality of the resources on which productivity depends. These resources include land, soil, water and climate, as well as other issues. For an example, for agricultural stability and overall sustainability, it is essential that the basic soil and water resources be and remain available in ample quantity and of good quality.

In the present study, many indicators under the five headings – land, soil, water, climate and other - (Table S1) were determined from secondary data obtained from various sources, for example the
upazila soil profile of Bangladesh Soil Resource Development Institute, reports of Disaster Management Bureau and reports of Department of Environment in order to assess the state of the agricultural resource. ‘Land’ refers to general landscape factors of the food production area distinguishing it from ‘soil’, which refers to the chemical and physical properties of the medium in which plants grow. ‘Other factors’ are usually those that relate to the built environment, most of which are outside the control of farmers in the communities being studied.

In giving a value to each indicator, we did not use actual values that had been measured. Many of the data with headings like land types (elevation), soil salinity, soil micronutrient that were available from various government departments or the upazila had already been placed in various semi-quantitative categories, using different scales. We assigned a numerical value to each category. For example for soil, a very low salinity was given a value of 5 while a very high salinity was valued at 1. In all cases, a high value means good condition and a low value poor condition. Table S1 and the reference tables in the appendix explain the methods of assigning values for different indicators.

Among stability indicators, soil and water salinity are highest importance. The salinity level in soil and water plays a very important role in determining the agricultural practices over a period of time. Salinity is high in soil and water in Shyamnagar. Most of the respondents of this study area were fully aware of the limitations for growing crops due to the high level of salinity in soil and water. This is the reason why conventional agriculture is difficult and why much of the area is devoted to culture of bagda shrimp. In Kaliganj, salinity of soil is lower than in Shyamnagar but water salinity remains elevated. As a result, the area is somewhat more suitable for rice while the abundant marine water supply enables bagda shrimp cultivation to be a continuing activity. However, a
majority of the respondents of Kaliganj are also concerned about the high level of salinity in water. They assume that in the long run this will increase salinity to the soil adjacent to the *gher* and as a result it will hamper their rice production. Dumuria, too, has elevated salinity in surface water and moderate salinity in soil, but fields are enclosed by embankments to protect land from tidal saline water, flood water and storm surges. The farmers of this area have not been allowing saline water in their fields for the last 15 to 10 years. By storing rain water in the *gher*, thus diluting the surface water, an integrated agricultural system including *galda* prawn, rice and a wide variety of vegetables has been developed. During the survey and group discussions the farmers of Dumuria opined that they were not interested in *bagda* shrimp cultivation as they were aware of its negative impacts on agriculture.

Table S1: Assigned values of stability indicators

<table>
<thead>
<tr>
<th>Stability indicators</th>
<th>Study area</th>
<th>Ref. Tables</th>
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<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
<td>Kaliganj</td>
</tr>
<tr>
<td>Land (S1)</td>
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<td>Land type*</td>
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<tr>
<td>Mobility of water on land surface*</td>
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<td>2</td>
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<tr>
<td>Crop production intensity*</td>
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<td>1</td>
</tr>
<tr>
<td>Land surface exposure to saline water*</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Land expose to cyclone*</td>
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<tr>
<td>Land affected by cyclone*</td>
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<td>1</td>
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<tr>
<td>Land affected by drought in <em>kharif</em> to <em>rabi</em> season*</td>
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<td>Existence of river bank erosion*</td>
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<td>Soil Chemical Properties (S2)</td>
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<tr>
<td>Iron (Fe)</td>
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AS1.1 & AS1.2
AS2.1, 2 & 3
### Sustainability of Changing Agricultural Systems in the Coastal Zone of Bangladesh

#### Stability indicators

<table>
<thead>
<tr>
<th>Stability indicators</th>
<th>Study area</th>
<th>Ref. Tables</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
<td>Kaliganj</td>
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<td>Manganese (Mn)</td>
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<td>Zinc (Zn)</td>
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#### Other Chemical Properties

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<td>pH b</td>
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#### Soil Physical properties

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#### Water (S3)

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<td>2</td>
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<tr>
<td>Salinity level of ground water b</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Arsenic concentration in ground water b</td>
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#### Climate (S4)

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</tr>
<tr>
<td>Trend Temperature (°C/100 year) <strong>b</strong></td>
<td>0.8**</td>
<td>0.8**</td>
</tr>
<tr>
<td>Current Rainfall (mm) b</td>
<td>1710</td>
<td>1710</td>
</tr>
<tr>
<td>Trend Rainfall (mm) b</td>
<td>91.8</td>
<td>91.8</td>
</tr>
</tbody>
</table>

#### Others Issues (S5)

<table>
<thead>
<tr>
<th>Others Issues</th>
<th>Study area</th>
<th>Ref. Tables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Withdraw of upstream water a</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Drying of river a</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Stability of embankment a</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Transportation system a</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Note: \(^b\)benchmark value is determined by the government organization of Bangladesh, \(^a\)value determined after literature survey, \(^*\)Significant at the 95% level of confidence; \(^**\)Significant at the 90% level of confidence; \(^\Omega\) Not significant at the 90% level of confidence. Negative value closes to mean and more certain. Positive value deviates from mean and more uncertain. Although climate is very important for agricultural activities, the data of the Bangladesh Metrological Department show that there has been no significant change in the last 100 years in the climatic condition of the study areas. Therefore, in this study, climatic conditions were not taken in consideration to assess stability.

In Kalaroa and Bhola Sadar the levels of salinity of soil and water were found to be low and moderate respectively. Therefore, diverse types of crops are possible in these areas. For the most part, aggregate values of other soil and water properties are similar in the five locations, but there are some surprising data too. The very low value for nitrogen in Dumuria soils requires some reflection in terms of the excellent productivity at that site. This value indicates a need to ensure that fertility is maintained if such yields are to continue into the future. The low nitrogen content may be attributed to low organic matter contents of most of the soils. Organic material is also low in
Kalaroa and Dumuria. This may be a future concern for the stability of the agriculture of these areas. Organic material is high in Kaliganj.

Soil in Shyamnagar is strongly alkaline and for this, micronutrient deficiencies expected in the future as alkalinity is a common factor leading to micronutrient deficiencies. This may impact future crop production in Shyamnagar. Soil pH is moderate to low in other study areas.

The texture of the soil of the study areas varies from clay to clay loam. In Shyamnagar clay soil is found. In clay soil, land preparation becomes very difficult as, when the soil dries out, deep and wide cracks develop and the surface soil becomes very hard. This makes tillage very difficult. Availability of fresh water for irrigation in Kalaroa, Dumuria as well as in Bhola Sadar is important for ensuring stability of crop production. Due to salinity, the available water of Kaliganj and Shyamnagar is not favourable for irrigation purposes in dry season. Scarcity of quality irrigation water during the dry season limits cultivation of crops in these two study areas. Farmers of all the study areas depend on rain water for agricultural purposes. However farmers reported that sometimes uncertain rainfall delays sowing/transplanting and sometimes flash floods wash away the standing crops. During field visits, it was observed that due to heavy rainfall a waterlogged situation was created in Kalaroa and several farmers reported damage of crops at that time.

Among the study areas, Shyamnagar, Kaliganj and Bhola Sadar are exposed to the sea and are most susceptible to cyclone events. As a result, occasionally these three areas are affected by extreme wind and rain, storm surges and tidal salt water. Kalaroa and Dumuria are less exposed to the sea and are protected to some degree by adjacent lands but still, due to their location in the coastal area, they too can be affected by such storm activity. Other climate data are obtained on a regional basis and, for the most part are not very different from site to site.
Some of the ‘other issues’ pointed out potential problems related to maintaining good production of food products in the area. The withdrawal of water from the rivers that empty into the ocean in this region of the country is of special concern. Withdrawal takes place upstream in India and in Bangladesh itself in order to support agriculture further to the north. As this practice increases, there is greater marine encroachment in the coastal regions, and this is the cause of increasing salinity that has been noted by researchers and farmers alike. Shyamnagar, Kaliganj, Kalaroa and Dumuria all belong to Ganges delta. These areas now receive a reduced quantity of water discharge due to water withdrawal at the Farakka Barrage point upstream in India for irrigation purposes in the lean season (Islam and Gnauck, 2008). As a consequence, there are falling water tables and increasing penetration of high saline sea water upstream of the study areas (Islam and Gnauck, 2008).
Combining all indicators and their weighting in MCDA analysis, the stability score is highest for Bhola Sadar followed by Kalaroa (Figure 4.3.2 and Table 4.3.2). The greatest concerns and the greatest variability centre around the water supplies. Although Bhola Sadar is exposed to the sea and cyclones, its geographical location in the freshwater estuary and the fact that it is in a deposition zone where fertile sediment makes up the soil base helps it to score high in many stability indicators. On the other hand, the score for stability is very low in Shyamnagar, an area which is affected by salinity and exposed to sea and cyclone. This affects many elements of the stability indicators. Stability scores are moderate in other three study areas.

4.3.3 Efficiency

The processes of crop production require a range of inputs, and efficiency is the measure of the extent to which those inputs enhance farm productivity. The agricultural system can be deemed to be highly efficient where a small supply of inputs results in excellent productivity. Inputs of many kinds work together in crop production. Inputs can be in the form of natural, human, social, physical and financial capital, and achieving efficiency as a component of agricultural sustainability involves consideration of all these inputs.

Efficiency of agriculture can be measured by different indicators, but the indicators used here are limited to those related to financial and physical capital. Multiple indicators were considered in
studying the five areas because of the need to examine the role of various inputs, especially non-renewable ones, in both energy and monetary terms. Energy is a comprehensive term, especially important in food production, in that the embodied energy of inputs (energy required to produce these inputs) can be compared with the caloric value of the food produced. The importance of monetary efficiency to farmers needs no further explanation.

As in the productivity category, both efficiency in growing rice (the principal crop), and efficiency for total food production in the agro-ecosystem were measured. In the case of rice, hectare wise monetary efficiency, signifying the income capability in growing a given area of the crop for one year, and overall energy efficiency to measure the output vs. input energy were both considered to be important from the perspectives of the farmers. Considering the agro-ecosystem as a whole, measures of monetary and energy efficiency were used along with an indicator for non-renewable energy efficiency. While there is considerable overlap in what is being measured through each of the five efficiency indicators, there are also unique aspects to each one. Weighting factors were again set taking into account the extent of the overlap. Values for efficiency indicators are summarized in Table 2.8.

The relation between agriculture and energy is very close. Agriculture itself is both an energy consumer and an energy supplier in the form of bio-energy. Natural energy inputs like sunlight and rain are the most basic requirements for agriculture, while human-provided energy like labour, seeds, agrochemicals, machinery are used for essential purposes of land preparation, irrigation, harvest, post-harvest processing, transportation of agricultural inputs and outputs.

Among the performances of energy efficiency for rice cultivation in the study areas, Dumuria stands out as being very good in comparison to other study areas. It was shown previously that yields of rice were highest in this area. After Dumuria, the efficiency of rice production was found to
be almost the same in the crop-diverse agricultural systems of Kalaroa and Bhola Sadar. Energy efficiency is low in bagda shrimp-dominated Shyamnagar and Kaliganj.

The energy efficiencies of the total agro-ecosystems of Kalaroa, Dumuria and Bhola Sadar are very similar - one of the benefits of the diversity in these three areas. As expected, the energy efficiency is very low in less diverse agro-ecosystem of Shyamnagar and Kaliganj. It would appear that energy inputs into marine production do not achieve a good return in terms of food energy, something also reflected in the poor yields of bagda at these two sites. For example, overall aquatic energy efficiency of Shyamnagar and Kaliganj are 0.11 and 0.10 while for rice in the same locations, energy efficiency was about 4.7. In Shyamnagar 9.71E+10 (j/kg) energy output is produced after giving 9.1672E+11 (j/kg) energy input. The pattern is similar in the case of non-renewable energy efficiency.

The three most favourable measures for monetary efficiency in rice production were found in Dumuria followed by Kalaroa and Kaliganj. To a large extent, these values track the values of productivity (Table P1) modified somewhat by the price of rice (Table E1.1 in Appendix). The price of the inputs like fertilizer, pesticides, seeds and labour are more or less the same in all the study areas. Per hectare wise monetary efficiency of rice is low in Shyamnagar and Bhola Sadar. In Shyamnagar, the price of rice is good but productivity is very low. As noted earlier, the price of the rice is very low in Bhola Sadar.

In considering the monetary efficiency of the agro-ecosystem as a whole, there was a large range of values, with Dumuria again standing out as most efficient. The very low values, especially for Shyamnagar are indicative of large money expenditures giving only limited gain to the farmers. This was widely recognized by the farmers in that area. One frustrated bagda farmer Bashanta
said, "Bagda is no longer profitable. We invest huge money for the preparation of gher, bagda shrimp fry collection and release in the gher, shrimp food and labour but if the gher is affected by virus or by cyclone then we do not get any return from the gher. We fall in total loss. In the beginning of bagda gher, 10-20 years ago it was so profitable but at present we are facing loss even after huge investments”.

Table E1: Efficiency indicators of the agricultural systems

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study areas</th>
<th>Ref. Tables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hectar wise efficiency ($/hectare)$\text{ac}$</td>
<td>Shyamnagar</td>
<td>373.75</td>
</tr>
<tr>
<td>Overall energy efficiency (Ratio of energy output and input)$\text{ac}$</td>
<td>Kaliganj</td>
<td>4.73</td>
</tr>
<tr>
<td>Agro-Ecosystem</td>
<td>Kalaroa</td>
<td>3161.49</td>
</tr>
<tr>
<td>Ratio ($output$/ input)$\text{ac}$</td>
<td>Dumuria</td>
<td>1.53</td>
</tr>
<tr>
<td>Overall energy efficiency (Ratio of energy output and input)$\text{ac}$</td>
<td>Bhola Sadar</td>
<td>1.37</td>
</tr>
<tr>
<td>Non-renewable energy efficiency$^{ac}$</td>
<td>1.53</td>
<td>2.24</td>
</tr>
<tr>
<td>Overall energy efficiency (Ratio of energy output and input)$\text{ac}$</td>
<td>0.78</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Note: (1) $\text{ac}$Actual value derived from questionnaire survey (2) For reference tables please see appendix. Source: Based on questionnaire survey, 2011
Table 4.3.3: Efficiency values after combining weightings and normalized results of indicators

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rice</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hectare wise efficiency</td>
<td>0.014</td>
<td>0.020</td>
<td>0.025</td>
<td>0.060</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td>Overall energy efficiency (Ratio of energy output and input)</td>
<td>0.013</td>
<td>0.026</td>
<td>0.051</td>
<td>0.107</td>
<td>0.013</td>
<td></td>
</tr>
<tr>
<td><strong>Agro-Ecosystem</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio(output/input)</td>
<td>0.015</td>
<td>0.014</td>
<td>0.016</td>
<td>0.027</td>
<td>0.017</td>
<td></td>
</tr>
<tr>
<td>Overall energy efficiency (Ratio of energy output and input)</td>
<td>0.037</td>
<td>0.044</td>
<td>0.103</td>
<td>0.120</td>
<td>0.116</td>
<td></td>
</tr>
<tr>
<td>Non-Renewable energy efficiency</td>
<td>0.010</td>
<td>0.014</td>
<td>0.039</td>
<td>0.039</td>
<td>0.039</td>
<td></td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td></td>
<td>0.087</td>
<td>0.119</td>
<td>0.234</td>
<td>0.353</td>
<td>0.206</td>
</tr>
</tbody>
</table>


Combining all indicators and their weighting in MCDA analysis, as expected the efficiency score is highest in Dumuria (Figure 4.3.3 and Table 4.3.3). Kalaroa and Bhola Sadar had intermediate values and Shyamnagar and Kaliganj showed consistently poor levels of efficiency.

### 4.3.4 Durability

Durability is defined as the ability of the agricultural system to resist stress while maintaining a good level of productivity (vanLoon et al., 2005). In some cases durability issues may overlap with issues of stability. Stability refers to long term factors upon which agriculture depends. In contrast, durability considers maintenance of productivity over a single season without the intervention of synthetic and high energy inputs, in the face of one or more imposed stresses. Ability to withstand economic stresses is also a durability issue. Irrigation is an example of a potential overlap of issues describing stability and durability. When productive stability is maintained by having an assured water supply, crop management systems are developed that rely on the continued availability of the irrigation resource. However, if the water supply becomes degraded or unavailable, the unmodified methods of crop production may become vulnerable to water stresses. Because of these connections, it is important that indicators that fall within both stability and durability.
categories be carefully considered. In this study, indicators that examine agricultural management to cope with stresses like pests, water and economic issues, and agricultural knowledge support were selected to measure durability (Table D1).

In the case of pest stress, a crop system is considered to be durable when it is grown successfully with minimal assistance from chemical protection methods. On the other hand, a low indicator value is indicative of extensive spraying. Shyamnagar had the lowest value as among farmers of this study area 83% make use of chemicals in control of pests in rice. In contrast, in Bhola Sadar 65% farmers grow crops without any pesticide, relying instead on nature to control pests. In the integrated agricultural system of Dumuria, 55% farmers relay on the natural system for pest control. Many farmers in this upazila spoke of the value of using an integrated pest management system in growing rice, vegetables and fish. In Kalaroa and Kaliganj, 42% of farmers depend on the natural system to control pests. Where chemicals were employed to control particularly insects when growing rice, extensive spraying may be required. During the FCDs, the farmers of the study areas informed that on average, spraying three times is required during a single rice season. This means that in places where three crops are grown in a year, pesticide use can be quite extensive.

The greater assurance of availability of water at two critical stages in rice growth - the transplanting and flowering stages - in Shyamnagar and Kaliganj gave these two sites a higher indicator value than in the other three areas. According to many farmers, Shyamnagar and Kaliganj nearly always get rain water during transplanting and flowering stage of rice. On the other hand, farmers in the other three areas complained about often not getting enough water during these times. In Bhola Sadar, farmers reported that they sometimes got excess water during rice transplanting and flowering stages which is also a problem for the crops. Throughout the study areas, rainfall occurs
almost at the same time but due to differences in the time of cultivation water availability at the transplanting and flowering stage may vary. Furthermore, differences were found in the accessibility to supplemental fresh water irrigation from rivers and ponds.

The scores related to availability of seed through proper storage or through the market are almost the same in all study areas. Farmers follow both traditional and improved methods to preserve sun-dried seeds across the study areas. In traditional methods, farmers keep seed in mud vessels covering the mouth loosely with a clay disc or other means. In improved methods, farmers keep their seeds in polythene bags or plastic or metal vessels, ensuring that the mouth is properly sealed. Availability of seeds during the cultivation period is very important for the production of crops. Almost every farmer expressed that the availability of seeds was adequate, either their own or through the market or government agencies.

To measure durability in the face of economic stress, we considered the value of product prices, availability of markets, livelihood diversification and years of economic hardship. Stress was found to be lowest (highest score) in Shyamnagar. Among respondents, 84% are satisfied with the agricultural product prices, in large part because of the demand and good prices for shrimp and fish in national and international markets. In addition to growing crops and shrimp in Shyamnagar, farmers are involved in diverse ancillary activities, like shrimp selling, transportation, shop keeping and labour, much associated with the shrimp industry. In the case of Kaliganj, Kalaroa and Dumuria, mixed response values were observed regarding economic stress. As a whole, the values of product prices are similar in these three upazilas. Some farmers in these areas opined that they got a low price for rice, vegetables and other products due to traders control over market. According to their opinion, the government does not have sufficiently strong mechanisms to control the markets. However, shrimp and prawn of Kaliganj and Dumuria are in high demand in national and international markets and fetch a good price. To some extent, farmers of Kaliganj, Kalaroa and
Dumuria are also involved in other economic activities apart from agriculture. The score for economic stress is lowest in Bhola Sadar. The upazila agricultural officer of Bhola Sadar said, “Being isolated from the main transport network the framers of Bhola Sadr cannot market their products properly, and as a result, they always get less price from the traders”. Economic diversity is good among the respondents of the Bhola Sadar as the farmers also generate extra income to sustain their economic condition through shop keeping, labour, and transport. As expected, however, farmers in this remote area still suffer from some measure of economic hardship. In focus group discussions, farmers expressed that they suffered economic hardship for at least 4 years out of the last ten years. The values of durability are relative and even in areas that have high values; the majority of respondents encounter significant economic challenges.

The ability to cope with stress is strengthened when farmers have access to good sources of information and advice through training or opportunities to speak to knowledgeable persons. Among study areas, the score for agricultural knowledge was found to be quite variable and was highest in Dumuria and lowest in Bhola Sadar. In Dumuria, the greatest percentages (23%) of farmers have received agricultural training. This is because some farmers want to improve their integrated agricultural system through training provided by the upazila agricultural office. In Kalaroa, surprisingly, the lowest percentage (3%) of farmers received agricultural training. Some farmers in Kaliganj and Shyamnagar take agricultural training on how to grow crops in salinity effects fields. It appears that especially in Kalaroa and Bhola, farmers rely on trial and error methods to deal with problems and to improve their agriculture. Across study areas, only 4% to 12% of farmers take advice from block supervisor - a government employee who promotes agricultural extension in villages, for agricultural activities. Seeking advice from this official is not very common; instead most farmers rely on improving their agriculture by trial and error methods or
by taking suggestions from their fellow farmers. Only a very few respondents have training on climate change awareness and adaptation of agriculture in the study areas. Among respondents, less than 18% farmers have training in climate change awareness. In the case of Bhola Sadar, no farmer has any kind of climate awareness training, which surprisingly is in a very vulnerable part of the coast. Unlike the other sites, in Kalaroa and Dumuria many respondents indicated that they regularly submit their soils for testing and follow the advice provided as a result of the test. No farmer from Bhola Sadar does any soil testing prior to engaging in agriculture.

Table D1: Durability indicators of the agricultural systems

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study areas</th>
<th>Ref. Tables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pests stress&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>Shyamnagar</td>
<td>Kaliganj</td>
</tr>
<tr>
<td></td>
<td>1.78</td>
<td>4.17</td>
</tr>
<tr>
<td><strong>Water availability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Availability at transplanting stage of rice&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Water availability at flowering stage of rice&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td><strong>Seed</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed preservation&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>2.5</td>
<td>2.88</td>
</tr>
<tr>
<td>Availability of seed&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>9.33</td>
<td>9.50</td>
</tr>
<tr>
<td><strong>Economics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product price&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>8.44</td>
<td>5</td>
</tr>
<tr>
<td>Availability of market&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>10.00</td>
<td>9.17</td>
</tr>
<tr>
<td>Livelihood diversification&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>6.22</td>
<td>4.33</td>
</tr>
<tr>
<td>Years of economic hardship&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>0.73</td>
<td>0.73</td>
</tr>
<tr>
<td><strong>Agricultural Knowledge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural training&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>1.33</td>
<td>1.83</td>
</tr>
<tr>
<td>Advices from Block Supervisor&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>0.66</td>
<td>1.17</td>
</tr>
<tr>
<td>Soil test&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>0.67</td>
<td>0.83</td>
</tr>
<tr>
<td>Climate change awareness&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>1.11</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Note: (1) abc-Scale down from actual value, actual value derived from questionnaire survey (2) For reference tables see appendix. Source: Based on questionnaire survey, 2011.
Table 4.3.4: Durability values after combining weightings and normalized results of indicators

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pests stress</td>
<td></td>
<td>0.008</td>
<td>0.019</td>
<td>0.019</td>
<td>0.025</td>
<td>0.029</td>
</tr>
<tr>
<td>Water availability</td>
<td></td>
<td>0.036</td>
<td>0.036</td>
<td>0.009</td>
<td>0.009</td>
<td>0.009</td>
</tr>
<tr>
<td>Seed</td>
<td></td>
<td>0.019</td>
<td>0.020</td>
<td>0.022</td>
<td>0.022</td>
<td>0.018</td>
</tr>
<tr>
<td>Economics</td>
<td></td>
<td>0.119</td>
<td>0.092</td>
<td>0.101</td>
<td>0.096</td>
<td>0.091</td>
</tr>
<tr>
<td>Agricultural knowledge</td>
<td></td>
<td>0.040</td>
<td>0.050</td>
<td>0.030</td>
<td>0.062</td>
<td>0.018</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>0.222</td>
<td>0.217</td>
<td>0.182</td>
<td>0.214</td>
<td>0.166</td>
</tr>
</tbody>
</table>


Taken as a whole and in aggregation, durability features are not very different at all five sites. In comparison to the overall score of the study areas, surprisingly the score of Shyamnagar is highest. After cyclone Aila in 2009, the government took some initiatives in promoting protection for agricultural activities. Perhaps those initiatives reflect in the score of the durability of Shyamnagar.
4.3.5 Compatibility

In a broad sense, compatibility refers to the ability of an agricultural system to fit in with the biogeophysical, human and socio-cultural surroundings in which the system is placed (vanLoon et al., 2005). Over time, depending on fundamental biogeochemistry and climatic features, there is mutual adjustment between the agro-ecosystem and the surroundings including land, living plants, animals and microorganisms. Human society depends on agriculture and human and agricultural systems are always intertwined, with each influencing the other.

Agriculture carries out many activities in natural settings for the well-being of humans but, at the same time, these activities can be a cause of environmental problems, such as water contamination, loss of biodiversity, soil erosion or other types of destruction in a healthy ecosystem. Therefore, in a sustainable agricultural system it is expected that agricultural activities will cause minimal harm but rather, provide widespread benefits for the well-being of both the human and the natural environment.

In this study, the compatibility indicators were categorized into human and biogeophysical types. Among human indicators, the quality of water available for domestic use was considered to be very important. There are many problems with water that is used for drinking or other domestic purposes in Shyamnagar. This was evidenced by the many drinking water related illnesses like diarrhoea and dysentery because families in this area depend on open ponds for drinking water. This condition exists because the installed tube-wells do not lift fresh water due to high salinity level in the ground water aquifer. Pond water is also contaminated. With increase of bagda cultivation, the fresh water ponds have also become more saline due to leaching from adjacent salt water gheras. Furthermore, in the recent 2009 storm surge over Shyamnagar additional saline water
was transported into the drinking water ponds; they were also contaminated due to human and animal fecal matter. During the survey and focus group discussions, farmers pointed out that no initiatives had subsequently been taken to make the pond water safe for drinking, resulting in a persistent drinking water crisis. Having no other options, many farmers continue to use contaminated water and face different kinds of water-related illnesses. Some respondents in Shyamnagar buy drinking water from water suppliers who collect safe drinking water from other upazilas. Some NGOs also help to supply safe drinking water in this study area. They bring safe drinking water by trucks or vans and distribute it under community management (Picture 4.4.5). Although some farmers obtain safe drinking water in this way, they continue to cook and wash their dishes using pond water. As a result, they are always at risk of contracting water-related illnesses.

In Kaliganj also, massive shrimp cultivation is taking place but this upazila is more remote from the ocean and there are some fresh water aquifers so that farmers can draw fresh drinking water from the ground through tube wells. However, the situation of drinking water in Kaliganj remains unsatisfactory in homesteads that are surrounded by gher. In contrast to Shyamnagar and Kaliganj, the situation of illness related to drinking water is better in Kalaroa and Bhola Sadar, and in Dumuria, no respondent reported any illness related to drinking water.

Even in areas where the drinking water does not cause acute illnesses, there remains the problem of arsenic contamination and consequent poisoning. According to the drinking water standard data provided by UNICEF and BBS, 2011, the presence of arsenic is very high in the ground water of Dumuria. Farmers of the area are aware of this development but poisoning is very slow and often not visible, leading to little or no concern about it. During the field visits, it was observed that the local administration had declared some tubewells to be arsenic free. In most cases, members of respondent’s’ household collect drinking water from the safe tube wells but use potentially
contaminated tube well water for other purposes – bathing, washing clothes etc. In the long run, however, there could be a serious problem for the Dumuria agricultural system if arsenic moves into food-stuffs and affects other parts of the agro-ecosystem. The arsenic concentration in drinking water is higher in Kalaroa and Bhola Sadar upazila but is lower in Shyamnagar and Kaliganj study areas.

The biophysical indicators focus on aspects of biodiversity. As expected, the overall biodiversity conditions are good in Kalaroa, Bhola Sadar and Dumuria (Picture 4.4.5) and poor in Shyamnagar and Kaliganj. The trend is accurately reflected in both the crop richness and in the percentage of non-crop areas. The condition of ecosystem services like crop production, forest production, preserving habitats and biodiversity, water quality regulation, carbon sequestration and regional climate and air quality regulation are also lowest in the agro-ecosystem of Shyamnagar and Kaliganj. According to respondents, the overall environmental condition is well known to be poor in Shyamnagar and Kaliganj. For example, in these two areas, during shrimp fry collection from the natural habitats (Picture 4.4.5) the transporting and sorting process results in a very large wastage of fry of both penaeid shrimps and other commercially important species, including fish. During the field visit it was observed that when the fry collectors use mosquito nets to catch shrimp fry, many other kinds of fry of aquatic species are killed in the process. Later when the fry are separated from other species, these species are simply discarded. This has become a serious biodiversity concern for the water bodies in Shyamnagar and Kaliganj. In almost every case according to the local fishermen these days you get hardly any fish in the river. Many farmers also said that due to bagda shrimp cultivation crop diversification has been severely undermined. Because of bagda cultivation they can no longer grow non-rice crops, vegetables and fodder for livestock. In some places even rice, which has some tolerance to salinity, cannot be grown. According to the farmers and the
upazila officer, the overall environmental conditions of Shyamnagar became even worse after the 2009 cyclone.

During the questionnaire survey in a village in Shyamnagar, one farmer named Farid Gazi pointed toward his gher said “in this land my family grew rice for years before bagda cultivation. Today, there is nothing but salt water. After bagda cultivation for twenty years nothing else grows here, even though we want to start rice again”. Another farmer named Rabi said “we are not interested in bagda cultivation anymore. We used to produce 10 to 15 maunds of rice per bigha before the bagda cultivation. Now it has come down to less than 5 maunds per bigha.”

Table C1: Compatibility indicators of the agricultural systems

<table>
<thead>
<tr>
<th>Compatibility Indicators</th>
<th>Study Areas</th>
<th>Ref. Tables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Human</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Illness from water $^{\text{sac}}$</td>
<td>0.00</td>
<td>8</td>
</tr>
<tr>
<td>Protected water supply $^{\text{sac}}$</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Arsenic concentration in drinking water supply $^{\text{sac}}$</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Biophysical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall biodiversity indicator $^{\text{sac}}$</td>
<td>1.75</td>
<td>2.76</td>
</tr>
<tr>
<td>Percentage of non-crop area $^{\text{sac}}$</td>
<td>7.54</td>
<td>6.48</td>
</tr>
<tr>
<td>Condition of ecosystem services $^{\text{sac}}$</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Crop richness $^{\text{sac}}$</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Overall environmental conditions $^{\text{sac}}$</td>
<td>1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Note: (1) $^{\text{sac}}$Scale down from actual value derived from questionnaire survey (2) For reference tables see appendix. Source: Based on questionnaire survey, 2011.
Table 4.3.5: Compatibility values after combining weightings and normalized results of indicators

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td><strong>Human</strong></td>
<td></td>
</tr>
<tr>
<td>Illness from drinking water</td>
<td>0.000</td>
</tr>
<tr>
<td>Protected water supply</td>
<td>0.017</td>
</tr>
<tr>
<td>Arsenic concentration in drinking water supply</td>
<td>0.012</td>
</tr>
<tr>
<td><strong>Biophysical Surroundings</strong></td>
<td></td>
</tr>
<tr>
<td>Overall biodiversity indicator</td>
<td>0.013</td>
</tr>
<tr>
<td>Percentage of non-crop area</td>
<td>0.011</td>
</tr>
<tr>
<td>Condition of ecosystem services</td>
<td>0.009</td>
</tr>
<tr>
<td>Crop Richness</td>
<td>0.004</td>
</tr>
<tr>
<td>Overall environmental conditions</td>
<td>0.005</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td><strong>0.070</strong></td>
</tr>
</tbody>
</table>

Combining all indicators and their weighting in MCDA analysis, the compatibility score is relatively high in Kalaroa, Bhola Sadar and Dumuria (Figure 4.3.5 and Table 4.3.5). Kaliganj showed moderate score whereas Shyamnagar showed an extremely poor score in compatibility.

![Picture 4.4: (A) Supply of drinking water by truck in Shyamnagar, (B) Collection of shrimp fry form natural habitat, (C) Homestead of Dumuria with rich biodiversity and (D) Rich biodiversity of agricultural fields and homesteads of Bhola Sadar.]

### 4.3.6 Equity

All aspects of agricultural activities must come together to support farmers for an adequate and comfortable standard of living. And conversely, social welfare of the community within an agro-ecosystem is extremely important for the sustainability of agriculture itself. In this study, we
measured social welfare as “equity” where the term equity is used to signify a balanced distribution of the benefits of agriculture to all the members of the community.

An equitable agro-ecosystem is one that would provide employment for all healthy adults and would not create significant disparities among farmers. There should be fairness with respect to males and females of all ages and efficient public services; with the essential ones being services for education and health. There are many issues to assess in examining the equity in an agro-ecosystem. In this study, four sets of equity indicators were considered under the general headings of education, economic conditions, health and decision making (Table 4.3.6).

Among indicators, the value for education was found to be highest in Dumuria where the farmers’ educational status as well as that of their male and female children’s education was good in comparison with other areas. The people of Dumuria have been exposed to formal education as far back as the British period. Apart from this, Dumuria upazila is located near the Khulna Division headquarters and as a result, the farmers’ family members have convenient access to the main educational facilities of the division. The lowest indicator value for education was in Bhola Sadar where 50% of respondents are illiterate, and education for children’s education is not well developed. This area has been deprived of educational facilities in part due to its isolated geographical location. In spite of government initiatives, the percentage of illiterate male (12.8%) and female children (9.1%) remains highest in Bhola Sadar among study areas. Note the surprising feature that the percentage of illiterate male children is slightly greater than that of female children. The same feature was observed in Kalaroa. It was found that most of the children of landless and marginal farmers in Bhola Sadar are illiterate because families engaged their male and female
children in economic activities - agricultural activities and also in selling of agricultural products in the rural market.

Except in Bhola Sadar, in the other study areas the percentage of illiterate children was always less than 7%. In Dumuria there are no illiterate male or female children. Through the study areas as a whole, the percentages of illiterate, primary schooling, secondary schooling and tertiary schooling male children are 5.8%, 42.0%, 26.3% and 25.9% respectively and for female children 4.0%, 32.1%, 22.3% and 19.6%. In all study areas, it was found that the respondents are strongly supportive of children’s education because of the awareness created by the government, media and NGOs. The Government of Bangladesh has a strong plan and policy to promote education among children as part of achieving one of the Millennium Development Goals. Therefore in general, the education participation rate is quite good among children of the study areas.

Electronic media (TV, satellite and radio) provide informal opportunities to educate the farmers in various issues. To have access to electronic media, farmers need electricity and within the study area, Dumuria has the best provision of electrical power. Access to electronic media is also good in Kaliganj and Kalaroa. Although there is no public electricity supply in Shyamnagar, a large number of farmers are getting personal use of electronic media through generating electricity by using solar panels. The access to electronic media is poor in Bhola Sadar where only 38% of families have this privilege.

Economics-related issues of the study areas were measured in both direct and indirect ways. Among economic issues, the yearly average agricultural income of farmers is highest in Kaliganj. Both rice and bagda shrimp are the main crops of this area and in particular, farmers get a good income from bagda which is a profitable agricultural product in Bangladesh. Like Kaliganj, the
farmers of Shyamnagar are also heavily involved in *bagda* cultivation but, as mentioned earlier, due to virus effects and cyclones the ecosystem of the *bagda* shrimp gher has been disrupted, and shrimp and rice yields are unusually low. As a result, the yearly average income in Shyamnagar was much lower than in the region further north. The other three areas all had moderately good average incomes with the variety of agricultural and aquatic products providing multiple sources of income. In comparison to the US$1,700 *per capita* annual income (adjusted by purchasing power parity) of Bangladesh (CIA, 2012), that found in the study areas is 96% and 17% higher in Kaliganj and Dumuria, while it is 61%, 19% and 37% lower in Shyamnagar, Kalaroa and Bhola Sadar. Incomes from agricultural land vary considerably; a landless farmer earns between US$3 in Shyamnagar to US$ 71 in Kaliganj, whereas large farmer incomes vary from US$ 3433 in Bhola Sadar to US$ 13 490 in Kaliganj. Across the study areas the incomes for marginal to medium farmers vary from US$ 36 to US$ 3178. It is clear that sufficient land is a prerequisite to a good yearly income. In the study areas, marginal farmers have ownership of 0.01 ha to 0.2 ha land whereas small farmer has ownership of 0.5 ha to 1 ha land. In case of medium to large farmers, the range is from 1.5 ha to 13.2 ha. In the case of Shyamnagar and Kaliganj the range of land ownership is particularly large.

Table E1: Indicators of equity of the agricultural systems

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
<th>Ref. Tables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
<td>Kaliganj</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education status of farmer$^{Sac}$</td>
<td>8.56</td>
<td>9.25</td>
</tr>
<tr>
<td>Education status of male children$^{Sac}$</td>
<td>10.00</td>
<td>9.49</td>
</tr>
<tr>
<td>Education status of female children$^{Sac}$</td>
<td>9.07</td>
<td>10.54</td>
</tr>
<tr>
<td>Access to electronic media$^{Sac}$</td>
<td>7.78</td>
<td>9.17</td>
</tr>
<tr>
<td><strong>Economic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Farmer income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average income from agro</td>
<td>648.23</td>
<td>3340.55</td>
</tr>
</tbody>
</table>
Another economic issue is average value of farm assets which is highest in Kaliganj and Dumuria reflecting the higher average yearly income in these areas. Most of the small, medium and large farmers of these two study areas own a television set, a mobile phone and one or more bicycles along with agricultural equipment like a water pump and power tiller. Some large and medium landholding families have a refrigerator as well. In contrast, throughout the study areas, it was found that most of the landless and marginal farmers had few of these assets. One surprising thing however, was that almost every farmer family has a mobile phone. Farm assets are limited in both Bhola Sadar and Shyamnagar although in Shyamnagar some medium and large farmers have TV.
and other electronic goods. Some small and marginal farmers informed us that they had owned a TV before 2009 cyclone, but they lost most of their assets in that event.

The average wage of a farm labourer is highest in Dumuria as there is a demand for labour all year round due to the wide diversity of agricultural activities there. In Shyamnagar and Kaliganj, a large number of labourers are required only at the time of preparation of the ghers, an activity that typically requires about 8 weeks each year. In Kaliganj and Shyamnagar, female labourers also work along with male labourer in rice fields and ghers. In the case of Bhola due to the conservative nature of society, female labourers are not allowed to work in the fields. Therefore, there is a shortage of labourers and wages are relatively high. The gender-based wage differential is significant throughout the five upazilas. In Dumuria and Kaliganj, women typically make on average US$ 1.06 and US$ 0.67 per day compared with men who made US$ 2.13 to US$ 2.0. The average wage is the same for male (US$2) and female (US$0.67) labourers in Shyamnagar and Kaliganj. In both areas women made only 33% of the daily wage of men. We estimate that most labourers would be employed for between 90 and 240 days per year and so the total yearly income from agriculture could be quite low. Throughout Bangladesh people who depend on farm wages are the most disadvantaged of the employed population.

Measuring the fraction of households with electricity connections was an indirect measure of economic condition as the pattern of household energy consumption is often an indication of the stage of welfare. Being located near a large urban area where the Bangladesh electrical system is well developed, every household of Dumuria is connected by electricity. To provide light in houses in Shyamnagar and Bhola, most respondents use kerosene hurricane lamps. As noted above, in Shyamnagar, some medium and large farmers have solar panels to get electricity for their houses.
While electricity connections are good in Kaliganj and Kalaroa, farmers complained of not getting a continuous supply of electricity during the day. In those upazilas most of the landless and marginal farmers do not have any electricity connection in their houses. According to many farmers, having electricity helps to generate income (water pumps for irrigation), helps in education, and helps to get better health facilities. The variable extent of household connections to electricity is clear evidence of regional differences of economic development.

In the case of health, the overall score was relatively good in Dumuria, Kalaroa and Kaliganj and significantly poorer in the other two places. Most of the small, middle and large farmers in Kaliganj, Kalaroa, Dumuria and Bhola Sadar were able to produce sufficient staple food on their own farm. Almost every landless farmer, of course, is required to access rice from the market unless their wages are paid in part by rice itself. Many marginal and some small farmers also buy staple foods from the market. Because only a single crop can be grown each year, and the yield is usually relatively poor, most households in Shyamnagar must also supplement their own supply from the market. The value of per person average calorie intake from staple food ranged from 1540 kcal in Shyamnagar to 2060 kcal in Dumuria. The Bangladesh Institute of Development Studies/ BIDS, in 2008, shows that the mean total food intake for all ages and sexes of the average Bangladeshi population is 681 grams. The energy that an individual can derive from this amount of food is approximately 1900 kcal. In this respect, the energy intake from staple food is above the national average in Dumuria, Kalaroa and Bhola Sadar. Nevertheless, these energy values indicate that there could be a substandard level of nutrition in many households, depending on the landholding size and the composition of the family. Clearly also, there are other aspects of nutrition which are required for good health.
The respondents of all study areas take medical treatment from a variety of health providers - an upazila hospital or clinic, a union health centre, a pharmacy or a minimally trained village doctor or kabiraz (traditional/herbal healers who have a longstanding involvement in rural community). Most of the respondents from Dumuria expressed that they have convenient access to health care facilities, being near to a large urban area. As expected, access to good facilities is lowest in Shyamnagar and Bhola. A large number of respondents of Shyamnagar, Kaliganj, Kalaroa and Bhola Sadar take treatment from the local pharmacy and village doctors. Like Dumuria, many respondents of Kaliganj and Kalaroa also have convenient access to upazila health offices but in Bhola Sadar, a very small number of respondents go to upazila health offices for treatment. Throughout the study areas, large and medium farmers prefer to visit upazila health offices or clinics whereas landless to small farmers more frequently choose the local pharmacy, village doctors or a kabiraz for treatment.

Sanitation is an important public health concern. Most homes had their own toilets and these were classified as either pucca or semi-pucca. Where the toilet room and slab are made of brick and concrete it is called a pucca toilet, and where the toilet room walls and the roof are tin or wood, and the slab is concrete, it is called semi-pucca. Compared to many other low-income countries, these types of facility are quite good, again due to government initiatives as part of achieving one of the Millennium Development Goals. In the study areas, 68% to 97% of toilets belong to pucca to semi pucca categories. In Kaliganj, Kalaroa and Dumuria there are no open toilets. In Shyamnagar, only one of the respondent’s households used an open toilet whereas two are open in Bhola Sadar. In all cases, these open toilets belong to landless farmers. Importantly, almost every respondent told that they use soap and water after returning from the toilet as part of hygienic practices.
As another measure of equity in health terms, cooking facilities were measured, with the highest value given to LPG and lowest value to firewood and other biomass types. Where various forms of biomass are used for cooking, women and children are exposed to smoke and this may have serious health impacts in future. Firewood, leaves and agricultural waste including dried cow dung were the main sources of household energy for cooking in every part of the study area. Because of this, the indicator value of cooking facilities tends to be low throughout. Furthermore, because of using a lot of agricultural waste, the fields are deprived of the natural manures for use as a soil amendment. It was found that the maximum use of such secondary material occurred in Kalaroa. Among respondents only in Kaliganj, a small number (6%) of respondents are using liquefied petroleum gas (LPG) as cooking fuel.

In the case of gender issues, we measured the participation of women in the work force and in political life within the community. The workforce score is highest in Dumuria. There, the women participate in a wide range of household agricultural activities like sun-drying the crops, seed preservation, vegetable gardening, feeding shrimp/fish and preparing fish feed, working in the field, animal nursing, raising chickens and ducks as well as other general agricultural work. Women of Kaliganj and Kalaroa also actively participate in household agricultural activities. Participation is much less in Shyamnagar and Bhola Sadar due to emphasis on shrimp cultivation in Shyamnagar and to the conservative society in Bhola Sadar and. In these two study areas, women have less opportunity to be involved in household agricultural activities. However, some women grow vegetables for family consumption in the homestead area. In shrimp cultivation, shrimp are often sold from the gher directly to the trader or brought to a market in a nearby town, so women have less chance to work on agricultural activities. In general, apart from agricultural activities women of the study areas are also involved in other household work like cooking, clothes and dishes.
washing, cleaning household and yard, fuel collection, drinking water collection, sewing and mending clothes, nursing the sick, child care, .

Women’s participation at the local government level is crucial so that they have a voice in decision making on issues that affect the community. The Government of Bangladesh ensures women participation in the Union Parishad (local government or Union Council) by law. The Union Parishad is the smallest rural administrative and local government unit in the country. A quota system was introduced in the local government (Union Parishad) elections in 1997. Each Union Parishad has nine constituencies and one chairperson position open for competition by both men and women. In addition, each block of three constituencies has one reserved seat for directly elected women. Thus the reserved ratio is three reserved seats for women for every nine non-reserved seats – or 25 percent. Among the study areas, it was found that no more than the minimum 25% representatives within the Union Parishad are from women. No additional elected woman representative was found in the local government in any of the unions studied.
Table 4.3.6: Equity values after combining weightings and normalized results of indicators

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Education</td>
<td>0.040</td>
</tr>
<tr>
<td>Economics</td>
<td>0.046</td>
</tr>
<tr>
<td>Health</td>
<td>0.034</td>
</tr>
<tr>
<td>Gender issue</td>
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</tr>
<tr>
<td>Overall</td>
<td>0.154</td>
</tr>
</tbody>
</table>

Combining all indicators and their weighting in MCDA analysis, the equity score is highest in Dumuria (Figure 4.3.6 and Table 4.3.6) and lowest in Bhola Sadar. Similar intermediate values were found in Shyamnagar, Kaliganj and Kalaroa. We found differences in equity across landholding categories and in male and female where Bhola Sadar stands out to be very conservative and Dumuria stands out as progressive. One very important observation is that except for Bhola Sadar, the other study areas are doing well in terms of child education.

Figure 4.4:6 (A) Women are working in an agricultural field of Kaliganj, (B) Farmer and his wife are working together preparing food for galda prawn in Dumuria, (C) Male and female children of farmers in a classroom of a primary school of Kalaroa and (D) Solar panel in a homestead of Shyamnagar to run and charge electronic goods like TV, mobile etc.
4.3.7 Discussion

A quiet agricultural transformation has been taking place in Coastal Bangladesh. In spite of several visible constraints, agriculture in this part of the country is facing a challenge to reinvent itself. It has to withstand the competition of national and international economic demands, take into account global environmental problems and provide food and employment opportunities for the coastal population. In the coastal areas, agriculture is beginning to change from a largely peasant-based subsistence activity to a commercial activity which is driven by the farmers themselves and the government initiatives.

Coastal agriculture has been especially influenced by the establishment of embankments/polders during the 1960s to the 1980s. Over this time, the resulting new agricultural paradigm has brought a significant change in the landscape ecology of these areas which include the five *upazilas* under study here. Shyamnagar and Kaliganj have observed transformation from a saline water-based rice cultivation system to mixed *bagda* shrimp and rice cultivation. Dumuria has experienced transformation to a rice-, *galda* prawn- and vegetables-based integrated agricultural system. Kalaroa and Bhola Sadar are also protected by embankments, but the agriculture of these two areas has changed much less except for some improvements in traditional agricultural practices.

To assess and draw a broad picture of agricultural sustainability, an interdisciplinary perspective of sustainable development is necessary. Therefore, the agriculture of these study areas has been viewed through six categories: productivity, stability, efficiency, durability, compatibility and equity. For this, initiatives were taken to collect comprehensive data for each category from representative landholding categories within each of the five *upazilas*. After surveying the literature, brainstorming with experts, field observations and data collection, a set of indicators were developed, and they
were estimated for each site. At this stage, the major challenges of the study were selecting appropriate indicators for each category and identifying proper primary and secondary data for those indicators. Most of the indicators are relative within the study areas since they are influenced by site-specific conditions and numerous biological, physical, social and economic factors. A few indicators like soil properties, salinity level, land types etc. have more broadly-based benchmark values with which they can be compared. For example, if the soil salinity level is 12-15 dS/m, it is considered to be a high salinity soil using information developed by the Bangladesh Soil Resource Development Institute.

After selection of the indicators, a scheme of weightings was developed according to the deemed importance of the categories and their respective indicators. In the present study, weighting was assigned by us after discussions with respondents, both farmers and experts. Using the indicator data and assigned weightings, MCDA (Multi-Criteria Decision Analysis) was used to calculate the sustainability level within each of the categories. In MCDA, the benchmark value, actual value and scale-down benchmark or actual values were used. The indicators values were normalized and inserted in MCDA. For each parameter, the individual values for the five sites were normalized in the following way: the values were summed and each individual site value was divided by the sum, giving normalized results on a 0 to 1 scale. The normalized results were then weighted. After MCDA analysis, scores of the categories were compared among study areas and finally a level of sustainability for each study area was generated. As with many indicators, there was no benchmark level of agricultural sustainability at the national level in order to make comparisons beyond the study area.
When it comes to the possible methods of assessing agricultural sustainability there have been a large number of approaches, most making use of indicators and often assigning the indicators to different categories (Dantsis, 2010; Eilers et al. 2010; OECD, 1999; Walker, 2002). While there are differences in each of the proposed assessments, there are also many commonalities with issues like biodiversity, soil and water properties, use of chemicals and economic resilience being measured in various ways (Eilers et al. 2010; OECD, 1999; Walker, 2002). Unlike some studies, our work considers productivity to be of prime importance, efficiency in resource use is measured and social issues are considered to be an important aspect of sustainability in the village setting (vanLoon et al., 2005).

Another challenge in quantifying sustainability is how to aggregate the data values obtained for different categories. This has been a problem identified in earlier studies, for example in an evaluation of sustainability in the Tungabhadra region of South India (vanLoon et al., 2005). To cope with this problem, the study here has shown how MCDA can be a useful tool for aggregating individual values. The individual results and aggregated summaries provided using MCDA make it possible to compare the level of sustainability of each study area and assign differences to various components of sustainability.

Various studies have proposed and discussed methodological approaches regarding assessment of agricultural sustainability (Binder et al., 2010; Dantsis et al., 2010; Van Cauwenbergh et al., 2007). These studies showed several advantages, disadvantages and limitations of the agricultural sustainability assessment. Dantsis et al. in 2010 proposed a MCDA-based methodological framework for the assessment and comparison of the sustainability of agricultural on a regional scale in Greece by using easily obtained indicators through an empirical study, utilizing
questionnaires completed during interviews with farm managers. The indicators were analyzed to evaluate the contribution of different indicators to the final goal of sustainability. This study has some similarities with our study in comparison of agricultural sustainability of different study areas by applying MCDA. Van Cauwenbergh et al., in their study in 2007 argued about Sustainability Assessment of Farming and the Environment (SAFE) framework describing the ability to assess the sustainability of agriculture. However, according to the authors “this framework is not intended to find a common solution for sustainability in agriculture as a whole, but to serve as an assessment tool for the identification, the development and the evaluation of agricultural production systems, techniques and policies”. Binder et al. in 2010 developed an indicator-based agricultural sustainability assessment method which includes a bottom-up approach by integrated participatory or trans-disciplinary methods. In our study a trans-disciplinary and participatory approach is also used to develop indicators from the field and from secondary information. In Bangladesh in 2003, Rasul and Thapa carried out a study on sustainability of ecological and conventional agricultural systems in the middle part of Bangladesh. It is based on environmental, economic and social perspectives of the two agricultural systems. In assessing agricultural sustainability of two production systems they used empirical data collected through a household survey, soil sample analysis, observations and discussions with key informants. In our study we also used similar methods to collect information. The study of Rasul and Thapa suggests that ecological agriculture has a tendency towards becoming ecologically, economically and socially more sound than conventional agriculture. In our study we find that the integrated agricultural system is more sustainable than any other system. Although an integrated agricultural system does not rigidly follow ecological agriculture, it emphasizes that the natural environment is an important component of agricultural practices.
In Bangladesh, studies address some issues of coastal agricultural sustainability in different ways. Datta et al. in 2005 address some sustainability issues of shrimp culture (like movement of shrimp cultivation and shrimp disease and impacts) of the south-western coastal regions. The study shows that outbreak of disease is a major hindrance for shrimp culture. A study on “Adaptive Crop Agriculture Including Innovative Farming Practices in the Coastal Zone of Bangladesh” in Satkhira District finds suitable adaptation measures (e.g. introducing high varieties of rice- BRRldhan29, BRRldhan45 and BRRldhan47 etc., saline tolerant rice and vegetables according to soil properties) that can be employed to adapt to changing conditions (CEGIS, 2008). In order to assess and analyze the problems, this study appraised the existing findings from a literature review and community consultation. Karim in 2008 by using questionnaires, observation and satellite imagery identified that a decrease of crop production, many environmental problems (like shortage of livestock fodder, fuel scarcity and decreases in traditional labour forces) and social problems are associated with shrimp cultivation. Miah in 2010, by using a multi-disciplinary, participatory and interactive method in “Assessing Long-term Impacts of Vulnerabilities on Crop Production Due to Climate Change in the Coastal Areas of Bangladesh” investigated climate impacts on crop production systems. He suggested appropriate coping strategies and adaptation options for improving coastal agriculture to increase agricultural production. He also wanted to find better livelihood options for the vulnerable members of the farming community. Roy and Chan in 2011, based on reviews and synthesis, proposed a set of indicators (economic, social and ecological) for assessing agricultural sustainability in Bangladesh. In our study we also developed indicators which also cover the same issues, relevant specifically to the coastal region. Moudud et al. in 1988 pointed out aspects of unsustainable development in Bangladesh coastal areas and proposed better application and management of coastal resources such as the Sunderban with its diverse
flora and fauna. Shang et al., in 1998 suggest reduction in production cost and negative environmental impacts through bio-technical improvement and efficient management are of key importance for sustainable development of the shrimp sector of Bangladesh.

Deb (1998) reveals the fact that if the societal values of the coastal environment that supports life-and-livelihood of millions of coastal communities of Bangladesh are not recognized, the aquaculture industry might give rise to severe ecological, economic and social problems and conflicts.

Other studies also address different aspects of coastal agricultural sustainability. Some of the literature focuses on the environmental impact of shrimp while focus on both environmental and social issues. There is a general conception that shrimp farming in Bangladesh has many negative environmental impacts including salinization of soil and water, loss of wild and domesticated flora and fauna, mangrove destruction, change in cropping patterns and species composition (Ahmad, 2004; Ali, 2006; Bhattacharya et al., 1999a, Bhattacharya et al. 1999b, DoE, 2005; Manju, 2000; MoWR 2006). Although all the studies address the issue of agricultural sustainability, they do not attempt to provide a quantitative or semi-quantitative measure of sustainability. In this respect our study is unique in that it is the first attempt to measure sustainability of present agricultural practices in coastal regions.

Despite some limitations, the present study has been able to use a systematic indicator-based approach supported by MCDA aggregation that contributes to assessing the sustainability of agriculture in each study area. As a broad conclusion, our assessment provides substantial evidence to prove the success of the integrated system followed by many farmers in Dumuria: it is clearly more sustainable than in the other study areas combining all categories of agricultural sustainability. The level of sustainability of diversified traditional agriculture in Kalaroa is also
relatively good. A common feature of practices followed in Dumuria and Kalaroa is an emphasis on
diversity which plays into all the categories of sustainability, even contributing to strengths in areas
of productivity and efficiency. The level of sustainability is low in Shyamnagar, an area where
farmers have been devoting considerable energy and resources to cultivating *bagda* shrimp. The
increase of salinity and rapid alteration of the landscape ecology have created problems in that
area. Bhola Sadar is following patterns of traditional agriculture including substantial diversification
which produce moderate productivity, but due to its isolated location and the effects of cyclones the
agricultural system has severe limitations in terms of sustainability.

The level of the sustainability measured here allows for a comparison among the five sites. No
comparison was done with an overall national benchmark value as no such value exists. However,
among sustainable categories, some aspects of productivity, stability and equity can be compared
with the national benchmark values; for the other three categories comparisons are difficult as, for
example, there is no standard measurement for efficiency. Productivity can readily compared with
other national and international values. The average yearly productivity of rice of the study areas
vary from 2.26 t/ha in Shyamnagar to 6.51 t/ha in Dumuria which bracket the average yearly
productivity of rice of Bangladesh (2.8 t/ha) and the World (4.37 t/ha). It was significant that in the
integrated agricultural system, rice productivity is much higher than in the other areas, and is better
even than the global average. The stability of the study areas is largely determined by the soil and
water salinity and the natural calamities of the areas as well as efficient management of the
embankment and withdrawals of the upstream water. The integrated system of Dumuria and
diverse agricultural system of Kalaroa turned out to be the most efficient and durable agricultural
systems among study areas. In all study areas there are significant equity problems, but indicators
of education and toilet facilities came out favorably, which is on track with the target of the Millennium Development Goals for Bangladesh and other developing countries. There are other challenges in terms of equity. It is very clear that agricultural land is not equitably distributed among farmers. For example, landless farmers hold less than 0.01 ha of land whereas large farmers held 13.2 ha on average.

Sustainable agriculture means successful management of resources for agriculture to satisfy the changing human needs, while maintaining or enhancing the quality of environment and conserving natural resources. The first priority of sustainable agriculture is to understand the sustainability level of the present situation. This study, depending on various indicators and MCDA analysis provides a way of measuring the level of coastal agricultural sustainability of Bangladesh. This information can be used in formulating policies for the country.

4.3.8 Level of Agricultural Sustainability in the Study Areas

Combining all the overall scores of all categories and their respective weightings as described in the methodology chapter (Table 2.8), MCDA analysis (Figure 4.3.7 and 4.3.8 and Table 4.3.7) shows that the sustainability score is highest in Dumuria. Among six categories, the scores of productivity, efficiency and equity are highest at that site and the scores of the rest three categories are also good. This designates that the performance of agriculture in terms of agricultural sustainability is better in Dumuria in comparison to other study areas. In this respect, it is worthwhile to mention that, during the field visit, questionnaire survey and FGD, almost every farmer in Dumuria expressed their satisfaction for the present agricultural practices. On the other hand, as expected after field observation, the lowest score of agricultural sustainability is observed in Shyamnagar. The farmers and the upazila officials are concerned about agricultural
sustainability of the area. The scores of the productivity, efficiency and compatibility category are very low in Shyamnagar. The score for productivity is very poor as the repetitive *bagda* cultivation is hampered by shrimp diseases and occasionally by cyclones; furthermore the production of rice is limited due to the impacts of salinity. According to farmers of this study area, saline water intrusion is a naturally occurring phenomenon for the fields of the area that affects land productivity even in the absence of shrimp culture, but massive shrimp cultivation has clearly had an impact in destroying the natural setting for crop production. In the overall score, Kalara scored second highest after Dumuria. The farmers of this study area are practicing mostly traditional agriculture with some improved methods. Farmers are satisfied about their agricultural practices as they generally achieve a good economic return and at the same time they are aware of the negative impacts of extensive shrimp cultivation. According to the farmers and *upazila* officials agro-biodiversity in the Kalara area plays a major role in promoting good performance in terms of agricultural sustainability. The sustainability score of Kaliganj is much better than of Shyamnagar. During the field study and FGD in Kaliganj, the farmers expressed their concerns about the sustainability of their agricultural system. Like Shyamnagar, they have observed the negative effects of shrimp cultivation in their agro-ecology system too. They started producing shrimp for its good economic return but now they are concerned about the cost and benefit of shrimp cultivation and its effect on traditional agriculture in terms of sustainability. They stated that they were conscious about the impacts of *bagda* shrimp cultivation, and that they know about the benefits of the integrated agricultural practices of Dumuria. Some farmers opined that they were considering adjusting their agriculture practices to be more like those of Dumuria. In Bhola Sadar, the sustainability score is third highest. This area is subject to frequent cyclones and is isolated from the main land. Because of these factors, it showed low performance in some categories of
sustainability. Some farmers of this area have heard about the integrated rice, fish and vegetable systems. They are interested in adopting some of the newer methods, but they are not sure about the success of these systems as the physical environment of this area is different from the other study areas. Kalaroa and Bhola Sadar are both rich in agro-biodiversity and are mostly following traditional farming, but in terms of performance of sustainability, Kalaroa is better than Bhola Sadar. However, within each study area, even in Dumuria, there remain some inequities, largely based on the amount of land owned by households. In some cases also, gender based inequities exist.

Figure 4.3.7: Value of sustainability of the study areas by MCDA
Table 4.3.7 Sustainability level after combining weightings and MCDA results of categories

<table>
<thead>
<tr>
<th>Categories</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Productivity</td>
<td>0.017</td>
</tr>
<tr>
<td>Stability</td>
<td>0.026</td>
</tr>
<tr>
<td>Efficiency</td>
<td>0.013</td>
</tr>
<tr>
<td>Durability</td>
<td>0.022</td>
</tr>
<tr>
<td>Compatibility</td>
<td>0.007</td>
</tr>
<tr>
<td>Equity</td>
<td>0.023</td>
</tr>
<tr>
<td>Overall</td>
<td>0.109</td>
</tr>
</tbody>
</table>

Source: Based on MCDA analysis, 2012.

Figure 4.3.8 Comparison of the level of agricultural sustainability of the study areas in spider diagram
Chapter-5: Conclusion & Recommendations

“What are the sustainability features of adaptive agricultural systems that are practised for pursuing livelihoods, especially in comparison with different farming systems that are followed in different parts of the coastal areas? This can be answered by measuring the sustainability of agricultural practices”.

This was the research question I set out to answer and the thesis has described what has been learned in working to this end.

Agricultural sustainability was assessed and compared by measuring indicators of productivity, stability, efficiency, durability, compatibility and equity and aggregating them using Multi Component Decision Analysis (MCDA) methodology in five sites within the Bangladesh coastal region. Measuring agricultural sustainability in this way produces a useful summary of sustainability issues and also provides some vital learning experiences. Choosing indicators to satisfy assessment within the six categories is an iterative process where it is necessary to make use of past experience, expert opinion and advice from local farmers and their families, all things being considered within the requirement of having indicators that can be readily measured in the field or determined from secondary information. Combining multiple pieces of diverse types of data expressed in the indicators was another challenge and it was found that MCDA could be a useful tool for this purpose.

In the end, a holistic and interdisciplinary approach was developed for assessing and comparing the sustainability level of agricultural systems and it has the potential to become useful as a framework for future analyses of sustainability.
There were challenges in doing this work and, in some cases; these challenges meant that there are limitations in what could be done. To investigate sustainability, a large amount of primary and secondary data was collected from the five different study areas. The coastal region of Bangladesh covers a vast area and the agricultural practices of the region vary from site to site. Due to time constraints and lack of appropriate transportation and logistics support we could not spend as much time as we wished in order to observe all the agricultural systems within the five sites. Furthermore, during the field survey, we found that some respondents appeared to be afraid and reluctant to interact freely with the investigators. In focus group discussions, all participants were not active in participation. This made it difficult to collect all the information we required. Also, due to unfriendly weather, the law and order and political situations, a more detailed investigation could not be done in study areas. Secondary data collection was very time consuming and it was frequently difficult to obtain data from government agencies due to complex rules and regulations. Finally, only a few studies have touched on issues of assessment of sustainability in the coastal agriculture of Bangladesh. As a result, there is limited literature to enrich the analysis in this study by reviewing other findings.

Within these limitations, the information obtained from the random samples chosen, from focus groups, from discussions with experts and from government documents taken together provides a realistic picture of many of the commonly used practices at each location.

Agricultural development in the saline coastal belt of Bangladesh is constrained by various physical, chemical and social factors. Water and soil salinity are among the most dominant limiting factors in the region, especially during the dry season. Soil salinity affects many crops including
rice, the most important, at different levels and at critical stages of growth. As a consequence, yields can be reduced and in severe cases total yield is lost. The presence of salinity in surface and ground water in different areas near the coast is another factor affecting crop production. In spite of these difficulties, in some places this research has shown that an integrated agricultural management system involving multiple crops as well as aquaculture is doing well in the coastal areas. This study shows that the integrated systems are productive and efficient and, in general, the level of sustainability in these areas is the highest of all systems that were studied.

The findings of this research will be transmitted to local authorities in Bangladesh with the hope that they will enable agricultural policy making departments to plan management actions for sustainable agricultural development in the coastal regions.

Some of the recommendations that arise from this study are:

1. Based on the present study, it is recommended that an indicator-based analysis be one method by which the sustainability level of different agricultural systems be assessed. The information thus gained can be used as one factor for determining coastal agricultural policy of Bangladesh.

2. The coastal population of Bangladesh is dependent on agriculture for income and employment. Therefore, government should emphasize introducing agricultural practices that ensure productivity and employment.

3. Comprehensive investigation is needed to understand the present agricultural practices and to bring diversification in the agricultural system for reducing yield gaps.
4. There is a need to design and enforce a policy and institutional framework for natural resources management and conservation to support agricultural growth in the coastal areas of Bangladesh.

5. Improving physical and social infrastructure - roads, electricity, communication, water and sanitation, health and education – in rural areas is fundamental for sustainable development in agriculture.

6. Proper operation of embankments should be ensured for protecting agriculture from saline water and storm surges.

7. Rain water should be stored in the saline-affected water areas to minimize the salinity effect of the surface water during the dry season.

8. Introduction of integrated agricultural system by storing rain water in saline affected areas may be a new strategy to cope with emerging adverse situations.

9. Government should formulate a project to promote the feasibility of integrated agricultural system in the salinity affected areas of Bangladesh to ensure the sustainability of coastal agriculture.


Sustainability of Changing Agricultural Systems in the Coastal Zone of Bangladesh
Sustainability of Changing Agricultural Systems in the Coastal Zone of Bangladesh


BMD (Bangladesh Metrological Department). (2011). Climate of Bangladesh. Dhaka, Bangladesh


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[Accessed 20 March 2012]


[Accessed on July 10 2012]


[Accessed 12 May 2012]
Appendices
## Appendix-Tables

### Table AP1.1: Productivity indicators of rice

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land use in three seasons (hectare)</td>
<td></td>
<td>18.96</td>
<td>59.4</td>
<td>75.6</td>
<td>18.34</td>
<td>73.82</td>
</tr>
<tr>
<td>Total production (tonnes)</td>
<td></td>
<td>42.92</td>
<td>261.75</td>
<td>395.22</td>
<td>119.44</td>
<td>211.06</td>
</tr>
<tr>
<td>Market value of per kg rice (In Tk.)</td>
<td></td>
<td>19.05</td>
<td>19.38</td>
<td>20.29</td>
<td>22.33</td>
<td>13.82</td>
</tr>
<tr>
<td>Total cost of total production (in Tk.)</td>
<td></td>
<td>817626</td>
<td>5072715</td>
<td>8018608</td>
<td>2667095.2</td>
<td>2916849.20</td>
</tr>
<tr>
<td>Net income (in Tk.)</td>
<td></td>
<td>294330</td>
<td>2207021</td>
<td>5048534</td>
<td>2046275</td>
<td>1452680</td>
</tr>
<tr>
<td>Net income (In $)</td>
<td></td>
<td>206.98</td>
<td>495.40</td>
<td>890.39</td>
<td>1487.66</td>
<td>262.38</td>
</tr>
<tr>
<td>Productivity: Yield (tonnes/hectare)</td>
<td></td>
<td>2.28</td>
<td>4.41</td>
<td>5.25</td>
<td>6.51</td>
<td>2.86</td>
</tr>
<tr>
<td>Net income yield ($/ha)</td>
<td></td>
<td>3924.4</td>
<td>29426.95</td>
<td>67313.79</td>
<td>19369.06</td>
<td></td>
</tr>
<tr>
<td>Average yield of the World (tonnes/hectare)</td>
<td></td>
<td>4.37</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average yield of Bangladesh_2008 (tonnes/hectare)</td>
<td></td>
<td>2.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: 1$ US= Tk.75 (based on study period), Source: Based on questionnaire survey, 2011.

### Table AP1.2: Productivity indicators of aro-ecosystem

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Use( ha)</td>
<td>Rice+ Other crops</td>
<td>10.50(11.2%)</td>
<td>37.86(19.27%)</td>
<td>44.78(87.77%)</td>
<td>8.63(35.56%)</td>
<td>48.99(100%)</td>
</tr>
<tr>
<td></td>
<td>Aquatic Resources</td>
<td>83.25(88.8%)</td>
<td>158.58(80.73%)</td>
<td>6.24(12.23%)</td>
<td>15.64(64.44%)</td>
<td></td>
</tr>
<tr>
<td>Total Land( ha)</td>
<td></td>
<td>93.75(100%)</td>
<td>196.43(100%)</td>
<td>51.02(100%)</td>
<td>24.27(100%)</td>
<td>48.99(100%)</td>
</tr>
<tr>
<td>Food Production (tonne)</td>
<td>Rice+ Other crops</td>
<td>42.92(68.85%)</td>
<td>272.84(81.78%)</td>
<td>423.55(99.95%)</td>
<td>120.87(96%)</td>
<td>227.13(100%)</td>
</tr>
<tr>
<td></td>
<td>Aquatic Resources</td>
<td>19.42(31.15%)</td>
<td>60.79(18.22%)</td>
<td>0.20(0.05%)</td>
<td>5.03(4%)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>62.34(100%)</td>
<td>333.63(100%)</td>
<td>423.75(100%)</td>
<td>125.9(100%)</td>
<td>227.13(100%)</td>
</tr>
<tr>
<td>Food production(tonne/ha)</td>
<td></td>
<td>0.66</td>
<td>1.70</td>
<td>8.31</td>
<td>5.19</td>
<td>4.64</td>
</tr>
<tr>
<td>Net Income($)</td>
<td>Rice+ Other crops</td>
<td>3924.4(13.45%)</td>
<td>30878.3(15.4%)</td>
<td>80377.49(99.33%)</td>
<td>29232.56(66.70%)</td>
<td>26651.44(100%)</td>
</tr>
<tr>
<td></td>
<td>Aquatic Resources</td>
<td>25245.8(86.55%)</td>
<td>169557.7(84.6%)</td>
<td>536.26(0.67%)</td>
<td>14593.07(33.30%)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>29170.2(100%)</td>
<td>200436(100%)</td>
<td>80913.75(100%)</td>
<td>43825.63(100%)</td>
<td>26651.44(100%)</td>
</tr>
<tr>
<td>Income($/ha)</td>
<td>Rice+ Other crops</td>
<td>311.15</td>
<td>1020.39</td>
<td>1583.92</td>
<td>1583.75</td>
<td>544.01</td>
</tr>
<tr>
<td></td>
<td>Aquatic Resources</td>
<td>2918.56(45.50%)</td>
<td>17604.86(62.16%)</td>
<td>80377.49(99.33%)</td>
<td>29232.56(66.70%)</td>
<td>26651.44(100%)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3210.72</td>
<td>20625.25</td>
<td>1583.92</td>
<td>1583.75</td>
<td>544.01</td>
</tr>
<tr>
<td>Food Protein(kg)</td>
<td>Rice+ Other crops</td>
<td>6.2X10³(100%)</td>
<td>3.8X10³(100%)</td>
<td>5.9X10³(100%)</td>
<td>1.7X10³(100%)</td>
<td>3.1X10³(100%)</td>
</tr>
<tr>
<td></td>
<td>Aquatic Resources</td>
<td>9.7X10³(100%)</td>
<td>3.0X10³(100%)</td>
<td>1.0X10³(100%)</td>
<td>2.5X10³(100%)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>15.9X10³</td>
<td>6.8X10³</td>
<td>6.9X10³</td>
<td>3.2X10³</td>
<td></td>
</tr>
<tr>
<td>Food Energy(J/ha)</td>
<td>Rice+ Other crops</td>
<td>6.2X10¹³(100%)</td>
<td>3.8X10¹³(100%)</td>
<td>5.9X10¹³(100%)</td>
<td>1.7X10¹³(100%)</td>
<td>3.1X10¹³(100%)</td>
</tr>
<tr>
<td></td>
<td>Aquatic Resources</td>
<td>2.4X10¹³(100%)</td>
<td>9.3X10¹³(100%)</td>
<td>3.0X10¹³(100%)</td>
<td>9.5X10¹³(100%)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>8.6X10¹³</td>
<td>1.3X10¹³</td>
<td>9.9X10¹³</td>
<td>1.6X10¹³</td>
<td></td>
</tr>
</tbody>
</table>

Source: Based on questionnaire survey, 2011.
### Table AP1.3: Yields of Aus, Aman and Bora Rice in the study areas

<table>
<thead>
<tr>
<th>Study Areas</th>
<th>Aus (t/ha)</th>
<th>Aman (t/ha)</th>
<th>Bora (t/ha)</th>
<th>Yearly Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TLU (ha)</td>
<td>TP (t)</td>
<td>TLU (ha)</td>
<td>TP (t)</td>
</tr>
<tr>
<td>Shyamnagar</td>
<td>9.98</td>
<td>13.54</td>
<td>1.36</td>
<td>7.00</td>
</tr>
<tr>
<td>Kalijang</td>
<td>3.86</td>
<td>16.55</td>
<td>4.29</td>
<td>31.76</td>
</tr>
<tr>
<td>Kalaroa</td>
<td>2.21</td>
<td>13.03</td>
<td>5.89</td>
<td>39.43</td>
</tr>
<tr>
<td>Dumuria</td>
<td>2.77</td>
<td>12.54</td>
<td>4.52</td>
<td>4.95</td>
</tr>
<tr>
<td>Bhola Sadar</td>
<td>23.44</td>
<td>50.50</td>
<td>2.15</td>
<td>34.64</td>
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</table>

Note: TLU=Total land used, TP=Total population. Source: Based on questionnaire survey, 2011.

### Table AS.1.1: Stability Indicators for land

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<tr>
<th>Stability Indicators</th>
<th>Study areas</th>
<th>References</th>
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<tr>
<td>Land types(elevation)</td>
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<td></td>
<td>Kaliganj</td>
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</tr>
<tr>
<td></td>
<td>Kalaroa</td>
<td>High to Medium high</td>
</tr>
<tr>
<td></td>
<td>Dumuria</td>
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<tr>
<td></td>
<td>Bhola Sadar</td>
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<tr>
<td></td>
<td></td>
<td>SRDi, 2001 and Field visit, 2010</td>
</tr>
<tr>
<td>Mobility of water on land surface</td>
<td>Early</td>
<td>Early</td>
</tr>
<tr>
<td></td>
<td>Delay</td>
<td>Too early</td>
</tr>
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<td></td>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal</td>
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<tr>
<td>Crops production intensity</td>
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<td>One crop</td>
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<tr>
<td></td>
<td>Three crops</td>
<td>Three crops</td>
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<td></td>
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<td>Three crops</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SRDi, 2001 and Field visit, 2010</td>
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<tr>
<td>Land surface exposure to saline water</td>
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<tr>
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<td></td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>SRDi, 2001 and Field visit, 2010</td>
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<td></td>
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<td>Interior</td>
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<td>Interior</td>
<td>Interior</td>
</tr>
<tr>
<td></td>
<td>Exposed</td>
<td>SRDi, 2001 and Field visit, 2010</td>
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<tr>
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<td>High</td>
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<td>Low</td>
<td>SRDi, 2001 and Field visit, 2010</td>
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<tr>
<td>Land effected by drought in Kharif to Rabi season</td>
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<td>Moderate to Severe</td>
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<td>Low</td>
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<td>ADPC and FOA, 2007</td>
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<td>SRDi, 2001 and Field visit, 2010</td>
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<td>No</td>
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### Table AS1.2: Ranking for land related indicators

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<th>Properties</th>
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<th>Quantitative Ranking</th>
<th>Remarks</th>
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<td>Highland</td>
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<td>Land which is above normal flood-level. It is good for various vegetables and orchard trees</td>
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<tr>
<td>Medium highland</td>
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<td>4</td>
<td>Land which normally is flooded up to about 90 cm deep during the flood season. It is good for rice and jute.</td>
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<tr>
<td>Medium lowland</td>
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<td>3</td>
<td>Land which normally is flooded between 90 and 180 cm deep during the flood season. It is very good for rice, jute, oilseeds etc.</td>
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<tr>
<td>Lowland</td>
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<td>Land which normally is flooded between 180 and 300 cm deep during the flood season. It is good for deep water rice and local Boro rice.</td>
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<td>Very lowland</td>
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<td>Land which normally is flooded above 300 cm during the flood season. It is good for deep water rice.</td>
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<tr>
<td>Too Early</td>
<td>Too Early</td>
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<td>Water moved from the land surface within Ashshin (September-November)</td>
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<tr>
<td>Early</td>
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<td>Water moved from the land surface after Ashshin (September-November) but within Kartik (October-November)</td>
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<td>Water moved from the land surface after Kartik (October-November) but within Ogrohaean (November-December)</td>
</tr>
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<td>Delay</td>
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<td>2</td>
<td>Water moved from the land surface after Ogrohaean (November-December) but within second week of Poush (December-January)</td>
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<td>Land produce three crops in a year</td>
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<tr>
<td>Two crops</td>
<td>Two crops</td>
<td>2</td>
<td>Land produce two crops in a year</td>
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<tr>
<td>One crops</td>
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<td>1</td>
<td>Land produce four crops in a year</td>
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<td>Land Exposure to Cyclone</td>
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<td>Land Effected by Cyclone</td>
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<tr>
<td>High</td>
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<td>Land effected by drought in kharif to rabi season</td>
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<td>No</td>
<td>No</td>
<td>4</td>
<td>Depend on ground, surface and rain water</td>
</tr>
<tr>
<td>Lightly</td>
<td>Lightly</td>
<td>3</td>
<td>Depend on partly surface water and rain water</td>
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<tr>
<td>Moderate</td>
<td>Moderate</td>
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<td>Depends on mostly rainwater</td>
</tr>
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<td>Severe</td>
<td>Severe</td>
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<td>Very good</td>
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<td>Depend on ground, surface and rain water</td>
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<td>Good</td>
<td>Good</td>
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<td>Depend on ground and rain water</td>
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<td>Medium</td>
<td>Medium</td>
<td>2</td>
<td>Depend on partly surface water and rain water</td>
</tr>
<tr>
<td>Poor</td>
<td>Poor</td>
<td>1</td>
<td>Depends on mostly rainwater</td>
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<tr>
<td>Existence of river bank erosion</td>
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<td>No</td>
<td>2</td>
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<tr>
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Sources: SRDI, 2001, Note: Quantitative ranking (estimated.), 2011
Sustainability of Changing Agricultural Systems in the Coastal Zone of Bangladesh

Table AS2.1: Stability indicators for soil

<table>
<thead>
<tr>
<th>Stability Indicators</th>
<th>Unit</th>
<th>Study Areas</th>
<th>References</th>
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</thead>
<tbody>
<tr>
<td>Soil Chemical Properties</td>
<td></td>
<td>Shyamnagar</td>
<td>Kaliganj</td>
</tr>
<tr>
<td>Macronutrients</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total Nitrogen(N) (%)</td>
<td>0.162</td>
<td>0.30</td>
<td>0.29</td>
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<tr>
<td>Sulfur(S) meq /100gm</td>
<td>132.78</td>
<td>68</td>
<td>19</td>
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<tr>
<td>Phosphorus(P) μg/g</td>
<td>14.43</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Calcium(Ca) meq /100gm</td>
<td>5.0</td>
<td>16.0</td>
<td>0.40</td>
</tr>
<tr>
<td>Potassium(K) meq /100gm</td>
<td>1.0</td>
<td>0.43</td>
<td>0.28</td>
</tr>
<tr>
<td>Magnesium(Mg) meq /100gm</td>
<td>16.5</td>
<td>7.41</td>
<td>0.20</td>
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<td>Micronutrients</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Boron (B) μg/g</td>
<td>3.96</td>
<td>1.09</td>
<td>1.25</td>
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<tr>
<td>Copper(Cu) μg/g</td>
<td>5.82</td>
<td>8.1</td>
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<td>Iron (Fe) μg/g</td>
<td>240.2</td>
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<td>11</td>
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<td>Manganese(Mn) μg/g</td>
<td>41.84</td>
<td>14.0</td>
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<tr>
<td>Zinc(Zn) μg/g</td>
<td>2.94</td>
<td>2.5</td>
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<td>Other Chemical Properties</td>
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<td>Salinity dS/m</td>
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<tr>
<td>pH</td>
<td>3.8</td>
<td>6.1</td>
<td>7.89</td>
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<tr>
<td>Organic materials %</td>
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<td>4.11</td>
<td>1.74</td>
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<td>Soil Physical properties</td>
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Table AS2.2: Loamy to clayey soils

<table>
<thead>
<tr>
<th>Nutrient element*</th>
<th>Very Low</th>
<th>Low</th>
<th>Medium</th>
<th>Optimum</th>
<th>High</th>
<th>Very high</th>
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<tbody>
<tr>
<td>N (%)</td>
<td>&lt; 0.09</td>
<td>0.091-0.18</td>
<td>0.181-0.27</td>
<td>0.271-0.36</td>
<td>0.361-0.45</td>
<td>&gt;0.45</td>
</tr>
<tr>
<td>P (μg/g soil) (Olsen method)</td>
<td>&lt; 7.5</td>
<td>7.51-15.0</td>
<td>15.1-22.5</td>
<td>22.51-30</td>
<td>30.1-37.5</td>
<td>&gt;37.5</td>
</tr>
<tr>
<td>P (μg/g) (Bray &amp; Kurtz method)</td>
<td>&lt; 5.25</td>
<td>5.25-10.5</td>
<td>10.51-15.75</td>
<td>15.76-21.0</td>
<td>21.1-26.25</td>
<td>&gt;26.25</td>
</tr>
<tr>
<td>S (μg/g) soil</td>
<td>&lt; 7.5</td>
<td>7.51-15.0</td>
<td>15.1-22.5</td>
<td>22.51-30</td>
<td>30.1-37.5</td>
<td>&gt;37.5</td>
</tr>
<tr>
<td>K (meq/100g)</td>
<td>&lt; 0.09</td>
<td>0.091-0.18</td>
<td>0.181-0.27</td>
<td>0.271-0.36</td>
<td>0.361-0.45</td>
<td>&gt;0.45</td>
</tr>
<tr>
<td>Ca (meq/100g)</td>
<td>&lt; 1.5</td>
<td>1.51-3.0</td>
<td>3.1-4.5</td>
<td>4.51-6.0</td>
<td>6.1-7.5</td>
<td>&gt;7.5</td>
</tr>
<tr>
<td>Mg (meq /100g)</td>
<td>&lt; 0.375</td>
<td>0.376-0.75</td>
<td>0.751-1.125</td>
<td>1.126-1.5</td>
<td>1.51-1.875</td>
<td>&gt;1.875</td>
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<tr>
<td>Cu (μg/g)</td>
<td>&lt; 0.15</td>
<td>0.151-0.3</td>
<td>0.31-0.45</td>
<td>0.451-0.6</td>
<td>0.61-0.75</td>
<td>&gt;0.75</td>
</tr>
<tr>
<td>Zn (μg/g)</td>
<td>&lt; 0.45</td>
<td>0.451-0.9</td>
<td>0.91-1.35</td>
<td>1.351-1.8</td>
<td>1.81-2.25</td>
<td>&gt;2.25</td>
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<tr>
<td>Fe (μg/g)</td>
<td>&lt; 3.0</td>
<td>3.1-6.0</td>
<td>6.1-9.0</td>
<td>9.1-12.0</td>
<td>12.1-15.0</td>
<td>&gt;15.0</td>
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<tr>
<td>Mn (μ/l)</td>
<td>&lt; 0.75</td>
<td>0.756-1.5</td>
<td>1.51-2.25</td>
<td>2.256-3.0</td>
<td>3.1-3.75</td>
<td>&gt;3.75</td>
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<td>B (μg/g)</td>
<td>&lt; 0.15</td>
<td>0.151-0.3</td>
<td>0.31-0.45</td>
<td>0.451-0.6</td>
<td>0.61-0.75</td>
<td>&gt;0.75</td>
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<tr>
<td>Mo (μ/g)</td>
<td>&lt; 0.075</td>
<td>0.076-0.15</td>
<td>0.151-0.225</td>
<td>0.226-0.30</td>
<td>0.31-0.375</td>
<td>&gt;0.375</td>
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Note: Interpretation of soil test values based on critical limits, Source: FRG, BARC, 2005
### Table AS2.3: Ranking for soil properties

<table>
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<tr>
<th>Properties</th>
<th>Qualitative Ranking</th>
<th>Quantitative Ranking</th>
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<td>Chemical Properties</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>Optimum</td>
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<tr>
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</tr>
<tr>
<td></td>
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<td>Micronutrients</td>
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<td></td>
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<tr>
<td></td>
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<td></td>
<td>Optimum</td>
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<tr>
<td></td>
<td>Low</td>
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<tr>
<td>Physical Properties</td>
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<tr>
<td>Soil Texture</td>
<td>Loam (Very good for main crops)</td>
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<td>Clay Loam (Ok for main crops)</td>
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<td>Sandy Loam (Slightly Ok for main crops)</td>
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<tr>
<td></td>
<td>Clay (Slightly good for main crops)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sandy (Not good for main crops)</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

### Table AS2.4: Classification of soils on the basis of salinity

<table>
<thead>
<tr>
<th>Salinity Classification</th>
<th>Salinity (dS/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>&gt;15</td>
</tr>
<tr>
<td>High</td>
<td>12-15</td>
</tr>
<tr>
<td>Medium</td>
<td>8-12</td>
</tr>
<tr>
<td>Low</td>
<td>4-8</td>
</tr>
<tr>
<td>Very low</td>
<td>2-4</td>
</tr>
<tr>
<td>Non saline</td>
<td>&lt;2</td>
</tr>
</tbody>
</table>

Source: SRDI, 2001; BARC, 2005
### Table AS2.5: Classification of soils on the basis of pH values

<table>
<thead>
<tr>
<th>pH</th>
<th>Soil reaction class</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;4.5</td>
<td>Very strongly acidic</td>
</tr>
<tr>
<td>4.6-5.5</td>
<td>Strongly acidic</td>
</tr>
<tr>
<td>5.6-6.5</td>
<td>Slightly acid</td>
</tr>
<tr>
<td>6.6-7.3</td>
<td>Neutral</td>
</tr>
</tbody>
</table>

Source: SRDI, 2001

### Table AS2.6: Classification of soils on the basis of organic matter content

<table>
<thead>
<tr>
<th>Class</th>
<th>Organic Matter (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>&gt;5.5</td>
</tr>
<tr>
<td>High</td>
<td>3.5-5.5</td>
</tr>
<tr>
<td>Medium</td>
<td>1.8-3.4</td>
</tr>
<tr>
<td>Low</td>
<td>1.0-1.7</td>
</tr>
<tr>
<td>Very low</td>
<td>&lt;1.0</td>
</tr>
</tbody>
</table>


### Table AS3.1: Stability Indicators for Water

<table>
<thead>
<tr>
<th>Stability Indicators</th>
<th>Study area</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salinity level of surface water (dS/m)</td>
<td>&gt;10</td>
<td>5-10</td>
<td>5-10</td>
<td>5-10</td>
<td>1-5</td>
<td></td>
</tr>
<tr>
<td>Salinity level of ground water (dS/m)</td>
<td>&gt;10</td>
<td>5-10</td>
<td>5-10</td>
<td>1-2</td>
<td>2-5</td>
<td></td>
</tr>
<tr>
<td>Arsenic concentration of in ground water</td>
<td>Moderate concentration</td>
<td>Moderate concentration</td>
<td>Moderate concentration</td>
<td>Moderate concentration</td>
<td>Little to mild concentration</td>
<td></td>
</tr>
</tbody>
</table>

Source: SDRI, 2001; Field visit 2011 and Uddin and Kaudstal, 2003

### Table AS3.2: Stability indicators for water-ranking

<table>
<thead>
<tr>
<th>Properties</th>
<th>Amount</th>
<th>Qualitative Ranking</th>
<th>Quantitative Ranking</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Related</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity level of surface water (dS/m)</td>
<td>&lt;1</td>
<td>Low</td>
<td>5</td>
<td>Qualitative Ranking suggested by SRDI, 2001 and Quantitative Ranking Suggested by author, 2011</td>
</tr>
<tr>
<td></td>
<td>1-2</td>
<td>Medium</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2-5</td>
<td>Optimum</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5-10</td>
<td>High</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;10</td>
<td>Very High</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Salinity level of ground water (dS/m)</td>
<td>&lt;1</td>
<td>Low</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1-2</td>
<td>Medium</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2-5</td>
<td>Optimum</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5-10</td>
<td>High</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;10</td>
<td>Very High</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Arsenic concentration of in ground water</td>
<td>Non concentration</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Little to mild concentration</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mild concentration</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Qualitative ranking suggested by SRDI, 2001 and Quantitative ranking suggested by author, 2011
Table AS5.1: Stability indicators for others

<table>
<thead>
<tr>
<th>Stability Indicators</th>
<th>Study area</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
<td>Kaliganj</td>
</tr>
<tr>
<td>Withdraw of upstream water</td>
<td>Effected</td>
<td>Effected</td>
</tr>
<tr>
<td>Drying of river</td>
<td>Observed</td>
<td>Observed</td>
</tr>
<tr>
<td>Stability of embankment</td>
<td>Poorly managed and protected</td>
<td>Well managed and protected</td>
</tr>
<tr>
<td>Transportation system</td>
<td>Moderate</td>
<td>Good</td>
</tr>
</tbody>
</table>

Field visit, 2010

WARP, 2010

Table AS5.2: Ranking for other stability indicators

<table>
<thead>
<tr>
<th>Properties</th>
<th>Qualitative Ranking</th>
<th>Quantitative Ranking</th>
<th>Remarks</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Withdraw of upstream water</td>
<td>Not Effected</td>
<td>2</td>
<td>Effects are reported in literature</td>
<td>WARP, 2010</td>
</tr>
<tr>
<td></td>
<td>Effected</td>
<td>1</td>
<td>Effects not reported in literature</td>
<td></td>
</tr>
<tr>
<td>Dying of river</td>
<td>Not Observed</td>
<td>2</td>
<td>Remain flow during summer and winter season</td>
<td>Field visit, 2010</td>
</tr>
<tr>
<td></td>
<td>Observed</td>
<td>1</td>
<td>Flow of water stopped</td>
<td></td>
</tr>
<tr>
<td>Stability of embankment</td>
<td>Well protected</td>
<td>2</td>
<td>Embankment did not fail over 20 years</td>
<td>Field visit, 2010</td>
</tr>
<tr>
<td></td>
<td>Poorly protected</td>
<td>1</td>
<td>Embankment failed within 20 years</td>
<td></td>
</tr>
<tr>
<td>Transportation system</td>
<td>Good</td>
<td>3</td>
<td>Connected with national high way</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>2</td>
<td>Somewhat connected with national high way</td>
<td>Field visit, 2010</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>1</td>
<td>Not connected with national high way</td>
<td></td>
</tr>
</tbody>
</table>

Field visit, 2010

Note: Suggested by author, 2011
Table AE1.1: Efficiency indicator of rice

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Study Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Total land area for rice cultivation (ha)</td>
<td>10.50</td>
</tr>
<tr>
<td>Total income from input (in $)</td>
<td>6977.28</td>
</tr>
<tr>
<td>Total cost of output (in $)</td>
<td>10901.68</td>
</tr>
<tr>
<td>Hectare wise efficiency in rice ($/hectare)</td>
<td>373.75</td>
</tr>
<tr>
<td>Energy from output (J)</td>
<td></td>
</tr>
<tr>
<td>Total Harvest</td>
<td>6.32X10^11</td>
</tr>
<tr>
<td>Mass of Stalks</td>
<td>1.0X10^12</td>
</tr>
<tr>
<td>Total Output Energy</td>
<td>1.6X10^12</td>
</tr>
<tr>
<td>Energy from Inputs (J)</td>
<td></td>
</tr>
<tr>
<td>Seed</td>
<td></td>
</tr>
<tr>
<td>Fertilizer</td>
<td></td>
</tr>
<tr>
<td>Urea (N)*</td>
<td>2.6X10^10</td>
</tr>
<tr>
<td>TSP (K)*</td>
<td>2.0X10^11</td>
</tr>
<tr>
<td>MOP (P)*</td>
<td>3.0X10^10</td>
</tr>
<tr>
<td>Gypsum*</td>
<td>9.2X10^9</td>
</tr>
<tr>
<td>Agro-Chemicals/Pesticide (Liquid)*</td>
<td>6.2X10^9</td>
</tr>
<tr>
<td>Diesel*</td>
<td>3.5X10^10</td>
</tr>
<tr>
<td>Bullock Labour</td>
<td>1.4X10^10</td>
</tr>
<tr>
<td>Human Labour</td>
<td>2.3X10^10</td>
</tr>
<tr>
<td>Total Input Energy (J)</td>
<td>3.5X10^11</td>
</tr>
<tr>
<td>Overall energy Efficiency</td>
<td>4.73</td>
</tr>
<tr>
<td>Primary Energy Efficiency</td>
<td>1.81</td>
</tr>
<tr>
<td>Non-renewable primary energy efficiency</td>
<td>2.13</td>
</tr>
<tr>
<td>Non Renewable energy fraction</td>
<td>85.1%</td>
</tr>
<tr>
<td>Renewable energy fraction</td>
<td>14.9%</td>
</tr>
</tbody>
</table>

Note: (1) *Aspects of the operations that consume non-renewable energy. (2) N, P and K stands for Nitrogen, Potash and Phosphate. (2) Table E1.1 is based on Table E1.3, E1.4, E1.5, E1.6 and E 1.7.
0.35 solid/powder pesticide is used and 1.2L liquid pesticide is used (Estimated).

**Table AE1.3: Total inputs used for rice production**

<table>
<thead>
<tr>
<th>Total Inputs Used</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Land (ha)</td>
<td>18.96</td>
</tr>
<tr>
<td>Seed (kg)</td>
<td>1760.10</td>
</tr>
<tr>
<td>Urea (kg)</td>
<td>3355.92</td>
</tr>
<tr>
<td>TSP (kg)</td>
<td>2730.24</td>
</tr>
<tr>
<td>MOP (kg)</td>
<td>833.20</td>
</tr>
<tr>
<td>Gypsum (kg)</td>
<td>618.36</td>
</tr>
<tr>
<td>Boron (kg)</td>
<td>-</td>
</tr>
<tr>
<td>Cow dung (kg)</td>
<td>-</td>
</tr>
<tr>
<td>Liquid Pesticide (L)</td>
<td>294.34</td>
</tr>
<tr>
<td>Diesel (L)</td>
<td>321.10</td>
</tr>
<tr>
<td>Human labour (man day)</td>
<td>1636</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011. Note: (1) *A man day was considered to be 8.00 hours in a day. (2) Per hectare 0.35 solid/powder pesticide is used and 1.2L liquid pesticide is used (Estimated).
Table AE1.4: Unit price observed for inputs used in rice production in study areas

<table>
<thead>
<tr>
<th>Unit price</th>
<th>Study Areas</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed (Tk/kg)</td>
<td></td>
<td>40</td>
<td>38</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urea (Tk/kg)</td>
<td></td>
<td>12</td>
<td>14</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>TSP (Tk/kg)</td>
<td></td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>MOP (Tk/kg)</td>
<td></td>
<td>15</td>
<td>18</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Gypsum (Tk/kg)</td>
<td></td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Boron (Tk/kg)</td>
<td></td>
<td>150</td>
<td>150</td>
<td>160</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cow dung (Tk/kg)</td>
<td></td>
<td>6-7</td>
<td>4-5</td>
<td>5-6</td>
<td>5-6</td>
<td>3-4</td>
</tr>
<tr>
<td>Liquid Pesticide (Tk/L)</td>
<td></td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Diesel (Tk/L)</td>
<td></td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Human labour (Tk/Man day)</td>
<td></td>
<td>150</td>
<td>150</td>
<td>160</td>
<td>170</td>
<td>120</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011. Note: Man-day = the amount of work per operation (day ha⁻¹); LH = the labor hours per day (8 h day⁻¹ in this study).

Table AE1.5: Output parameters of rice production

<table>
<thead>
<tr>
<th>Crops</th>
<th>Study Areas</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>TH</td>
<td>MS*</td>
<td>TH</td>
<td>MS*</td>
<td>TH</td>
</tr>
<tr>
<td>Grain (Rice)</td>
<td></td>
<td>42.96</td>
<td>64.44</td>
<td>261.75</td>
<td>392.63</td>
<td>395.22</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.33</td>
</tr>
<tr>
<td>Aquatic Resources</td>
<td></td>
<td>19.42</td>
<td>-</td>
<td>60.79</td>
<td>-</td>
<td>0.20</td>
</tr>
<tr>
<td>Jute</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>18.07</td>
</tr>
<tr>
<td>Oil seeds (Sesame, Mustard)</td>
<td></td>
<td>-</td>
<td>-</td>
<td>0.07</td>
<td>0.09</td>
<td>0.30</td>
</tr>
<tr>
<td>Leguminous crops (Masoor Dhal, Kesari Dhal, Mung Dhal, Palen Dhal, Boot Dhal)</td>
<td></td>
<td>-</td>
<td>-</td>
<td>0.07</td>
<td>0.09</td>
<td>0.30</td>
</tr>
<tr>
<td>Vegetables (Potato, Brinjal, Onion, Garlic, Kachur Mukhi, Oal Kachu, Indian spinach)</td>
<td></td>
<td>-</td>
<td>-</td>
<td>11.01</td>
<td>2.2</td>
<td>2.94</td>
</tr>
<tr>
<td>Spices (Turmeric)</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6.8</td>
</tr>
<tr>
<td>Fruits (Mango, Betel Nut)</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011. Note: (1) TH=Total Harvest (in tonne), MS=Mass of Stalks (in tonne), (2) 1.25kg stalks per 1 kg grain (estimated)*, (3) 0.2kg stalks per 1kg vegetable (estimated)*, (4) 2kg stalks per 1kg jute (estimated).
### Table AE1.6: Energy co-efficient of different inputs and outputs

<table>
<thead>
<tr>
<th>Input</th>
<th>Crops</th>
<th>Energy (MJ/kg⁻¹)</th>
<th>Output</th>
<th>Energy (MJ/kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed</td>
<td>Jute</td>
<td>16.91</td>
<td>Jute fibre (cap.)</td>
<td>19.12</td>
</tr>
<tr>
<td></td>
<td>Rice</td>
<td>14.70</td>
<td>Jute fibre (oli.)</td>
<td>17.84</td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td>14.70</td>
<td>Rice grain</td>
<td>14.70</td>
</tr>
<tr>
<td></td>
<td>Potato</td>
<td>4.06</td>
<td>Wheat grain</td>
<td>14.70</td>
</tr>
<tr>
<td></td>
<td>Lentil</td>
<td>14.40</td>
<td>Lentil grain</td>
<td>14.40</td>
</tr>
<tr>
<td></td>
<td>Dhaingcha</td>
<td>14.70</td>
<td>Potato tuber</td>
<td>4.06</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>Urea (Nitrogen)</td>
<td>60.10</td>
<td>Jute stick</td>
<td>16.91</td>
</tr>
<tr>
<td></td>
<td>MOP (Potash)</td>
<td>11.10</td>
<td>Rice straw</td>
<td>15.59</td>
</tr>
<tr>
<td></td>
<td>TSP (Phosphate)</td>
<td>11.10</td>
<td>Wheat straw</td>
<td>15.76</td>
</tr>
<tr>
<td></td>
<td>Gypsum</td>
<td>10.0*</td>
<td>Lentil stover</td>
<td>12.50</td>
</tr>
<tr>
<td>Agrochemicals</td>
<td>Solid/powder</td>
<td>12.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Liquid</td>
<td>120.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel</td>
<td></td>
<td>56.31 MJ L⁻¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human labour</td>
<td></td>
<td>1.96 MJ hr⁻¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aquatic resources (estimated)</td>
<td></td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Khan and Hossin, 2007; *vanloon et al., 2005

### Table AE1.7: Protein and energy value in different agricultural products

<table>
<thead>
<tr>
<th>Agricultural Production</th>
<th>Protein (g/100g)</th>
<th>Energy (Kcal/100g)</th>
<th>Energy (J/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>6.8</td>
<td>345</td>
<td>1.4E+07</td>
</tr>
<tr>
<td>Wheat</td>
<td>11.8</td>
<td>346</td>
<td>1.4E+07</td>
</tr>
<tr>
<td>Potato</td>
<td>1.6</td>
<td>97</td>
<td>4054600</td>
</tr>
<tr>
<td>Mustard</td>
<td>4.0</td>
<td>34 this is for leaves</td>
<td>1421200</td>
</tr>
<tr>
<td>Masoor Dhal</td>
<td>18.3</td>
<td>563</td>
<td>2.4E+07</td>
</tr>
<tr>
<td>Kesari Dhal</td>
<td>28.2</td>
<td>345</td>
<td>1.4E+07</td>
</tr>
<tr>
<td>Mung Dhal</td>
<td>24.0</td>
<td>334</td>
<td>1.4E+07</td>
</tr>
<tr>
<td>Palen Dhal</td>
<td>24.0(est)</td>
<td>334</td>
<td>1.4E+07</td>
</tr>
<tr>
<td>Boat Dhal</td>
<td>24.0(est)</td>
<td>334</td>
<td>1.4E+07</td>
</tr>
<tr>
<td>Turmeric</td>
<td>6.3</td>
<td>349</td>
<td>1.5E+07</td>
</tr>
<tr>
<td>Garlic</td>
<td>6.3</td>
<td>145</td>
<td>6061000</td>
</tr>
<tr>
<td>Onion</td>
<td>1.8</td>
<td>59</td>
<td>2466200</td>
</tr>
<tr>
<td>Chilli</td>
<td>2.9</td>
<td>29</td>
<td>1212200</td>
</tr>
<tr>
<td>Ladies Finger</td>
<td>1.9</td>
<td>35</td>
<td>1463000</td>
</tr>
<tr>
<td>Bringle</td>
<td>1.4</td>
<td>24</td>
<td>1003200</td>
</tr>
<tr>
<td>Indian Spinach</td>
<td>2.0</td>
<td>26</td>
<td>1086800</td>
</tr>
<tr>
<td>Mukhi Kachu (Colocasia esculenta)</td>
<td>3.0</td>
<td>97</td>
<td>4054600</td>
</tr>
<tr>
<td>Oal Kachu</td>
<td>3.0</td>
<td>97</td>
<td>4054600</td>
</tr>
<tr>
<td>Vegetable</td>
<td>1.7 (est)</td>
<td>50 (est)</td>
<td>2090000</td>
</tr>
<tr>
<td>Bitter Gourd</td>
<td>2.1</td>
<td>60</td>
<td>2508000</td>
</tr>
<tr>
<td>Sweet Pumpkin</td>
<td>1.4</td>
<td>25</td>
<td>1045000</td>
</tr>
<tr>
<td>Pumpkin (Kumra)</td>
<td>0.7(est)</td>
<td>17(est)</td>
<td>710800</td>
</tr>
<tr>
<td>Water melon</td>
<td>0.5</td>
<td>17(est)</td>
<td>710600</td>
</tr>
<tr>
<td>Betel nut</td>
<td>4.9</td>
<td>249</td>
<td>1E+07</td>
</tr>
<tr>
<td>Mango</td>
<td>0.6</td>
<td>74</td>
<td>3093200</td>
</tr>
<tr>
<td>Aquatic production (fishes)</td>
<td>18 (avg, not dried)</td>
<td>120 (avg, not dried)</td>
<td>5016000</td>
</tr>
</tbody>
</table>

Source: Gopalan et al., 1996
### Table AE1.8: Energy efficiency in aquatic resources

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Total Fish Harvest</td>
<td>9.71X10^{10}</td>
</tr>
<tr>
<td>Mass of Stalks</td>
<td>-</td>
</tr>
<tr>
<td>Total Output Energy</td>
<td>9.71X10^{10}</td>
</tr>
<tr>
<td>Fish Fry</td>
<td>-</td>
</tr>
<tr>
<td>Fertilizer</td>
<td></td>
</tr>
<tr>
<td>Cow dung</td>
<td></td>
</tr>
<tr>
<td>Urea (N)*</td>
<td>2X10^{11}</td>
</tr>
<tr>
<td>TSP (K)*</td>
<td>6X10^{9}</td>
</tr>
<tr>
<td>Lime and others</td>
<td>-</td>
</tr>
<tr>
<td>Power tiller</td>
<td>8X10^{9}</td>
</tr>
<tr>
<td>Human Labour</td>
<td>7X10^{11}</td>
</tr>
<tr>
<td>Overall energy Efficiency</td>
<td>4.68</td>
</tr>
<tr>
<td>Primary Energy Efficiency</td>
<td>1.79</td>
</tr>
<tr>
<td>Non-renewable primary energy efficiency</td>
<td>2.10</td>
</tr>
<tr>
<td>Non Renewable energy fraction</td>
<td>85.4%</td>
</tr>
</tbody>
</table>

Note: (1) *Aspects of the operations that consume non-renewable energy (2) N, P and K stands for Nitrogen, Potash and Phosphate.

### Table AE1.9: Total inputs used for aquatic resources production

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Power tiller(Hours)</td>
<td>1346.15</td>
</tr>
<tr>
<td>Labour</td>
<td>2200</td>
</tr>
<tr>
<td>Fertilizer</td>
<td></td>
</tr>
<tr>
<td>Cow dung(kg)</td>
<td>14000</td>
</tr>
<tr>
<td>Urea(kg)</td>
<td>2800</td>
</tr>
<tr>
<td>TSP(kg)</td>
<td>515</td>
</tr>
<tr>
<td>Lime(kg)</td>
<td>20888</td>
</tr>
<tr>
<td>Feed(kg)</td>
<td>10708.6</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011
Table AD1.1: Number of farmers not using chemical pesticide for agriculture

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Chemical Response to Pest Stress</td>
<td>Shyamanagr</td>
</tr>
<tr>
<td>Number of total farmer</td>
<td>45</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

Table AD1.2: Farmers’ perception about critical month’s water availability

<table>
<thead>
<tr>
<th>Stage</th>
<th>Dry Spell length(days)</th>
<th>Drought Perception</th>
<th>Ranking</th>
<th>Score</th>
<th>Highest Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transplanting Stage</td>
<td>0</td>
<td>No water scarcity</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0-5</td>
<td>Slightly water scarcity</td>
<td>3</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5-8</td>
<td>Mild water scarcity</td>
<td>2</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8-15</td>
<td>Moderate water scarcity</td>
<td>1</td>
<td>0.25</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>More than 15</td>
<td>Severe water scarcity</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Flowering Stage</td>
<td>0</td>
<td>No water scarcity</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0-5</td>
<td>Slightly water scarcity</td>
<td>3</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5-7</td>
<td>Mild water scarcity</td>
<td>2</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7-12</td>
<td>Moderate water scarcity</td>
<td>1</td>
<td>0.25</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>More than 12</td>
<td>Severe water scarcity</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Source: FGD, 2011. Note: Based on the length of dry spells and crop phonological stages in study areas

Table AD1.3: Critical months of water availability for main crop (rice)

<table>
<thead>
<tr>
<th>Study Areas</th>
<th>Transplanting Stage</th>
<th>Flowering Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ranking</td>
<td>Score</td>
</tr>
<tr>
<td>Shyamanagr</td>
<td>3</td>
<td>0.75</td>
</tr>
<tr>
<td>Kaliganj</td>
<td>3</td>
<td>0.75</td>
</tr>
<tr>
<td>Kalaroa</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>Dumuria</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>Bhola Sadar</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>Standard</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: FGD, 2011

Table AD1.4: Number of farmers followed traditional and modern methods of seeds preservation

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow traditional system of seed preservation</td>
<td>Shyamanagr</td>
</tr>
<tr>
<td>Number of total farmer</td>
<td>45</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011
Table AD1.5: Ranking-seed preservation system

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Ranking</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional system of seed preservation</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Improve system of seed preservation</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Highest ranking</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Table AD1.6: Number of farmer followed traditional seeds preservation methods

<table>
<thead>
<tr>
<th>Study Areas</th>
<th>Indicators</th>
<th>Score for traditional system</th>
<th>Score for improve system</th>
<th>Total score</th>
<th>Probable highest score</th>
<th>Score in 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shyamanagr</td>
<td>45X0.5=22.5</td>
<td></td>
<td>0X2=0</td>
<td>22.5</td>
<td>45X2=90</td>
<td>(22.5/90)*10=2.5</td>
</tr>
<tr>
<td>Kaliganj</td>
<td>57X0.5=28.5</td>
<td>3X2=6</td>
<td>34.5</td>
<td>60X2=120</td>
<td>3.12</td>
<td></td>
</tr>
<tr>
<td>Kalaroa</td>
<td>54X0.5=27</td>
<td>5X2=10</td>
<td>37</td>
<td>59X2=118</td>
<td>3.18</td>
<td></td>
</tr>
<tr>
<td>Dumuria</td>
<td>20X0.5=10</td>
<td>2X2=4</td>
<td>14</td>
<td>22X2=44</td>
<td>3.18</td>
<td></td>
</tr>
<tr>
<td>Bhola Sadar</td>
<td>26X0.5=13</td>
<td>0X2=0</td>
<td>13</td>
<td>26X2=52</td>
<td>2.5</td>
<td></td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

Table AD1.7: Number of farmer reported of availability of seeds

<table>
<thead>
<tr>
<th>Study Areas</th>
<th>Indicators</th>
<th>Shyamanagr</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of seed</td>
<td>42</td>
<td>57</td>
<td>59</td>
<td>22</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Number of total farmer</td>
<td>45</td>
<td>60</td>
<td>59</td>
<td>22</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

Table AD1.8: Number of farmer reported of good price of products

<table>
<thead>
<tr>
<th>Study Areas</th>
<th>Indicators</th>
<th>Shyamanagr</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Price of the products</td>
<td>38</td>
<td>30</td>
<td>27</td>
<td>10</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Number of total farmer</td>
<td>45</td>
<td>60</td>
<td>59</td>
<td>22</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

Table AD1.9: Number of farmer reported of availability of market

<table>
<thead>
<tr>
<th>Study Areas</th>
<th>Indicators</th>
<th>Shyamanagr</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of market</td>
<td>45</td>
<td>55</td>
<td>50</td>
<td>22</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Number of total farmer</td>
<td>45</td>
<td>60</td>
<td>59</td>
<td>22</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011
Table AD1.10: Number of farmer engaged in other economic activities

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of total farmer</td>
<td>Shyamanag</td>
</tr>
<tr>
<td>Other Economic Activities</td>
<td>28</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

Table AD1.11: Number of years when farmer’s income fall below a critical level

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numbers of Years</td>
<td>Shyamanag</td>
</tr>
<tr>
<td></td>
<td>3*</td>
</tr>
</tbody>
</table>

Source: Literature survey and FGD, 2010. * Agriculture losses occurred due to cyclone effect. After 2009 Aila Cyclone, farmer of the study areas observed losses in agriculture for one to three years

Table AD1.12: Ranking of years of economic hardship

<table>
<thead>
<tr>
<th>Numbers of Economic Hardship Years</th>
<th>Ranking</th>
<th>Score</th>
<th>Highest Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>11</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0.91</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>0.55</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>0.09</td>
<td></td>
</tr>
</tbody>
</table>

Source: Developed by us, 2010

Table AD1.13: Number of farmer received agricultural training

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Received agricultural training</td>
<td>Shyamanag</td>
</tr>
<tr>
<td>Number of total farmer</td>
<td>6</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

Table AD1.14: Number of farmer took advices from block supervisor

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take advices from Block Supervisor</td>
<td>Shyamanag</td>
</tr>
<tr>
<td>Number of total farmer</td>
<td>45</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011
Table AD1.15: Number of farmer followed soil test for farm management

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamanagr</td>
</tr>
<tr>
<td>Number of farmer do soil Test</td>
<td>3</td>
</tr>
<tr>
<td>Number of total farmer</td>
<td>45</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

Table AD1.16: Number of farmer took part on climate change awareness programme

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamanagr</td>
</tr>
<tr>
<td>Climate change awareness</td>
<td>5</td>
</tr>
<tr>
<td>Number of total farmer</td>
<td>45</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

Table AC1.1: Health related information of surveyed households

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of Household</td>
<td>45</td>
<td>60</td>
<td>59</td>
<td>22</td>
<td>26</td>
</tr>
<tr>
<td>Total population</td>
<td>253</td>
<td>294</td>
<td>305</td>
<td>121</td>
<td>190</td>
</tr>
<tr>
<td>No. of drinking water related illness</td>
<td>51</td>
<td>13</td>
<td>7</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>No. of household have access to protected water</td>
<td>21</td>
<td>60</td>
<td>59</td>
<td>22</td>
<td>26</td>
</tr>
</tbody>
</table>

Source: Field survey, 2011

Table AC1.2: Concentration of arsenic in drinking water of the study areas

<table>
<thead>
<tr>
<th>Concentration in Drinking Water</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic(μg/L)</td>
<td>10-50</td>
<td>10-50</td>
<td>&lt;5</td>
<td>50-200</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>

WHO Standard | Reference
---|-----------------|
10 | UNICEF and BBS , 2011

Table AC1.3: Ranking of arsenic

<table>
<thead>
<tr>
<th>Concentration in Drinking Water</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Arsenic(μg/L)</td>
<td>10-50</td>
</tr>
<tr>
<td>Ranking</td>
<td>3</td>
</tr>
</tbody>
</table>

WHO Standard | Reference
---|-----------------|
10 | UNICEF and BBS , 2011
### Table AC1.4: Land use in the study areas in 2010

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Study Areas</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
<td>Kaliganj</td>
<td>Kalara</td>
<td>Dumuria</td>
<td>Bhola Sadar</td>
<td></td>
<td></td>
<td></td>
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<td>% of T.A</td>
<td>% of C.A</td>
<td>% of T.A</td>
<td>% of C.A</td>
<td>% of T.A</td>
<td>% of C.A</td>
<td>% of T.A</td>
<td>% of C.A</td>
<td>% of T.A</td>
<td>% of C.A</td>
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<td>Homestead Area</td>
<td>5.17</td>
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<td>13.83</td>
<td>12.83</td>
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<td>Water Area (Pond)</td>
<td>2.37</td>
<td>2.43</td>
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<td>Aqua Culture Area</td>
<td>82.11</td>
<td>88.8</td>
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<td>Rice</td>
<td>10.36</td>
<td>11.20</td>
<td>18.02</td>
<td>19.27</td>
<td>67.57</td>
<td>87.77</td>
<td>29.96</td>
<td>35.56</td>
<td>81.32</td>
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<td>Potato</td>
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<td>0.34</td>
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<td>Sesame</td>
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<td>0.07</td>
<td>0.88</td>
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<td>Bringel</td>
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<td>Kachur Mukhi</td>
<td>0.50</td>
<td>0.53</td>
<td>0.60</td>
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<td>Mustard</td>
<td>0.20</td>
<td>0.25</td>
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<td>0.37</td>
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<td>Oal kachu</td>
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<td>Indian spinach</td>
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<td>Bitter gourd</td>
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<td>0.25</td>
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<td>Betel nut</td>
<td>0.06</td>
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<td>3.09</td>
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<td>Mango</td>
<td>2.35</td>
<td>3.06</td>
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<td>Vegetables (8 types)</td>
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<td>8.68</td>
<td>10.30</td>
<td>0.07</td>
<td>0.08</td>
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<tr>
<td>Masoor dhal</td>
<td>3.98</td>
<td>5.17</td>
<td>4.18</td>
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<td>Kesari Dhal</td>
<td>3.50</td>
<td>4.31</td>
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<tr>
<td>Mung Dhal</td>
<td>1.05</td>
<td>1.29</td>
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<td>Palen Dhal</td>
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<td>1.96</td>
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<td>Boot Dhal</td>
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<td>0.33</td>
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<td>Chilli</td>
<td>2.36</td>
<td>2.90</td>
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<tr>
<td>Pumpkin (kumra)</td>
<td>0.20</td>
<td>0.25</td>
<td>0.03</td>
<td>0.04</td>
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<td>Water melon</td>
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<td></td>
<td>3.85</td>
<td>4.74</td>
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<tr>
<td>Ladies finger</td>
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<td></td>
<td>0.02</td>
<td>0.02</td>
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<td></td>
<td></td>
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<tr>
<td>Total Agricultural Land Area</td>
<td>93.75</td>
<td>196.44</td>
<td>51.02</td>
<td>24.27</td>
<td>48.99</td>
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<td></td>
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<tr>
<td>Total Land Area</td>
<td>101.39</td>
<td>210.05</td>
<td>66.27</td>
<td>28.80</td>
<td>60.24</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>% of non-crop area</td>
<td>7.54</td>
<td>6.48</td>
<td>23.01</td>
<td>15.73</td>
<td>18.68</td>
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</tr>
</tbody>
</table>

Note: T.A=Total Area, C.A=Cultivated Area, All areas in ha., Source: Field survey, 2011
Table AC1.5: Ecosystem services provided by agricultural system

<table>
<thead>
<tr>
<th>Ecosystem Services</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop production</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Forest production</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Preserving habitats and biodiversity</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Water quality regulation</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Carbon sequestration</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Regional climate and air quality regulation</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Infectious diseases mediation</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Total score</td>
<td>7</td>
<td>14</td>
<td>23</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>Highest score</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>

| Ecosystem services indicators of the study areas | 2.5 | 5.0 | 8.2 | 8.2 | 9.6 |

Note: In 0 to 4 scales Poor = 1, Medium = 2, Good = 3, very Good = 4. Source: Filed observation, 2011

Table AC1.6: Crop richness

<table>
<thead>
<tr>
<th>Study Areas</th>
<th>Number of Crop Grown</th>
<th>Richness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shyamnagar</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Kaliganj</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Kalaroa</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Dumuria</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Bhola Sadar</td>
<td>17</td>
<td>17</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011. Note: Poor = 1, Medium = 2, Good = 3, Very Good = 4

Table AC1.7: Farmer opinion on overall environmental condition

<table>
<thead>
<tr>
<th>Study Areas</th>
<th>Biodiversity Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Qualitative Ranking</td>
</tr>
<tr>
<td>Shyamnagar</td>
<td>Poor</td>
</tr>
<tr>
<td>Kaliganj</td>
<td>Poor to Medium</td>
</tr>
<tr>
<td>Kalaroa</td>
<td>Medium to Good</td>
</tr>
<tr>
<td>Dumuria</td>
<td>Good</td>
</tr>
<tr>
<td>Bhola Sadar</td>
<td>Good</td>
</tr>
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</table>

Source: FGD, 2011. Note: Poor = 1, Medium = 2, Good = 3, Very Good = 4
Table AEQ1.1: Educational status of the respondent

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Illiterate (No schooling)</td>
<td>8</td>
</tr>
<tr>
<td>Primary schooling</td>
<td>11</td>
</tr>
<tr>
<td>Secondary schooling</td>
<td>19</td>
</tr>
<tr>
<td>Tertiary schooling</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>45</td>
</tr>
<tr>
<td>Score</td>
<td>8.56</td>
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</tbody>
</table>

Source: Questionnaire survey, 2011.

Table AEQ1.2: Educational status of respondents’ male children

<table>
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<tr>
<th>Indicators</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illiterate</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Primary schooling</td>
<td>13</td>
<td>16</td>
<td>18</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Secondary schooling</td>
<td>8</td>
<td>9</td>
<td>18</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Tertiary schooling</td>
<td>5</td>
<td>11</td>
<td>20</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
<td>37</td>
<td>60</td>
<td>18</td>
<td>33</td>
</tr>
<tr>
<td>Score</td>
<td>10.00</td>
<td>9.49</td>
<td>11.20</td>
<td>13.10</td>
<td>7.45</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011.

Table AEQ1.3: Educational status of respondent’s female children

<table>
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<tr>
<th>Indicators</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N.</td>
<td>S.</td>
<td>T.S</td>
<td>N.</td>
<td>S.</td>
</tr>
<tr>
<td>Illiterate</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Primary schooling</td>
<td>13</td>
<td>0.5</td>
<td>6.5</td>
<td>16</td>
<td>0.5</td>
</tr>
<tr>
<td>Secondary schooling</td>
<td>8</td>
<td>1</td>
<td>8</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Tertiary schooling</td>
<td>5</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
<td>24.5</td>
<td>37</td>
<td>39</td>
<td>60</td>
</tr>
<tr>
<td>Score</td>
<td>24.5/27*10=9.07</td>
<td>39/37*10=10.54</td>
<td>67/60*10=11.17</td>
<td>22.5/18*10=12.50</td>
<td>21/33*10=6.36</td>
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</table>

Source: Questionnaire survey, 2011. N=Number, S=Score, T.S=Total Score

Table AEQ1.4: Education status scoring system

<table>
<thead>
<tr>
<th>Education Status</th>
<th>Score</th>
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<tbody>
<tr>
<td>Iliterate (no schooling)</td>
<td>0</td>
</tr>
<tr>
<td>Primary schooling</td>
<td>0.5</td>
</tr>
<tr>
<td>Secondary schooling</td>
<td>1</td>
</tr>
<tr>
<td>Tertiary education</td>
<td>2</td>
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</tbody>
</table>

Source: vanloon et al., 2005
Table AEQ1.5: Average income of the agro-ecosystem (in US$)

<table>
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<tr>
<th>Indicators</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total income from a ha agro ecosystem (in $)</td>
<td>311.148</td>
<td>1020.377</td>
<td>1585.81</td>
<td>1806.035</td>
<td>544.0181</td>
</tr>
<tr>
<td>Total income from agro ecosystem (in $)</td>
<td>29170.2</td>
<td>200432.7</td>
<td>80908.04</td>
<td>43832.48</td>
<td>26651.44</td>
</tr>
<tr>
<td><strong>Average income of agro ecosystem (in $)</strong></td>
<td>648.23</td>
<td>3340.545</td>
<td>1371.32</td>
<td>1992.38</td>
<td>1025.056</td>
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</table>


Table AEQ1.6: Farm assets value

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm Assets Value (in Tk)</td>
<td>38992</td>
<td>93992</td>
<td>52799</td>
<td>84822</td>
<td>32007</td>
</tr>
<tr>
<td>Farm Assets Value (in $)</td>
<td>519.89</td>
<td>1253.23</td>
<td>703.99</td>
<td>1130.99</td>
<td>426.76</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

Table AEQ1.7: Total wage of farm labours

<table>
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<tr>
<th>Indicators</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men labour (about 8 house)</td>
<td>150</td>
<td>150</td>
<td>160</td>
<td>170</td>
<td>120</td>
</tr>
<tr>
<td>Women labour (about 6 hours)</td>
<td>50</td>
<td>50</td>
<td>80</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Average wage</td>
<td>100</td>
<td>100</td>
<td>120</td>
<td>135</td>
<td>120</td>
</tr>
<tr>
<td>Gender-based wage Differentials</td>
<td>0.33</td>
<td>0.33</td>
<td>0.5</td>
<td>0.59</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

Table AEQ1.8: Percentage of people above extreme poor

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Percentage of people above extreme poor</strong></td>
<td>56.00</td>
<td>56.00</td>
<td>62.00</td>
<td>90.00</td>
<td>72.00</td>
</tr>
<tr>
<td><strong>Score</strong></td>
<td>5.60</td>
<td>5.60</td>
<td>6.20</td>
<td>9.00</td>
<td>7.20</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

Table AEQ1.9: Availability of staple food from own production

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of household produce own staple food</td>
<td>9</td>
<td>40</td>
<td>38</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Production of own staple food (% of people)</td>
<td>2.00</td>
<td>6.67</td>
<td>6.44</td>
<td>6.36</td>
<td>5.00</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011
### Table AEQ1.10: Nutrition intake status from staple food

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Amount of total food (in kg)</td>
<td>51498.4</td>
</tr>
<tr>
<td>Number of household</td>
<td>45</td>
</tr>
<tr>
<td>Consumed by each household (in kg)</td>
<td>1144.4</td>
</tr>
<tr>
<td>Number of family member in each household</td>
<td>6</td>
</tr>
<tr>
<td>Rice consumed by each family member (in kg)</td>
<td>190.73</td>
</tr>
<tr>
<td>Total calorie intake by each family member on average (considering rice)</td>
<td>1537.68</td>
</tr>
<tr>
<td>Score</td>
<td>5.49</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

### Table AEQ1.11: Settings of treatment

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Upazila hospital or clinic</td>
<td>130</td>
</tr>
<tr>
<td>Union health centre</td>
<td>32</td>
</tr>
<tr>
<td>Pharmacy</td>
<td>48</td>
</tr>
<tr>
<td>Village quack/doctor or kabiraz</td>
<td>43</td>
</tr>
<tr>
<td>Total</td>
<td>253</td>
</tr>
<tr>
<td>Score</td>
<td>3.51</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

### Table AEQ1.12: Cooking facilities

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Electricity</td>
<td>0</td>
</tr>
<tr>
<td>LPG</td>
<td>0</td>
</tr>
<tr>
<td>Kerosene</td>
<td>0</td>
</tr>
<tr>
<td>Fuel wood</td>
<td>210</td>
</tr>
<tr>
<td>Bio fuel in traditional woven</td>
<td>123</td>
</tr>
<tr>
<td>Total</td>
<td>333</td>
</tr>
<tr>
<td>Score</td>
<td>4.01</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011
### Table AEQ1.13: Toilet facilities

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Pucca</td>
<td>120</td>
</tr>
<tr>
<td>Semi pucca</td>
<td>208</td>
</tr>
<tr>
<td>Earthen</td>
<td>18</td>
</tr>
<tr>
<td>Open</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>346</td>
</tr>
<tr>
<td>Score</td>
<td>7.69</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

### Table AEQ1.14: Electricity connection

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Number of household connected by electricity</td>
<td>0</td>
</tr>
<tr>
<td>score</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

### Table AEQ1.15: Women participation in agricultural activities

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Percentage of women representative in local government</td>
<td>30</td>
</tr>
<tr>
<td>Score</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

### Table AEQ1.16: Percentage of women representative in local government

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>Percentage of women representative in local government</td>
<td>25</td>
</tr>
<tr>
<td>Score</td>
<td>1.67</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011

### Table AEQ1.17: Access to electronic media

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shyamnagar</td>
</tr>
<tr>
<td>No. of household have access to Electronic media (TV, Radio, Mobile etc.)</td>
<td>35</td>
</tr>
<tr>
<td>Score</td>
<td>7.78</td>
</tr>
</tbody>
</table>

Source: Questionnaire survey, 2011
Appendix - Questionnaire

Question No: Date:

GPS information:

Questionnaire on
Sustainability of changing agricultural systems in the coastal region of Bangladesh

Part-1: General information

1.1 Code:

1.2 Age: 

1.3 Address:
Village: Union: Upazila: District:

1.4 Sex: Female ☐ Male ☐

1.5 Marital status: Unmarried ☐ Married ☐ Widow ☐ Widower ☐

1.6 Educational level of the respondent:

<table>
<thead>
<tr>
<th>Education Level</th>
<th>Please Tick</th>
</tr>
</thead>
<tbody>
<tr>
<td>General education</td>
<td></td>
</tr>
<tr>
<td>Can write name</td>
<td></td>
</tr>
<tr>
<td>Can read and write</td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td></td>
</tr>
<tr>
<td>Secondary</td>
<td></td>
</tr>
<tr>
<td>Diploma</td>
<td></td>
</tr>
<tr>
<td>SSC</td>
<td></td>
</tr>
<tr>
<td>HSC</td>
<td></td>
</tr>
<tr>
<td>Bachelor</td>
<td></td>
</tr>
<tr>
<td>Honours</td>
<td></td>
</tr>
<tr>
<td>Masters</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
<tr>
<td>Madrasa Education</td>
<td></td>
</tr>
<tr>
<td>Can write name</td>
<td></td>
</tr>
<tr>
<td>Can write and read</td>
<td></td>
</tr>
<tr>
<td>Elementary</td>
<td></td>
</tr>
<tr>
<td>Alim (12th Grade)</td>
<td></td>
</tr>
<tr>
<td>Fazil (14th grade)</td>
<td></td>
</tr>
<tr>
<td>Kamil (16th Grade)</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
</tbody>
</table>
1.7 Number of family member: 

1.8 Structure of the family: Joint Family [ ] Single family [ ]

1.9 Age of the children:

<table>
<thead>
<tr>
<th>Childre n No. and sex</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td>M</td>
<td>F</td>
<td>M</td>
<td>F</td>
<td>M</td>
<td>F</td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>Age (in years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: M=male, F=female*

1.10 Educational status of the children:

<table>
<thead>
<tr>
<th>Childre n No. &amp; sex</th>
<th>Education Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>General Education</td>
</tr>
<tr>
<td>No.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: CWN=Can Write Name; CR&W=Can Read and Write; P=Primary; S=Secondary; D=Diploma; B=Bachelor; H=Honours; M=Masters; O=Others; E=Elementary; A=Alim; F=Fazil; and K=Kamil*
1.11 Occupation:

<table>
<thead>
<tr>
<th>Family member</th>
<th>Occupation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household head</td>
<td></td>
</tr>
<tr>
<td>Wife</td>
<td></td>
</tr>
<tr>
<td>1st children</td>
<td></td>
</tr>
<tr>
<td>2nd children</td>
<td></td>
</tr>
<tr>
<td>3rd children</td>
<td></td>
</tr>
<tr>
<td>4th children</td>
<td></td>
</tr>
<tr>
<td>5th children</td>
<td></td>
</tr>
<tr>
<td>6th children</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
</tbody>
</table>

1.12 Usual food intake (by family member):

<table>
<thead>
<tr>
<th>Time</th>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td></td>
</tr>
<tr>
<td>Noon</td>
<td></td>
</tr>
<tr>
<td>Night</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
</tbody>
</table>

1.13 Information about disease among family members:

<table>
<thead>
<tr>
<th>Name of the disease (in last one year)</th>
<th>Effected person’s age</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
</tr>
<tr>
<td>Diarrhoea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stomach pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholera</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lose motion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decentre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hookworm infection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ring worm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Itching</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allergic reaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influenza</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fever</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malaria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typhoid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dengue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High blood pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low blood pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuberculosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jaundice (Hepatitis)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenicosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anaemia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead poisoning</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Malnutrition
Polio
Scabies
Blindness
Cataract
Drossiness
Other diseases (agro chemical related disease)

1.14 Sources of drinking, household use and irrigation water:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the Sources</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Household</td>
</tr>
<tr>
<td></td>
<td>Tube well</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deep tube well</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Open well</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shallow well</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protected well</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hand pump/paddle pump</td>
<td></td>
</tr>
<tr>
<td></td>
<td>River</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pond</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wetlands</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rain water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td></td>
</tr>
</tbody>
</table>

1.15 Land area of homestead (in local unit): [ ]

1.16 Area of agriculture land (in local unit): [ ]

1.17 Number of Ghare: [ ]

1.18 Area of Ghare: [ ]

1.19 Number of pond: [ ]

1.20 Area of pond: [ ]

1.21 Total family income (in a year): [ ]

1.22 Assets:

---

1. Acre = 100 Decimals, 1 Bigha = 33 Decimals, 1 Kattha = 720 sq.ft., 1 Bigha = 20

Sustainability of Changing Agricultural Systems in the Coastal Zone of Bangladesh 167
1.23 Housing materials:

<table>
<thead>
<tr>
<th>No. of House</th>
<th>Wall</th>
<th>Roof</th>
<th>Structure</th>
<th>Floor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>T</td>
<td>M</td>
<td>P</td>
</tr>
</tbody>
</table>

*Note: B=bamboo, T=Tin, P= Plastic, M=Mud, O=Others*

1.24 What is the sharing mechanism of agriculture productions?

<table>
<thead>
<tr>
<th>Share</th>
<th>Amount of production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer share</td>
<td></td>
</tr>
<tr>
<td>Land Owner share</td>
<td></td>
</tr>
<tr>
<td>Other Information</td>
<td></td>
</tr>
</tbody>
</table>

4.16: Is there any migration among family members. If yes, who migrated and why and where? How long? What are the ages of the migrants?

**Part-2: Information of crop production**
### 2.1 Total amount of rice production in 2010 and 2011:

<table>
<thead>
<tr>
<th>Season</th>
<th>SI. No.</th>
<th>2010 Land area</th>
<th>Name of the Rice</th>
<th>Total Amount (in Mon)</th>
<th>Market value (in Tk.)</th>
<th>2011 Land area</th>
<th>Name of the Rice</th>
<th>Total Amount (in Mon)</th>
<th>Market value (in Tk.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kharif-1</td>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kharif-2</td>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.</td>
<td></td>
<td></td>
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Additional information:
### 2.2 Total amount of fish production in 2010 and 2011:

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</tbody>
</table>

Additional information: (How much fish can they catch from river, wetlands and sea? Type of caught fishes, catching cost and market value etc.)
2.3 Total amount of other crops production in 2010 and 2011:

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<th>Season</th>
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<th>Crops Name</th>
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<th>Market value (in Tk.)</th>
<th>Land area</th>
<th>Crops Name</th>
<th>Total Amount (in Mon)</th>
<th>Market value (in TK.)</th>
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Additional information:

2.4 Total amount of poultry production in 2010 and 2011:

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<th>Poultry</th>
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<td></td>
<td>Total number</td>
<td>Market value (in TK.)</td>
</tr>
<tr>
<td>Hen for meat</td>
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<tr>
<td>Hen for egg</td>
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<td>Duck for egg</td>
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<tr>
<td>Duck for meat</td>
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<td>Pigeons for meat</td>
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Additional information:

2.5 Total amount of cattle production in 2010 and 2011:

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<th>Cattle</th>
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<td>Meat</td>
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<td>Cow for milk/plough</td>
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<tr>
<td>Caw for meat/plough/cart</td>
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<tr>
<td>Goat/ Ram</td>
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### Additional information:

2.6 Total amount of vegetables production in 2010 and 2011:

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<th>Vegetables name</th>
<th>Total Amount (in Mon)</th>
<th>Market value (in TK.)</th>
<th>Land area</th>
<th>Vegetables name</th>
<th>Total Amount (in Mon)</th>
<th>Market value (in TK.)</th>
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### Additional information:

2.7 Total amount of homestead production in 2010 and 2011:

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<th>Total Amout/numb/er</th>
<th>Market value</th>
<th>Land area</th>
<th>crops/vegetable/fruits/vegetation Name</th>
<th>Total Amound/numb/er</th>
<th>Market value</th>
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**Additional information (Name of the trees in the homestead area):**
Part-3: Information related to crop production cost

3.1 Cost of seeds:

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<tbody>
<tr>
<td></td>
<td>Name of the seeds/seedlings</td>
<td>Total amount of seeds</td>
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<td>Kharif-1</td>
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<tr>
<td>Kharif-2</td>
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<td>Rabi</td>
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Additional information:
### 3.2 Cost of fertilizer:

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<tr>
<td></td>
<td>Name of the fertilizer</td>
<td>Total amount (in kg)</td>
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<tr>
<td></td>
<td>Commercial</td>
<td>Chemical</td>
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<td>Kharif-1</td>
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<tr>
<td>Kharif-2</td>
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</tr>
<tr>
<td>Rabi</td>
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</tbody>
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Additional information (Organic fertilizer):
### Cost of Pesticide

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<th>2011</th>
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<tbody>
<tr>
<td></td>
<td>Name of the insecticide</td>
<td>Total amount (in kg/litter)</td>
<td>Total Cost (in TK.)</td>
<td>Name of the insecticide</td>
<td>Total Amount (in kg/litter)</td>
</tr>
<tr>
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<td>Commercial</td>
<td>Chemical</td>
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#### Additional Information:
### 3.4 Cost of irrigation:

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<td>Total Cost (in TK.)</td>
<td>Total Amount (in litter)</td>
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<tr>
<td>Kharif 2</td>
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**Additional information:**
3.5 Cost of labour:

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</thead>
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<td></td>
<td>Name of the crops</td>
<td>Number of labour</td>
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Additional information:
3.6 Cost of electricity or diesel:

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<td>Total cost (in Tk.)</td>
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<td>Total diesel used</td>
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<td>Total Cost (in Tk.)</td>
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Additional information:

3.7 Transport cost of agriculture production (from field to home):

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Additional information:

3.8 Cost of agriculture equipments (for ploughing, irrigation, liquid insecticide spraying etc.):

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<td>Total Cost (in Tk.)</td>
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</tbody>
</table>
### 3.9 Cost related to fish/shrimp cultivation:

<table>
<thead>
<tr>
<th>Items</th>
<th>2010 Amount/number</th>
<th>Total Cost</th>
<th>2011 Amount/number</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ghare preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial name</td>
<td>Medicine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific name</td>
<td>Security</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish feed</td>
<td>Labour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport cost(source to market)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Additional information:**

**Note:**
- Cost data for 2010 and 2011 are not provided. Please provide the necessary data to complete the table.
### 3.10 Cost of shrimp fry:

<table>
<thead>
<tr>
<th>Source place</th>
<th>Type</th>
<th>Amount</th>
<th>Total Cost (in TK.)</th>
<th>Source place</th>
<th>Type</th>
<th>Amount</th>
<th>Total Cost (in TK.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Additional information (transport cost):

### 3.11 Cost related to cattle cultivation:

<table>
<thead>
<tr>
<th>Items</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount/number</td>
<td>Total Cost</td>
</tr>
<tr>
<td>Chemical use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial name</td>
<td>Scientific name</td>
<td></td>
</tr>
<tr>
<td>Medicine</td>
<td></td>
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<tr>
<td>Security</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle feed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle house</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional information:
3.12 Cost related to poultry cultivation:

<table>
<thead>
<tr>
<th>Items</th>
<th>2010</th>
<th></th>
<th>2011</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount/number</td>
<td>Total Cost (in TK.)</td>
<td>Amount/number</td>
<td>Total Cost (in TK.)</td>
</tr>
<tr>
<td>Chemical use</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Medicine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poultry feed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poultry house</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Security</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Additional information:**
3.13 Cost of horticulture:

<table>
<thead>
<tr>
<th>Name of the Horticulture</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Number</td>
<td>Total Cost (in TK.)</td>
</tr>
</tbody>
</table>

Additional information:

3.14 Locally produced manures

<table>
<thead>
<tr>
<th>Name of the Manure</th>
<th>Materials use</th>
<th>Amount of production</th>
<th>Production Cost</th>
<th>Market value</th>
<th>Production places</th>
</tr>
</thead>
</table>

Additional information:

3.15 Poultry and fish feed

<table>
<thead>
<tr>
<th>Name of the feed</th>
<th>Materials use</th>
<th>Amount of production</th>
<th>Production Cost</th>
<th>Market value</th>
<th>Production places</th>
</tr>
</thead>
</table>

Additional information:
Part-4: Other information

4.1 How many hours a woman work inside and outside (agriculture field/pond/ghare etc.) of home?

<table>
<thead>
<tr>
<th>At Home</th>
<th>Outside Home</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Field</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.2 What roles do women play in agricultural productions?

4.3 Do you produce your seeds? If yes, where do you produce? If no, from where do you buy your seeds?

4.4 What seeds are not available? How do you manage them?

4.5 How do you preserve your seeds? How do you preserve?
4.6 Do you have any access of common resources? If yes, where do you have access? What do you do there? Amount of production? Cost of collected goods? What is the market value of collected goods?

4.7 Where do you sale your products? Is the market of your product available?

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Name of the products</th>
<th>2010 Sale place/people</th>
<th>2011 Sale place/people</th>
<th>Availability of Market</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional information:
4.8 How do you preserve your agricultural products?  

4.9 Do you have any agriculture loan? If yes, from where did you get that loan and purpose of the loan?  

<table>
<thead>
<tr>
<th>Sources:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount:</td>
</tr>
<tr>
<td>Purpose:</td>
</tr>
</tbody>
</table>

4.10 Do you have any micro credit? If yes, from where did you get that credit? What are the purposes of taking credit?  

4.11 Do you involve with any NGOs activities? If yes, what are those?  

4.12 Are you a member of any NGOs. If yes, what is the name of the NGO?  

---  

2 Preservation of agricultural products (fish, seed, crops, vegetables etc.)
4.13 Do you take any suggestion from NGOs/block supervisor for agriculture activities?

4.14 Do you avail any kind of government support for agricultural activities? If yes what are those?

4.15 What is your source of recreation?  

4.16 Where do you go for your health care?  
1.7 What safety measures do you maintain or take in using fertilizer spreading pesticide?

4.18 What do you know about climate change impacts on agriculture?

---

3 Recreation Source: Recreation (TV, dish antenna, radio, cinema, local cultural programme, sports etc.)
4.19: Do you know about any awareness programme on adaptation of agriculture in climate change? If yes, what is that? Who organize that programme?
Figure 1.1: Administrative map of Shyamnagar Upazila
Figure 1.2: Google imagery of the Munshiganj area

Figure 1.3: Administrative map of Nalta village
Figure 1.4: Google imagery of the Nalta area

Figure 1.5: Administrative map of Jogikhali
Figure 1.6: Google imagery of the Jogikhali area

Figure 1.7: Administrative map of Dumuria
Figure 1.8: Google imagery of the Dumuria area
Figure 1.9: Administrative map of Bhola Sadar
Figure 1.10: Google imagery of the Kunja Patti village
Appendix-MCDA Results

Appendix- MCDA result of productivity

Value Tree
0 Productivity
   1 Rice 0.300
      2 Productivity 0.400
         3 Shyamnagar 0.106
         3 Kaliyaj 0.207
         3 Bholo Sadar 0.134
         3 Kalaroa 0.246
         3 Dumuria 0.306
   2 NetIncome Y. 0.600
      3 Shyamnagar 0.062
      3 Kaliyaj 0.148
      3 Bholo Sadar 0.078
      3 Kalaroa 0.267
      3 Dumuria 0.445
   1 Agro-Ecosystme 0.700
      2 Net Income 0.500
         3 Shyamnagar 0.059
         3 Kaliyaj 0.194
         3 Bholo Sadar 0.103
         3 Kalaroa 0.301
         3 Dumuria 0.343
      2 Protein Yield 0.250
         3 Shyamnagar 0.047
         3 Kaliyaj 0.101
         3 Bholo Sadar 0.219
         3 Kalaroa 0.378
         3 Dumuria 0.256
      2 Energy Yield 0.250
         3 Shyamnagar 0.027
         3 Kaliyaj 0.074
         3 Bholo Sadar 0.225
         3 Kalaroa 0.422
         3 Dumuria 0.253

Composite Priorities

<table>
<thead>
<tr>
<th></th>
<th>Shyamnagar</th>
<th>Kaliyaj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bholo Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>NetIncome</td>
<td>0.011</td>
<td>0.027</td>
<td>0.048</td>
<td>0.080</td>
<td>0.014</td>
</tr>
<tr>
<td>Net Income</td>
<td>0.021</td>
<td>0.068</td>
<td>0.105</td>
<td>0.120</td>
<td>0.036</td>
</tr>
<tr>
<td>Protein Yi</td>
<td>0.008</td>
<td>0.018</td>
<td>0.066</td>
<td>0.045</td>
<td>0.038</td>
</tr>
<tr>
<td>Energy Yie</td>
<td>0.005</td>
<td>0.013</td>
<td>0.074</td>
<td>0.044</td>
<td>0.039</td>
</tr>
<tr>
<td>Productiv</td>
<td>0.013</td>
<td>0.025</td>
<td>0.030</td>
<td>0.037</td>
<td>0.016</td>
</tr>
<tr>
<td>Overall</td>
<td>0.057</td>
<td>0.150</td>
<td>0.323</td>
<td>0.326</td>
<td>0.144</td>
</tr>
</tbody>
</table>
Appendix- MCDA result of stability

Value Tree

0 Stability
1 Land 0.200
2 L.T. 0.200
   5 Shyamanagr 0.195
   5 Kaliganj 0.195
   5 Kalaroa 0.219
   5 Dumuria 0.195
   5 Bhola Sadar 0.195
2 M.O.W 0.100
   5 Shyamanagr 0.250
   5 Kaliganj 0.125
   5 Kalaroa 0.250
   5 Dumuria 0.188
   5 Bhola Sadar 0.188
2 C.P.I 0.100
   5 Shyamanagr 0.100
   5 Kaliganj 0.100
   5 Kalaroa 0.300
   5 Dumuria 0.200
   5 Bhola Sadar 0.300
2 E.T.S.W. 0.100
  5 Shyamanagr 0.100
  5 Kaliganj 0.100
  5 Kalaroa 0.300
  5 Dumuria 0.200
  5 Bhola Sadar 0.300

2 E.T.C 0.100
  5 Shyamanagr 0.125
  5 Kaliganj 0.250
  5 Kalaroa 0.250
  5 Dumuria 0.250
  5 Bhola Sadar 0.125

3 L.A.B.C 0.100
  5 Shyamanagr 0.111
  5 Kaliganj 0.111
  5 Kalaroa 0.333
  5 Dumuria 0.333
  5 Bhola Sadar 0.111

3 L.A.B.D 0.100
  5 Shyamanagr 0.143
  5 Kaliganj 0.143
  5 Kalaroa 0.190
  5 Dumuria 0.190
  5 Bhola Sadar 0.333

3 I.F. 0.100
  5 Shyamanagr 0.071
  5 Kaliganj 0.143
  5 Kalaroa 0.286
  5 Dumuria 0.214
  5 Bhola Sadar 0.286

3 R.B.E 0.100
  5 Shyamanagr 0.222
  5 Kaliganj 0.222
  5 Kalaroa 0.222
  5 Dumuria 0.222
  5 Bhola Sadar 0.111

1 Water 0.300

2 S.W. S. 0.600
  5 Shyamanagr 0.100
  5 Kaliganj 0.200
  5 Kalaroa 0.200
  5 Dumuria 0.200
  5 Bhola Sadar 0.300
2 G.W. S. 0.300
  5 Shyamanagr 0.083
  5 Kaliganj 0.167
  5 Kalaroa 0.167
  5 Dumuria 0.333
  5 Bhola Sadar 0.250

2 As C. 0.100
  5 Shyamanagr 0.167
  5 Kaliganj 0.167
  5 Kalaroa 0.167
  5 Dumuria 0.167
  5 Bhola Sadar 0.333

1 Others 0.100

2 W.U.S.W 0.250
  5 Shyamanagr 0.167
  5 Kaliganj 0.167
  5 Kalaroa 0.167
  5 Dumuria 0.167
  5 Bhola Sadar 0.333

2 D.O.R 0.250
  5 Shyamanagr 0.286
  5 Kaliganj 0.143
  5 Kalaroa 0.143
  5 Dumuria 0.143
  5 Bhola Sadar 0.286

2 T.S.C. 0.400
  5 Shyamanagr 0.167
  5 Kaliganj 0.250
  5 Kalaroa 0.250
  5 Dumuria 0.250
  5 Bhola Sadar 0.083

2 S.O.E 0.100
  5 Shyamanagr 0.125
  5 Kaliganj 0.250
  5 Kalaroa 0.125
  5 Dumuria 0.250
  5 Bhola Sadar 0.250

1 Soil 0.400

2 O.M. 0.200
  5 Shyamanagr 0.267
  5 Kaliganj 0.267
  5 Kalaroa 0.133
  5 Dumuria 0.200
  5 Bhola Sadar 0.133
2 S.T 0.100
  5 Shyamanagr 0.105
  5 Kaliganj 0.211
  5 Kalaroa 0.211
  5 Dumuria 0.211
  5 Bhola Sadar 0.263
2 C.P 0.200
3 pH 0.200
  5 Shyamanagr 0.071
  5 Kaliganj 0.214
  5 Kalaroa 0.286
  5 Dumuria 0.143
  5 Bhola Sadar 0.286
3 M.Nutrient 0.800
4 Micro 0.700
  5 Shyamanagr 0.255
  5 Kaliganj 0.204
  5 Kalaroa 0.163
  5 Dumuria 0.173
  5 Bhola Sadar 0.204
4 Macro 0.300
  5 Shyamanagr 0.213
  5 Kaliganj 0.185
  5 Kalaroa 0.185
  5 Dumuria 0.194
  5 Bhola Sadar 0.222
2 Soil Salinity 0.500
  5 Shyamanagr 0.048
  5 Kaliganj 0.238
  5 Kalaroa 0.286
  5 Dumuria 0.143
  5 Bhola Sadar 0.286

Composite Priorities

<table>
<thead>
<tr>
<th></th>
<th>Shyamanagr</th>
<th>Kaliganj</th>
<th>Kalaroa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>0.052</td>
<td>0.094</td>
<td>0.092</td>
<td>0.067</td>
<td>0.096</td>
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<tr>
<td>Water</td>
<td>0.030</td>
<td>0.056</td>
<td>0.056</td>
<td>0.071</td>
<td>0.086</td>
</tr>
<tr>
<td>Land</td>
<td>0.030</td>
<td>0.032</td>
<td>0.051</td>
<td>0.044</td>
<td>0.043</td>
</tr>
<tr>
<td>Others</td>
<td>0.019</td>
<td>0.020</td>
<td>0.019</td>
<td>0.020</td>
<td>0.021</td>
</tr>
<tr>
<td>Overall</td>
<td>0.132</td>
<td>0.201</td>
<td>0.218</td>
<td>0.202</td>
<td>0.247</td>
</tr>
</tbody>
</table>
Appendix- MCDA result of efficiency

Value Tree
0 Efficiency
  1 Rice 0.300
    2 Efficie. ($/ha) 0.700
      3 Shyamnagar 0.060
      3 kalaroa 0.242
      3 Kaliganj 0.125
      3 Dumuria 0.509
      3 Bhola Sadar 0.064
  2 O.E.E-Rice 0.300
    3 Shyamnagar 0.162
    3 kalaroa 0.180
    3 Kaliganj 0.161
    3 Dumuria 0.305
    3 Bhola Sadar 0.192
  1 Agroecosystem 0.700
    2 N.R.P.E.E-AgEco 0.600
      3 Shyamnagar 0.088
      3 kalaroa 0.246
      3 Kaliganj 0.104
      3 Dumuria 0.285
      3 Bhola Sadar 0.276
2. O.E.E-AgEco 0.200
3. Shyamnagar 0.068
3. kalara 0.276
3. Kaliganj 0.100
3. Dumuria 0.276
3. Bhola Sadar 0.279
2. $Output:$Input 0.200
3. Shyamnagar 0.098
3. kalara 0.179
3. Kaliganj 0.145
3. Dumuria 0.430
3. Bhola Sadar 0.148

**Composite Priorities**

<table>
<thead>
<tr>
<th></th>
<th>Shyamnagar</th>
<th>Kaliganj</th>
<th>kalara</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Output:$I</td>
<td>0.014</td>
<td>0.020</td>
<td>0.025</td>
<td>0.060</td>
<td>0.021</td>
</tr>
<tr>
<td>Efficiency</td>
<td>0.013</td>
<td>0.026</td>
<td>0.051</td>
<td>0.107</td>
<td>0.013</td>
</tr>
<tr>
<td>O.E.E-Rice</td>
<td>0.015</td>
<td>0.014</td>
<td>0.016</td>
<td>0.027</td>
<td>0.017</td>
</tr>
<tr>
<td>N.R.P.E.E-</td>
<td>0.037</td>
<td>0.044</td>
<td>0.103</td>
<td>0.120</td>
<td>0.116</td>
</tr>
<tr>
<td>O.E.E-AgEc</td>
<td>0.010</td>
<td>0.014</td>
<td>0.039</td>
<td>0.039</td>
<td>0.039</td>
</tr>
<tr>
<td>Overall</td>
<td>0.087</td>
<td>0.119</td>
<td>0.234</td>
<td>0.353</td>
<td>0.206</td>
</tr>
</tbody>
</table>
Appendix- MCDA result of durability

Value Tree

0 Durability
1 Pest Stress 0.100
  3 Shyamnagar 0.080
  3 Kaliganj 0.188
  3 Kalaroa 0.191
  3 Dumuria 0.246
  3 Bhola Sadar 0.295
1 Water availability 0.100
  2 W.A.T.S. 0.500
    3 Shyamnagar 0.357
    3 Kaliganj 0.357
    3 Kalaroa 0.095
    3 Dumuria 0.095
    3 Bhola Sadar 0.095
  2 W.A.F.S. 0.500
    3 Shyamnagar 0.357
    3 Kaliganj 0.357
    3 Kalaroa 0.095
    3 Dumuria 0.095
    3 Bhola Sadar 0.095
1 Seed 0.100
  2 S.P. 0.500
    3 Shyamnagar 0.176
    3 Kaliganj 0.203
    3 Kalaroa 0.220
    3 Dumuria 0.224
    3 Bhola Sadar 0.176
  2 A.S. 0.500
    3 Shyamnagar 0.196
    3 Kaliganj 0.199
    3 Kalaroa 0.210
    3 Dumuria 0.210
    3 Bhola Sadar 0.186
1 Economics 0.500
  2 P.P. 0.250
    3 Shyamnagar 0.320
    3 Kaliganj 0.190
    3 Kalaroa 0.174
    3 Dumuria 0.173
    3 Bhola Sadar 0.144
<table>
<thead>
<tr>
<th>Location</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shyamnagar</td>
<td>0.221</td>
</tr>
<tr>
<td>Kaliganj</td>
<td>0.202</td>
</tr>
<tr>
<td>Kalaroa</td>
<td>0.187</td>
</tr>
<tr>
<td>Dumuria</td>
<td>0.221</td>
</tr>
<tr>
<td>Bhola Sadar</td>
<td>0.170</td>
</tr>
<tr>
<td>Shyamnagar</td>
<td>0.223</td>
</tr>
<tr>
<td>Kaliganj</td>
<td>0.155</td>
</tr>
<tr>
<td>Kalaroa</td>
<td>0.212</td>
</tr>
<tr>
<td>Dumuria</td>
<td>0.163</td>
</tr>
<tr>
<td>Bhola Sadar</td>
<td>0.248</td>
</tr>
<tr>
<td>Shyamnagar</td>
<td>0.191</td>
</tr>
<tr>
<td>Kaliganj</td>
<td>0.191</td>
</tr>
<tr>
<td>Kalaroa</td>
<td>0.238</td>
</tr>
<tr>
<td>Dumuria</td>
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<tr>
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Composite Priorities

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<th>Kalaroa</th>
<th>Dumuria</th>
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Appendix- MCDA result of compatibility

Value Tree
0 Compatibility
  1 Human 0.500
  2 I.F.D.W. 0.500
  3 Shyamnagar 0.000
  3 Kaliganj 0.222
  3 Kalaroa 0.250
  3 Dumuria 0.278
  3 Bhola Sadar 0.250
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<tr>
<th>Category</th>
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<th>Kaliganj</th>
<th>Kalraoa</th>
<th>Dumuria</th>
<th>Bhola Sadar</th>
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<td>A.C.I.D.W.</td>
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<td>0.115</td>
<td>0.385</td>
<td>0.000</td>
<td>0.385</td>
</tr>
<tr>
<td>P.W.S.</td>
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<td>0.222</td>
<td>0.222</td>
<td>0.222</td>
<td>0.222</td>
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<tr>
<td>Shyamanagr</td>
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<td>0.115</td>
<td>0.385</td>
<td>0.000</td>
<td>0.385</td>
</tr>
<tr>
<td>Kaliganj</td>
<td>0.111</td>
<td>0.222</td>
<td>0.222</td>
<td>0.222</td>
<td>0.222</td>
</tr>
<tr>
<td>Kalaroa</td>
<td>0.222</td>
<td>0.222</td>
<td>0.222</td>
<td>0.222</td>
<td>0.222</td>
</tr>
<tr>
<td>Dumarra</td>
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<td>0.222</td>
<td>0.222</td>
<td>0.222</td>
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<tr>
<td>Bhola Sadar</td>
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<td>0.385</td>
<td>0.385</td>
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1. Bio. Surroundings 0.500
2. O.B.I 0.300
3. P.N.C.A. 0.200
4. Bio. Surroundings 0.500
5. O.B.I 0.300
6. P.N.C.A. 0.200
7. Bio. Surroundings 0.500
8. O.B.I 0.300
9. P.N.C.A. 0.200
10. Bio. Surroundings 0.500
11. O.B.I 0.300
12. P.N.C.A. 0.200
13. Bio. Surroundings 0.500
14. O.B.I 0.300
15. P.N.C.A. 0.200
## Appendix - MCDA result of equity

Value Tree

0 Equity
1 Education 0.200
2 E.S.O.F 0.200
   4 Shyamanagr 0.228
   4 Kaliganj 0.246
   4 Kalaroa 0.127
   4 Dumuria 0.266
   4 Bhola Sadar 0.133
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<tr>
<td>3</td>
<td>A.I.F.A.E 0.500</td>
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<tr>
<td>4</td>
<td>Shyamanagr 0.077</td>
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<td>4</td>
<td>Kaliganj 0.399</td>
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<tr>
<td>4</td>
<td>Kalaroa 0.164</td>
</tr>
<tr>
<td>4</td>
<td>Dumuria 0.238</td>
</tr>
<tr>
<td>4</td>
<td>Bhola Sadar 0.122</td>
</tr>
<tr>
<td>3</td>
<td>A.F.A.V 0.250</td>
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<tr>
<td>4</td>
<td>Shyamanagr 0.129</td>
</tr>
<tr>
<td>4</td>
<td>Kaliganj 0.311</td>
</tr>
<tr>
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<td>Kalaroa 0.175</td>
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<td>Dumuria 0.280</td>
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<td>4</td>
<td>Bhola Sadar 0.106</td>
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<tr>
<td>3</td>
<td>P.O.P.A.E.P 0.250</td>
</tr>
<tr>
<td>4</td>
<td>Shyamanagr 0.167</td>
</tr>
<tr>
<td>4</td>
<td>Kaliganj 0.167</td>
</tr>
<tr>
<td>4</td>
<td>Kalaroa 0.185</td>
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<tr>
<td>4</td>
<td>Dumuria 0.268</td>
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<td>4</td>
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<tr>
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<td>A.W.O.F.L. 0.600</td>
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<tr>
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<td>Kaliganj 0.174</td>
</tr>
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<td>4</td>
<td>Kalaroa 0.209</td>
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<td>4</td>
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<td>4</td>
<td>Bhola Sadar 0.209</td>
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<tr>
<td>Kaliganj</td>
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<td>Dumuria</td>
<td>0.195</td>
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<tr>
<td>Bhola Sadar</td>
<td>0.209</td>
</tr>
<tr>
<td><strong>Total</strong></td>
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1 Gender issue 0.200
2 W.P.I.A.A. 0.500
4 Shyamanag 0.143
4 Kaliganj 0.190
4 Kalaroa 0.238
4 Dumuria 0.310
4 Bhola Sadar 0.119
2 G.B.G.D 0.500
4 Shyamanag 0.200
4 Kaliganj 0.200
4 Kalaroa 0.200
4 Dumuria 0.200
4 Bhola Sadar 0.200

Composite Priorities

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<th>Kalaroa</th>
<th>Dumuria</th>
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Appendix - MCDA result of sustainability

Value Tree
1 Sus. Ag. 0.000
2 Productivity 0.300
  3 Shyamnagar 0.057
  3 Kaligonj 0.150
  3 Kalaroa 0.323
  3 Dumuria 0.326
  3 Bhola Sadar 0.144
2 Stability 0.200
  3 Shyamnagar 0.132
  3 Kaligonj 0.201
  3 Kalaroa 0.218
  3 Dumuria 0.202
  3 Bhola Sadar 0.247
2 Efficiency 0.150
  3 Shyamnagar 0.087
  3 Kaligonj 0.119
  3 Kalaroa 0.234
  3 Dumuria 0.353
  3 Bhola Sadar 0.206
2 Durability 0.100
  3 Shyamnagar 0.222
  3 Kaligonj 0.217
  3 Kalaroa 0.182
  3 Dumuria 0.214
  3 Bhola Sadar 0.166
2 Compatibility 0.100
  3 Shyamnagar 0.070
  3 Kaligonj 0.163
  3 Kalaroa 0.279
  3 Dumuria 0.219
  3 Bhola Sadar 0.270
2 Equity 0.150
  3 Shyamnagar 0.155
  3 Kaligonj 0.225
  3 Kalaroa 0.215
  3 Dumuria 0.258
  3 Bhola Sadar 0.147
## Composite Priorities

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<th>Kalaroa</th>
<th>Dumuria</th>
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*Composite Priorities*