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LAND USE FUNCTIONS ASSESSMENT FOR SUSTAINABLE LAND MANAGEMENT: A CASE STUDY IN BARIND TRACT OF BANGLADESH

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Abstract

Assessment of land use functions (LUFs) is increasingly recognized as a useful tool for evaluating sustainable land management. A study was designed to investigate the key indicators that act as main stimuli in changing agricultural land use and associated land use functions in Godagari under Barind Tract of Bangladesh. The capacity of seven land use types providing different LUFs was also evaluated. A participatory rural appraisal method was used to assess the LUFs, which includes four phases, i.e. literature review and site selection survey; LUFs specification; a ranking of priorities and weighting of LUFs; and visualization and discussion of the results. Primary information was collected from the different stakeholder's viz. agricultural officers, university teachers, irrigation specialists, public representatives, forest personnel and researchers. Three farming systems i.e. rainfed, irrigated and irrigated with tree-based farming were selected to assess the nine land use functions under three dimensions of social, economical and environmental category. Among the farming systems, fruit tree–based system provided most of the social, economic and environmental LUFs compared to irrigated and rainfed farming systems. However, environmental problem/dimension was more critical than the social and economic problems/dimension and associated with depletion of soil fertility, installation of brick kiln, the uncertainty of rainfall, flood, drought, overuse of groundwater. Among land use types, agricultural land use showed a higher overall capacity per unit area on LUFs than that of other land use categories. Participatory assessment methods of LUFs helped the different stakeholders, particularly the regional officers as well as policymakers to understand the significant linkages between LUFs and land uses for sustainable land management.

Keywords: Irrigated, rainfed, socioeconomic, environment, participatory assessment, stakeholders.

Introduction

Land use in Bangladesh has significantly changed during the last six decades due to economic development, climate change, and technological intervention in agriculture with increased food demand, but unfortunately causing serious environmental problems (Rahman, 2010). The country epitomizes the most sensitive hotspot for the catastrophic events of climate variability and change (Rahman *et al*., 2016). The multiplicity of the streams, the dominance of floodplains, almost flat topography, low elevation from sea level, monsoon climate, and melting Himalayan glaciers from the north make Bangladesh highly vulnerable to natural hazards (Rahman *et al*., 2017a). However, the northwestern region is predominantly very sensitive due to

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specific geo-climate and phylogeny activities. Frequent drought in the region causes greater yield loss of many crops during the pre-kaharif transitional period (World Bank, 2013). The differential gradients of drought affect around 4.5 million ha of land and 53% of the population in Bangladesh (MoA, 2013; Alauddin and Sarkar, 2014). Most of the climatic perils occur due to oscillations of climate variability, predominantly for rising temperature particularly during the monsoon season and arbitrary rainfall pattern (GOB and UNDP, 2009). It has been anticipated that the average day temperature of Bangladesh will be increased to about 1.0°C by 2030, 1.4°C by 2050 and 2.4°C by 2100 (Sarker *et al*., 2012). Interestingly, the annual rainfall intensity remains almost unchanged and there is a trend of increasing the number of days without rain. This situation may exacerbate the drought intensity in future (Amin *et al*., 2015). Thus, such changes in climate variables have already forced the people of the northwestern region of Bangladesh towards changes in agricultural land use systems.

A healthy land use system has structural integrity including functional continuity and additivity, which reflects the system's nature, behavior, and the relationships between the system and its external environment (Zhou *et al*., 2017). It is composed of economic, social and ecological sub-systems that generally perform production, living, and ecology functions (Bach *et al*., 2015; Verstegen *et al*., 2016). It is worth to mention that economic production is not the only function of land use that a piece of land can provide; the same piece of land also provides social, environmental, and ecological functions (Peng *et al*., 2017). Gradually, land use management has moved away from focusing on one single production function in consideration of multi-functional land use (Song *et al*., 2015; Zhang, 2015). Recently, more studies are paying close attention to "multi-functionality of land use or mixed land use" (Barnaud *et al*., 2013; Brown and Castellazzi, 2014; Peng *et al*., 2015; Song *et al*., 2015) that refers to functions providing products and services through different land use types (Zhang, 2015). This opened up a new research direction on sustainable land use.

Currently, Bangladesh accommodates more than 150 million people in an area of 148,394 km^2 and the projected population would be 250 million by 2050 that lead to decline per capita land from 0.07 ha to less than 0.04 ha (Khan, 2011). Moreover, agricultural land is converted to industry, brickfield and other unplanned non-agricultural uses at 0.73% annually during the last decade and the rate of conversion is continued at an alarming rate (Hasan *et al.,* 2013). Agricultural sector greatly supports the economy of Bangladesh providing employment opportunity of nearly half of the total population and contributes 18% of the gross domestic product (GDP) (Abdullah and Rahman, 2015). Unfortunately, the highly unfavorable man land ration and extremely high population density, gradually increasing land degradation, unplanned or misuse of land both in rural and urban areas could not be able to support the agro-based economy of Bangladesh in near future. With the increasing demand for agricultural produces the relevant land use changes are imperative. The agricultural production system and land use dynamics are very complex phenomena to understand. Land use change along with increasing cropping intensity and productivity may lead to deterioration of production environment and natural resources. To address the challenges of land use change, the researchers, policymakers and stockholders need adequate information on the driving forces of land use change and its consequences to formulate a sustainable land management strategy. A sustainable land management requires knowledge of goods and services provided by different land uses in terms of social, economic and ecological dimensions (Helming *et al*., 2011). The Land Use Functions (LUFs) framework designed by Perez-Soba *et al.* (2008) may help to include all three dimensions of sustainability into land use decisions. Therefore, the present study was aimed to identify the key indicators that act as a driving force towards changing in land use functions in terms of environmental, economic and social aspects of agricultural land use. Furthermore, capacity of different land use types to meet different land use functions was also evaluated as well as identify the existing scientific gaps for potential future research on sustainable land use.

Materials and Methods

Description of the study area

The study site was located in Godagari upazila under the Rajshahi district, which is situated at the northwestern region of Bangladesh (Fig. 1). The total area of Godagari Upazila is about 47552 ha of which 4218 ha (8.87%) are under rural settlement and vegetation. About 40-50% of homestead areas of Godagari are covered with vegetation (Fig. 1). A vast area (3%) is occupied by char land where insolvent farmers are settled and survive through subsistence production systems (Fig. 1). The area, a good representation of Barind Tract, is developed over Madhupur clay, comparatively higher elevation than the adjoining floodplain areas with reddish and yellowish clay soils, mostly dry and low moisture holding capacity. The temperature of the study area fluctuated between 8°C to 44°C and rainfall between 1500 mm to 2000 mm; although the monsoon season (June to October) covers 80% of the total rainfall of the area, whereas other seasons cover only the rest of 20% rainfall, which makes it different from the climatic condition of the rest of the country (Hasan and Mahmudul Islam, 2018). The region is designated as drought-prone zone and adversely affects the cultivation of crops. Rice is the major crop in the area, although other crops like wheat, maize, mustard, onion, garlic, vegetables etc. also are grown well. About 54% of the area is under double cropped and that of 34% triple cropped having cropping intensity of 225% (Fig. 1). Despite the multiplicity of cropping system such as “triple-crop” model food production increases remarkably. A large area is occupied by mango gardens where many kinds of delicious, juicy and fleshy mangos are grown. Mango farming is the most dynamic agro-based, labor-intensive and profit-oriented enterprises. Field crops and mango collectively yields a bumper output as well as turned the area into a productive zone of the country.

Assessment of land use functions (LUFs)

Participatory rural appraisal (PRA) method was used to assess LUFs. Two stakeholder workshops were conducted with the aim to judge the LUFs in three prominent farming systems of the study area (Table 1). The research has been conducted in four phases: literature review and preliminary site-

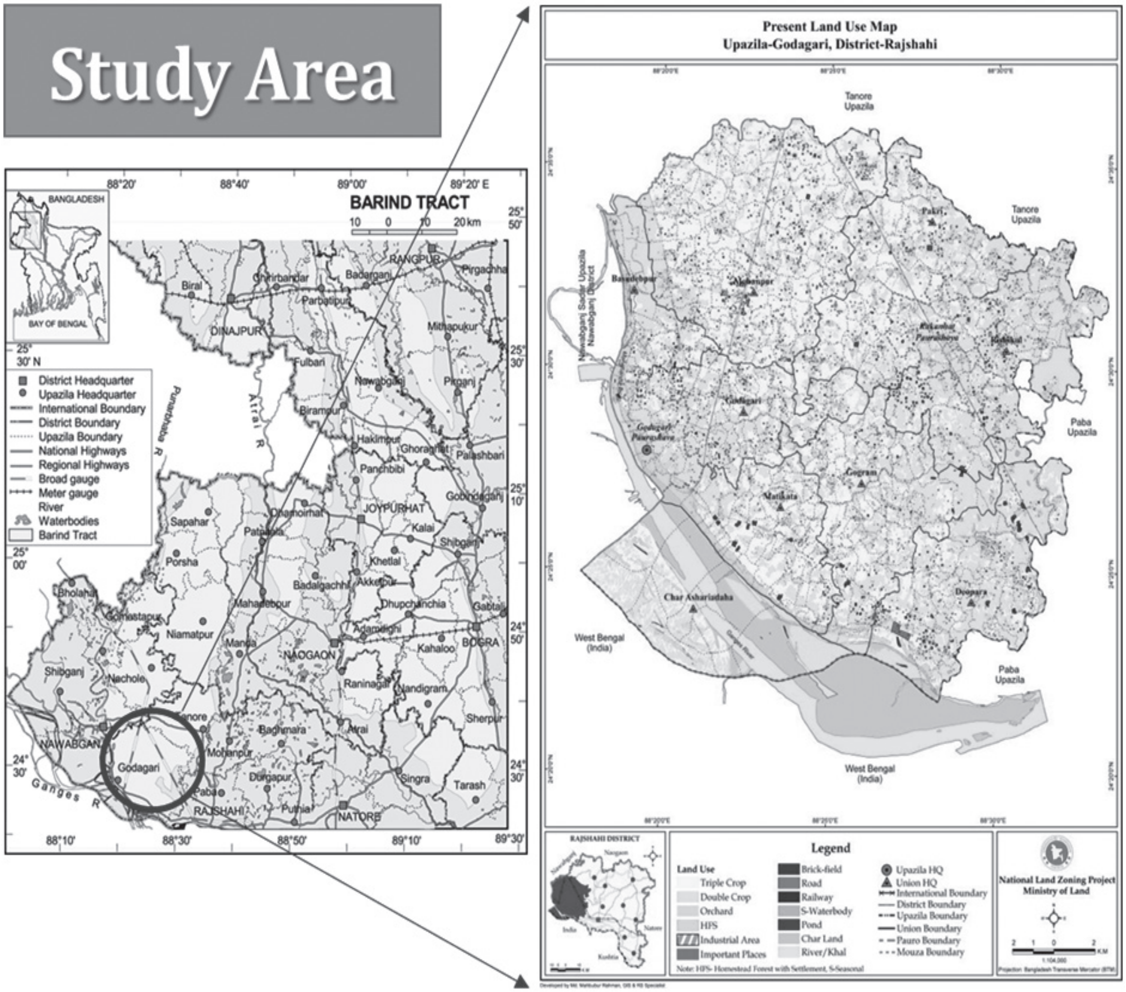

Fig. 1. Location of Godagari upazila and associated land use-land cover change map.
Source: National land zoning report: Godagari upazila, 2016

Table 1. Scenario development of three prominent farming systems

Study site	Scenario	Description
Godagari upazila, Rajshahi District (Barind tract)	BAU (Business as usual)	Rainfed agriculture (single crop)
	Irrigated farming	Crop intensity increased to 125% via enhanced irrigation facilities e.g. rice-rice/others
	Irrigated and/or rainfed including tree based farming	Crop intensity + agroforestry: crop intensity e.g. rice-legume crops/trees via enhanced rainfed or irrigation facilities for diversified production and improved soil health and maintained groundwater table

selection survey; specification of the LUF context; ranking of priorities and weighting of LUFs; and visualization and discussion of the results according to the methodology of Xue and Zhen (2018). Necessary precaution has been taken during participatory rural appraisal workshop to get the ground-truth information

Specification of the LUF context

Based on literature review and preliminary surveys, the assessment indicators were identified for the LUFs (Table 2). Two stakeholder workshops were conducted with the help of the extension personnel of the Department of Agricultural Extension (DAE) and Barind Multipurpose Development Authority (BMDA) in Godagari upazila of Rajshahi district. Involvement of many people in the workshops made the discussion too complex, therefore, 14 participants from different stakeholders including five agricultural officers, two university teachers, one irrigation specialist, two public representatives, two forest personnel and two personnel from research organizations (BRRI and ICRAF) were present in the workshops. The aim of this phase was to obtain information on the main issues affecting LUFs in Godagari upazila. Workshop procedure was followed according to the methods of Chao and Lin (2017).

Ranking of priorities and weighting of LUFs

A preference-based weighting process was performed to know the perceived importance of LUFs, in which the participants assigned a priority to each LUFs, using a scoring scheme from 0 (least important) to 5 (most important). The same priority had the opportunity to assign more than one functions. After the scoring, mean rankings were calculated and it was presented to the participants. After a moderate discussion, the participants improved their understanding of the importance of each LUFs. Thereafter, second scoring was done and modified their rankings. To explore the capacity of each land use type on LUFs, participants were asked to score each land use type (agricultural land, mango/litchi garden, water bodies, homestead vegetation, char land/sand, fallow/chance crop, build up) from 0 (least capacity) to 100 (most capacity). Then the results were presented to the participants. After a moderate discussion, the participants were given another chance to adjust their choices for the final weighting. In the third part of the workshop, the stakeholders assessed the impact of each of the three scenarios on the identified LUFs. A scoring scale from -3 to +3 was used to assess negative or positive impacts, respectively, with the following scores: 0 = no impact; -1 and +1 moderate impact; -2 and +2 high impact; and -3 and +3 extremely high impact. To make it informative, one of the research teams highlighted the contrasting positive and negative scenario impact scores given by individual participants. This step was important to make the participants reveal their arguments for the different scorings. All arguments were recorded by the research team through open discussion and then a second scoring round was completed.

Evaluation and/or visualization

At this stage, the final results of the LUFs assessment were evaluated according to the following formula of Chao and Lin (2017).

Table 2. LUFs and corresponding assessment indicators

Dimensions	Land use functions	Explain	Assessment indicator
Social	SOC1. Provision of work	Employment opportunities for economic activities based on natural resources.	Agricultural employment rate (%)
	SOC2. Quality of life	A 'good' living standard of rural people mainly interlink with income facilities	Market access for buying food
	SOC3. Food security	Access to and availability of sufficient quantity and quality of food.	Per capita food availability from own farm
Economical	ECO1. Land based production	Provision of land for economic production from land including agricultural and forest products.	Income from production
	ECO2. Artificial or non-land based production	Mainly refer to those land where production related secondary activities takes place	Product processing facilities
	ECO3. Infrastructure or transport	Mainly focus on rural transportation as means to connect rural regions with outer regions.	Road density and quality
Environmental	ENV1. Provision of abiotic resources	The role of land in regulating the supply and quality of soil and water	Soil fertility status Groundwater availability Soil moisture
	ENV2. Provision of biotic resources	Provision of habitat and biodiversity and factors affecting the capacity of the land to support regional biodiversity.	Fertilizer and agrochemicals uses Wetland ecosystem
	ENV3. Maintenance of ecosystem processes	The role of land in the regulation of ecosystem processes related to the production of food, biodiversity conservation, soil health and ecological supporting functions	Brickfield installation Expansion of settlement, infrastructure and industries Nutrient cycling

SOC*=social, ECO*= economic, ENV*= environmental

$$wi_d = \sum_{f=1}^{n} w_{f,d} * i_{f,d}$$

Where,

wi = weighted impact,

w = weights assigned to each land use function,

i = average impacts on each land use function,

d = sustainability dimension (economic, social, ecological),

f = land use function (n = 9).

Results and Discussion

Priorities of LUFs by the participants

It is recognized that the social and economic land use functions (LUFs) are considered as most important in the past land use system compared to present time, while environmental land use functions perceived higher preference at present (Fig. 2).

Social function priorities

In view of social function priorities, SOC1 was considered as moderately important (3.38) because of having opportunities of the peoples to work in rice mills, handy crafts, cottage industries, bamboo and cane industries, and poultry farms. On the other hand, higher income from the diversified sources acts as a key driving force for the scoring of SOC2 (3.05). At present, despite considerable progress in food grain production in the area, immense pressure of growing population has been made SOC3 higher importance (3.47).

Economic function priorities

Based on the preliminary survey and workshops, land-based production (ECO1) was considered as the most important economic LUFs, which is also in agreement with the result of Gutzler *et al.* (2015). This was followed by infrastructure and transport

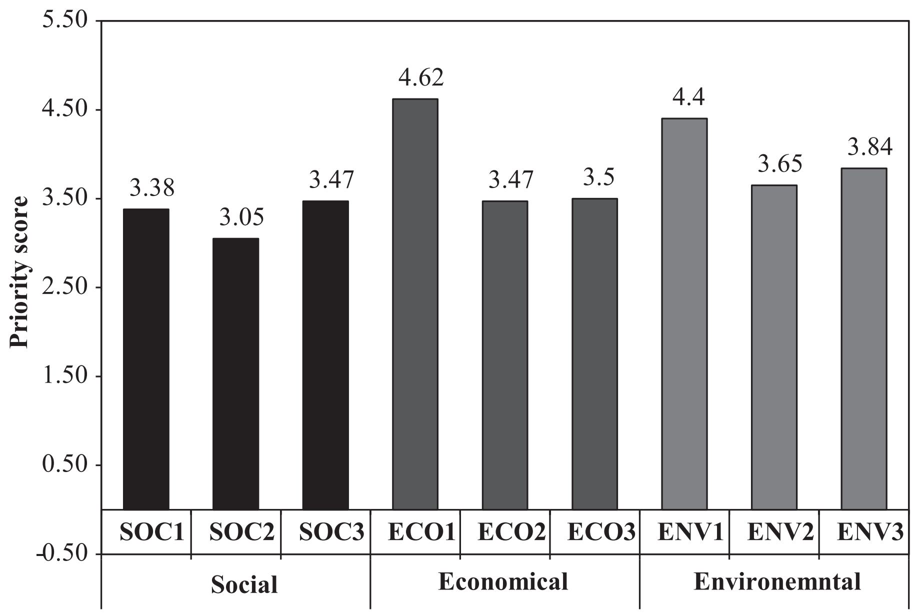

Fig. 2. The priorities of LUFs assigned by policy makers at present.

(ECO3) and artificial or non-land based production (ECO2). Most of the people in the study area were dependent on modern agriculture. As a result, they got higher output and believed that the cereals crops obtained from their field had higher importance (4.62) for their daily consumption and income generation. Agricultural production is satisfactory in the study area and can be exported to other parts of the country even abroad. The production is closely linked to good communication systems and the score of 3.50 on ECO3 seems rational. The diversified production from the agricultural field needs to well process- and the establishment of various agro-processing centers, food industries, fruit industries, etc. are imperative, thus, the moderate priority (3.47) given by the participants on ECO3 LUF is justifiable.

Environmental function priorities

Based on the opinions of participants, provision of abiotic resources (ENV1), provision of biotic resources (ENV2), and maintenance of ecosystem processes (ENV3) received higher priorities at present. In respect of ENV1, water was considered as a basic input for producing cereals and many other crops, particularly during the Rabi (dry) season. The sharp increase of irrigated area supports the notion of this agreement. Over-extraction of groundwater due to the expansion of irrigated area led to rapid depletion of groundwater level at present (Dey *et al.,* 2017). Therefore, the higher priority (4.40) given by the participants for the present land use system regarding ENV1 seems reasonable. Regarding ENV2, though the vegetation of the study area has increased in the present time, old aged trees are being cleared off because of the unplanned expansion of human settlements, brickfields, roads and infrastructures, and changes of land use pattern etc. Cutting of trees for timbers and firewood are the major factors for declining the forest resources (Rahman *et al.,* 2017b). Moreover, overuses of agrochemicals terminated the aquatic habitats. All of these factors had influenced participants to give a high importance (3.65) in respect of ENV2. Correspondingly, participants gave the second most important priorities (3.84) to ENV3. Application of fertilizer and agrochemicals have increased agricultural production and it has been reported that 25% of the total applied agrochemicals are being runoff and mixed into soil and water bodies of the study area, and are responsible for declining the aquatic biodiversity including land fertility (Saha and Zaman, 2013). On the other hand, hot summer with erratic rainfall and the aridity of the study area had forced the farmers to depend on irrigated agriculture that leads to over-extraction of groundwater. Though groundwater irrigation is having immense importance on agricultural production, it would lead to meteorological and hydrological droughts in the surrounding environment in the near future (Abdullah and Rahman, 2015). Based on all issues, the priority given by the participants on ENV3 seemed plausible at present.

Comparative analysis of land use categories on the capacity of LUFs

The LUF weighted results showed that agricultural land had the highest overall capacity (525.9) per unit area on LUFs (Table 3). Participants strongly believed that agricultural land significantly contributes towards food security, employment opportunities, and

Table 3. Weights assigned to the LUFs for different land use types

Dimensions	Land use functions	Weightage to land use types						
		Agricultural land	Fruit tree based system	Water bodies	Homestead vegetation	Char land	Fallow/ Chance crop	Build up
Social	Provision of work	98.5	44.5	5.5	16.5	25.6	11.5	63.6
	Quality of life and human health	86.5	31.8	3.5	57.6	7.8	1	32.4
	Food security	98.5	19.2	15.6	42.5	18.4	2.4	39.8
Economic/ Production	Land based production	97.5	30.3	12.5	39.5	47.8	7.8	2.5
	Artificial or non-land based production	17.5	51.4	5.5	12.4	40.5	1.5	65.5
	Infrastructure or transport	22.5	8.5	4.5	3.5	35.2	2	84.2
Environmental	Provision of abiotic resources	43.5	55.8	67.8	74.6	75.8	19.5	6.5
	Provision of biotic resources	36.4	68.2	78.2	80	46.2	14.8	4.5
	Maintenance of ecosystem processes	25	93.6	85.4	88.6	52.5	3.5	1.5
	Total	525.9	403.3	278.5	415.2	349.8	64	300.5

quality of life. The second weigh was given on homestead vegetation (415.2). A major portion of locally grown indigenous fruits, fuelwood, bamboo, sawn timbers come from homestead vegetation, which used to satisfy the need of the people. Homestead vegetation is not only a production unit but also a good niche for the conservation of local biodiversity both at species and genetic level as observed Miah and Hussain, (2010). Therefore, the weight given by the participants seems conceivable. Fruit-based farming has given third importance by the participants (403.3). It is very important to upkeep the environmental functions such as ecosystem services, conserve biotic and abiotic resources besides having the contribution to non-land based production. Miah *et al.* (2017) reported that farmers used to receive year-round benefit from fruit-based farming and get employment opportunity from fruit processing industry. Therefore, the weightage assigned by the participants is realistic. The fourth weight was given to *Char land* (349.8) having immense potential of cultivating both Rabi and early Kharif crops including high-value crops. Moreover, the forest department had brought 100 ha char land plantations during 2010–2011 through community's participation. Thus, the LUF value given by the participants on *Char land* is also realistic.

Despite having an immense negative impact on environmental functions build up activities for instances, brickfields, agro-processing center, *chatal*, rice mill, cottage industry, government and non-government organizations had a significant contribution towards employment opportunities that ensured the quality of life and food security, therefore its weightage (300.5) is justifiable.

The waterbodies are highly associated with the environmental dimensions compared to social and economic for which the weight assigned by the participants on waterbodies (248.5) seems credible. Sultana *et al.* (2017) observed that overexploitation, crop intensification, siltation of rivers and canals have direct impacts on wetland habitat, loss of breeding grounds and other aquatic fauna and flora in the region. Around 1.74% of the total land area was kept fallow in the study area, which was very often used for some productive purposes. Thus, the lowest importance (64.0) is given for fallow or chance cropping land use type.

Assessing the social land use functions indicators

Scoring of social land use functions indicators as affected by three farming systems is illustrated in Fig. 3. Participants opined that fruit tree-based farming system received a higher benefit (1.48) compared to irrigated (1.24) and rainfed farming systems (1.10) if the percentage of the agricultural employer was higher. Predominantly, rich and educated farmers practiced year-round fruit farming system, which required an ample amount of labor for both fruit harvesting and processing including crop management compared to the other two systems. Therefore, if the agricultural employment percentage getting higher, labor became available, while urban employment creates the dearth of agricultural labor, therefore, the value assigned by the participants seems rational. Participants opined that fruit tree-based farming system had an ample opportunity (2.00) to provide diversified food items for instances cereals, vegetables, fruits, etc. therefore, had greater prospect to enhance per capita food availability compared to irrigated (1.76) and rainfed farming systems (1.52). Thus, the impact assigned by the participants looked credible. Fruit tree-based farming system had a great opportunity to enhance income and the farmers have relatively high opportunity (0.28) to access the market for their daily needs. While farmers practicing crop farming either rainfed or irrigated are having low income due to use of traditional varieties including the risk of crop failure that may limit to access the market by the farmers. Nevertheless, the rainfed farming system was severely hampered (-1.64) through the uses of the traditional farming system such as the ploughing, broadcasting, local varieties etc. followed by fruit tree based (-1.40) and irrigated farming systems (-0.72). This is because, in the irrigated farming system, water acts as a key driving force towards boosting crop yield either it is local or HYV. Whereas, rainfed agriculture depends entirely and/or partially on natural rainfall, and fruit tree-based farming system required good management practices, which might be hampered by traditional land use techniques and might have limit their production.

Assessing the economic/production land use functions indicators

Scoring of economic land use functions indicators as affected by three farming system has been shown in Fig. 3. Fruit tree-based farming system was presumed to have the higher positive impacts (2.34) on annual average income from production due to the scope of growing diversified crops including fruits trees. This farming system gave higher value for having exporting potential of fruits and income generation compared to that obtained from irrigated (1.74) and rainfed farming systems (1.30). Establishment of several fruit industries and good transportation facilities played a promising role in exporting agricultural commodity and the socio-economic improvement of the area, which persuaded the participants to give higher positive impact on fruit farming system (2.25 and 2.36) regarding processing center as well as road density and quality as compared to irrigated (2.20 and 1.84) and rainfed land use systems (1.14 and 1.22), respectively.

Assessing the environmental land use functions indicators

Scoring of environmental land use functions indicators as affected by three farming systems is presented in Fig. 3. Participants opined that fruit tree-based farming system had a moderate positive impact (1.24) on soil fertility indicator followed by the irrigated farming system (0.74), while the rainfed system had a negative impact (-0.94) on it. Continual foliage addition from the fruit tree-based system added organic matter to the topsoil, which may have enhanced the microbial activity of the soil and, therefore, might improve the soil fertility status as observed by Miah *et al.* (2017). The irrigated farming system had an extreme negative impact (-2.74) on groundwater indicator as

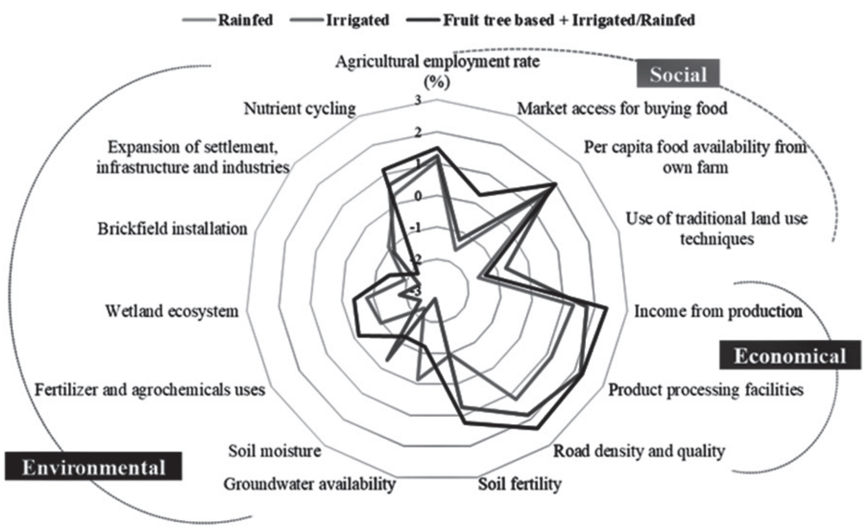

Fig. 3. Indicators for scoring of social, economic and environmental land use functions as affected by three farming system.

compared to other two farming systems due to over-extraction of groundwater and lack of opportunity to groundwater replenishment. In contrast, participants opined that irrigated farming system had lower negative impact on soil moisture (-0.32) indicator due to the scope of applying irrigation water. Whereas, higher negative impact regarding soil moisture (-2.32) was found in the rainfed farming system because of arbitrary rainfall pattern and moderate impact (-1.24) was found in the tree-based farming system due to the preservation of soil moisture by the foliage cover. The irrigated farming system has a high negative impact (-2.40) because of extensive application of agrochemicals in irrigated crop field to improve crop production as compared to rainfed (-0.97) and fruit tree-based farming systems (-0.16). Similarly, higher negative impact (-1.83) on wetland ecosystem indicator has been found in irrigated farming system followed by rainfed (-0.78) and fruit tree-based farming systems (-0.37). Runoff of applied agrochemicals in the irrigated farming system used to mix into the soil and water that caused environmental pollution, land fertility loss, water quality degradation, fish mortality, and loss of biodiversity (Sultana *et al.,* 2017). Thus, the impact consigned by the participants on irrigated farming regarding wetland ecosystem seems logical. The irrigated farming system was affected severely (-2.41) due to brickfield installation in the crop field as compared to rainfed (-1.92) and fruit tree-based farming systems (-1.44). Predominantly medium highland where people practiced irrigated farming were chosen for brickfield installation and bricks were made by collecting the fertile top-soil from a depth of about 1 to 2 m from the agricultural low land where farmers can grow two or three crops in a year. Moreover, "brick kiln black emission" hampers mango pollination process notably (Saha and Hosain, 2017). Participants opined that fruit tree-based farming system was affected negatively (-2.20) due to infrastructure development as compared to irrigated (-1.20) and rainfed farming (-0.95). People usually prefer high land near the roadside for construction work, where most of the fruit-based farming systems were developed. In contrast, the fruit-based farming system had a higher positive contribution (1.15) on nutrient cycling compared to irrigated (0.65) and rainfed farming systems (0.30). Fruit tree-based farming system offers a close and efficient nutrient cycling system. Plants take up nutrients from the soil and use them for metabolic processes. In turn, plants return nutrients to the soil either naturally as litterfall or deliberately as pruning or through root senescence. These plant parts are decomposed by soil microorganisms, releasing the nutrients bound in them into the soil. The nutrients then become available for plant uptake once again (Rahman *et al.,* 2018). Therefore, the impact given by the participants regarding nutrient cycling seems pragmatic.

Evaluation of three land use systems

The evaluation result of social functions (Wsoc) showed that rainfed farming system did not provide all LUFs properly (0.03), while irrigated framing system (5.65) and fruit tree (9.95) covered most of the LUFs (Table 4). Higher negative impact of limited access to the market for buying food, and use of traditional land used techniques were responsible for failure to provide LUFs properly by rainfed farming. Economic LUFs evaluation result (Weco) indicated that fruit-based farming system provided the higher economic LUFs (26.87) compared to irrigated (22.11) and rainfed farming systems (14.23). Higher positive impact of annual income due to diversified outputs including total yield, exporting opportunities were mostly responsible for this phenomena. As similar to the economic LUFs evaluation result, the fruit-based farming system also provided the higher environmental LUFs (Wenv) (-5.91) compared to irrigated (-14.91) and rainfed farming systems (-11.48). Fruit tree-based farming systems had a moderate higher impact on soil fertility by adding leaf litter, which might have accelerated close and efficient nutrient cycling system and, thereby, augmented soil fertility status. Moreover, litterfall also creates forest floor over the soil surface that helps to conserve soil moisture (Rahman *et al.,* 2018). All of these functions of fruit tree-based farming systems might be responsible for providing more environmental LUFs compared to irrigated and rainfed farming systems.

Conclusion

Participatory rural appraisal method was followed to assess the value of LUFs in Godagari upazila of Rajshahi district. The policymakers and/or experts noticed that environmental LUTs perceived higher preference at present due to over-exploitation of natural resources for producing more food for growing population. Weighting results of LUFs implied that agricultural land use gained the highest overall capacity per unit area on LUFs in comparison to other land use categories. Nevertheless, impact assessment of three land use systems on LUFs was in the order of fruit tree based-farming>irrigated

Table 4. Impact assessment of three land use scenarios on social, economical and environmental land use functions

Scenario	Social LUFs								Economic LUFs						Environmental LUFs						Weighted aggregation			
	SOC1		SOC2		SOC3		SOC4		ECO1		ECO2		ECO3		ENV1		ENV2		ENV3		Wsoc	Weco	Wenv	wi
	w	i	w	i	w	i	w	i	w	i	w	i	w	i	w	i	w	i	w	i				
Rainfed		1.1		-1.6		1.52		-1.64		1.3		1.14		1.22		-1.1367		-0.875		-0.8567	0.0344	14.2318	-11.485	2.7815
Irrigated		1.24		-1.26		1.76		-0.72		1.74		2.2		1.84		-0.7733		-2.115		-0.9867	5.6594	22.1128	-14.911	12.861
	3.38		3.05		4.38		3.33		4.62		3.47		3.5		4.4		3.65		3.84					
Irrigated/Non-Irrigated+Tree		1.48		0.28		2		-1.4		2.34		2.25		2.36		-0.4		-0.265		-0.83	9.9544	26.8783	-5.9145	30.918

farming>rainfed farming, which confers that fruit tree-based farming system had less impact on the environment and diversified year-round income facility. Despite the LUFs assessment method is based on qualitative knowledge and information; it is able to expose the key drivers that are interlinked to the land use and LUFs in economic, social, and environmental dimensions. The results indicate a new era for the improvement of future land use decisions at both local and national levels.

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