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Impact assessment of land use functions on the sustainable regional development of representative Asian countries – A comparative study in Bangladesh, China and Japan

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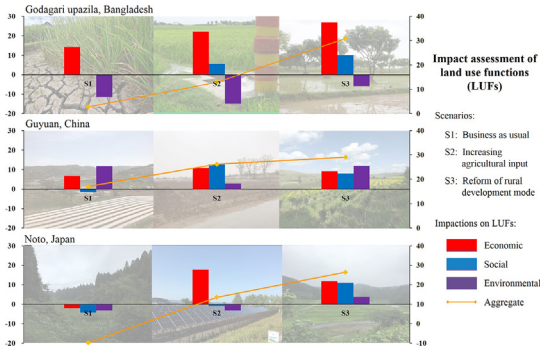
HIGHLIGHTS

- Multilevel stakeholders are involved in the entire process of assessing regional land use functions (LUFs)
- Farmers exhibited a decreasing dependence on land, although for different reasons
- LUFs in the environmental dimension are highly respected, although due to opposing factors
- The differences in land management needed for remote rural areas with different gradients are revealed

GRAPHICAL ABSTRACT



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ABSTRACT

Sustainable land use is a fundamental research field for land use planning. However, regional policymakers often lack access to the theoretical impacts that a land use policy might have on local development, especially in remote agricultural areas. Furthermore, knowledge exchange is important, especially in the context of globalization. This research employed the Framework of Participatory Impact Assessment and household surveys to combine multilevel stakeholders and comprehensively assessed the impacts of different land management scenarios on land use functions (LUFs) and local sustainable development. We completed this comparative study in typical remote agricultural areas in Godagari upazila of Bangladesh, Guyuan of China and Noto of Japan, which all have gradient differences in terms of their economic and social aspects, natural conditions and main land use issues. The selected scenarios were business as usual, increase in agricultural input and reform of rural development mode. The main conclusions are as follows: (1) the farmers at the three study sites all showed a decreasing dependence on their land and a relevant level of stress on environmental LUFs, but the rooted reasons were different and even opposing; (2) scenarios with a high aggregate impact on LUFs might not enable a sustainable development model, and the assessment of land management measures should consider the balance among environmental, economic and social dimensions; and (3) land use and management practices should be conducted with consideration of local conditions, and protecting agricultural development and enacting appropriate agricultural

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reforms could revitalize local agricultural development. The results revealed the demand for location-specific land management practices and underlined the knowledge of agricultural management on an international scale.

1. Introduction

Ecosystems have witnessed rapid and extensive changes over recent decades, and these changes have occurred to meet the growing demand for food and natural resources (Chiabai et al., 2018; Millennium Ecosystem Assessment, 2005). This scenario had affected approximately 61% of different degrees of land degradation around the world in 2011 and threatens sustainable land management at the local, regional and global levels (FAO, 2011; Orr et al., 2017). To promote prosperity while protecting the planet, the United Nations launched 17 sustainable development goals (SDGs) as part of a call for global action (United Nations, 2017b; United Nations Development Programme, 2015). Seven of the SDGs concern sustainable land development, and nearly all of the SDGs benefit from sustainability. However, it is inevitable that the future food demand will continue to increase by at least 50% by 2050 in response to the increasing population, growing levels of per capita consumption and shifts to animal-based diets (Godfray et al., 2010). Asia encompasses more than half of the world's population and has experienced rapid economic development in the last several decades (Lin et al., 2014). Thus, the governments must deal with more severe conflicts between economic and environmental development (Du et al., 2014; Feng et al., 2005; Zhen et al., 2010) and between land use and sustainability issues (Global Land Project, 2005; Sheng et al., 2019; Verburg et al., 2013). Finding a balance between the management of regional land use changes and economic development—while still ensuring regional sustainability—is currently a key issue for policymakers and the scientific community (Global Land Project, 2005; Lacher et al., 2019; Taelman et al., 2016).

The focus of studies on sustainable land use revolves around models that are built to project our understanding of sustainable land systems (Helming et al., 2008), place-based land use analysis (Banadda, 2010) and future land management scenario analysis (Seppelt et al., 2018). However, two issues are often raised during regional sustainable land use studies. The first issue is that regional sustainable development should represent the set of values identified by members of the community; however, the roles of residents and the local government have largely been ignored (Iyer-Raniga and Treloar, 2000), while regional policy makers often lack access to the theoretical or rational impact assessment results of how a land use policy affects local development; thus, land management measures are insufficiently adjusted. This issue seems more severe in remote agricultural areas. For example, in Guyuan of China, this problem remains, as land management measures should be readjusted according to different local conditions (Xue and Zhen, 2018). A comprehensive land use scenario analysis in Asia, especially in remote rural areas, is crucial to help decision-makers identify the potential impacts of different policy options and to better understand the contexts and processes (IPBES, 2016; Saito et al., 2018). Another issue is that previous researchers have drawn attention to the specific land use problems in particular areas, which hampers the perspectives of local development. Knowledge plays a key role in agricultural and rural development (Prager et al., 2016), especially in the context of globalization (Mauerhofer, 2016; Wang et al., 2016). Comparative research regarding sustainable land use policies based on special regional development stages and categorized natural conditions is urgently needed. The development of countries occurs simultaneously with a trend of depopulation, according to the population prospect (United Nations, 2017a), and Asian population growth is estimated to decline around 2050. The depopulation trend started in Japan in 2010 (United Nations, 2017a). Depending on the assumptions related to the plausible future trend in demographic variables, a depopulation trend appears around 2030 in China and 2050 in Bangladesh (United Nations, 2017a). Population changes and economic growth cause rapid land changes, and a thorough understanding of sustainable land use in different development stages appears to be a new critical concern. Bangladesh, China, and Japan have gradient differences in terms of their economic, social and natural conditions. The research practice of conducting land use policy scenario assessment and comparing representative study sites in these three countries could serve as a reference for land management strategy development in similar areas. The framework of land use functions (LUFs) was developed by an interdisciplinary team under the Sixth Framework Programme for Research launched by the European Commission to stress the need for evaluating the impact of land use changes on regional sustainability in a way that reflects the multiple dimensions inherent to the concept (Pérez-Soba et al., 2008). This approach has been widely used to assess regional sustainable development in developed and developing contexts around the world (König, 2013; Zhen et al., 2009). LUFs refer to the goods and services provided by different land uses and summarize the most relevant regional economic, environmental, and societal issues (Pérez-Soba et al., 2008; Zhen et al., 2009). The concept has currently been extended to support solution-oriented research and policy development (Peng et al., 2015; Wei, 2010), and therefore, this approach links land use and regional sustainable development.

The Framework for Participatory Impact Assessment (FoPIA) is a sustainability impact assessment method that focuses on the sustainability of land use management, strategies, and policies. The approach employs LUF criteria and contains indicators in economic, social, and environmental dimensions (Schindler et al., 2015). The FoPIA was conducted by researchers to obtain both qualitative knowledge (provided by stakeholders) and quantitative information (obtained by researchers or governments). The results from the FoPIA are meant to be used by policy makers and farmers (Schindler et al., 2015; Xue and Zhen, 2018). The assessment method has been well applied in Europe (Morris et al., 2011) and in some developing countries (König, 2013; König et al., 2013), including China (Dou et al., 2019; König et al., 2015), at local, regional and national levels. To ensure a successful sustainability assessment, the FoPIA encourages the participation of transdisciplinary experts to ensure that a rational and scientific assessment is provided (König et al., 2014).

This research employed the FoPIA and householder questionnaire surveys to include experts, government officers and farmers as multilevel stakeholders to assess the impacts of different land use policy scenarios on regional LUFs in typical remote agricultural areas in China, Japan, and Bangladesh. The specific objectives include the following: (1) Identify the key LUFs and associated assessment indicators using a participatory approach. (2) Compare the similarities and differences in LUFs at the three study sites and explore the drivers behind each of them. (3) Assess and compare the impacts of different land use scenarios on LUFs and regional sustainable development. It is expected that the findings of this study will provide a reference to local farmers, policy makers, and scientific communities for sustainable land use and management.

2. Materials and methods

2.1. Study area

The study areas are remote agricultural areas, including Godagari upazila within Barind tract in Bangladesh, Guyuan within Ninxia Hui Ningxia Hui Autonomous Region in China and Noto within Ishikawa Peninsula in Japan (Fig. 1). From the perspective of common features,

first, all sites are located in remote and marginal rural areas of the country, far from the central and developed regions. Second, the major industry is agriculture, and the agricultural lands are mostly located in uplands or sloped lands with slopes >15°; additionally, the farming practices have been strongly affected by regional, national and international land use policies in these areas. From the perspective of distinct features, the sites have gradient differences in terms of their economic dimensions, social dimensions, natural conditions, and main land use problems (Table 1). For instance, from the aspect of the social dimension, the lowest amount of arable land per capita is 0.097 ha/person in Noto, and the highest value is in Guyuan, at 0.25 ha/person, which is 2.58 times greater than that of Noto; additionally, the arable land per capita in Godagari upazila in Bangladesh is approximately 0.10 ha/person, representing a moderate condition that is lower than that of Guyuan but higher than that of Noto. From the aspect of land use issues in the three study sites, we identified a number of characteristics during workshops with the participating stakeholders (in Section 2.2.2 FoPIA, (1) implementation of the FoPIA-the preparation phase) e.g., the three study sites have different degrees and emphases on land use issues. In Godagari upazila, food security is improving because productivity is increasing. However, in Guyuan, food security is approximately sufficient and balanced nutritional intake is a key consideration; additionally, agricultural land abandonment caused by the reduced labour force on farmland is an increasingly important challenge. In Noto, the residents have high food security requirements. The severe trend of missing successors in paddy fields directly leads to the abandonment of farmlands. Moreover, Noto has confronted the low self-sufficiency rate and the further loss of cultural inheritance. Young people do not participate in local activities, including agricultural land practices, and cultural events are currently the most threatening trend in relation to local land management. The detailed gradient difference distributions are shown in Table 1.

Guyuan of Ningxia Hui Autonomous Region, China is located in the Loess Plateau, where the soil condition is fragile and suffers from historically severe soil erosion. The annual precipitation is limited and non-uniformly distributed in the spatial and temporal fields, with the mean annual rainfall ranging from 431.4 ± 197.9 mm in 2005 to 463.9 ± 150.8 mm in 2015 (Guyuan Bureau of Statistics, 2016). As of 2015, the main land use types were cultivated lands (44.7% of the total land use) and grasslands (44.9%) (DCRES-CAS, http://www.resdc.cn/). Approximately 41.6% of the total area has a slope >15°. The major crops are winter wheat in rotation with summer maize and potatoes. These crops account for 48.0% of the total cultivated area. The agricultural population is 1.11 million, accounting for 74.4% of the total population. The disposable income of rural households (7002.1 CNY) was only 61.3% of the national average (11,422.0 CNY) in 2015 (Guyuan Bureau of Statistics, 2016) (1USD = 6.2284 CNY, as of 2015).

Godagari upazila is located in the Rajshahi district (Barind tract) of north-western Bangladesh. It lies on the northern bank of the Padma River, and the land is predominantly highlands (71%), followed by medium highlands (10%) and medium lowlands (5%). The rice-based cropping pattern is dominated in Barind soil, and crops typically suffer from drought in the dry season. Historically, a single rainfed *aman* rice crop was cultivated in the rainy season. With the rapid expansion of groundwater irrigation after the 1980s, rice varieties with a range of yields were introduced in this area during the dry season. Agricultural land with single cropped, double cropped and triple cropped areas in Godagari upazila accounted for 6.4%, 28.4% and 12.3% of the total

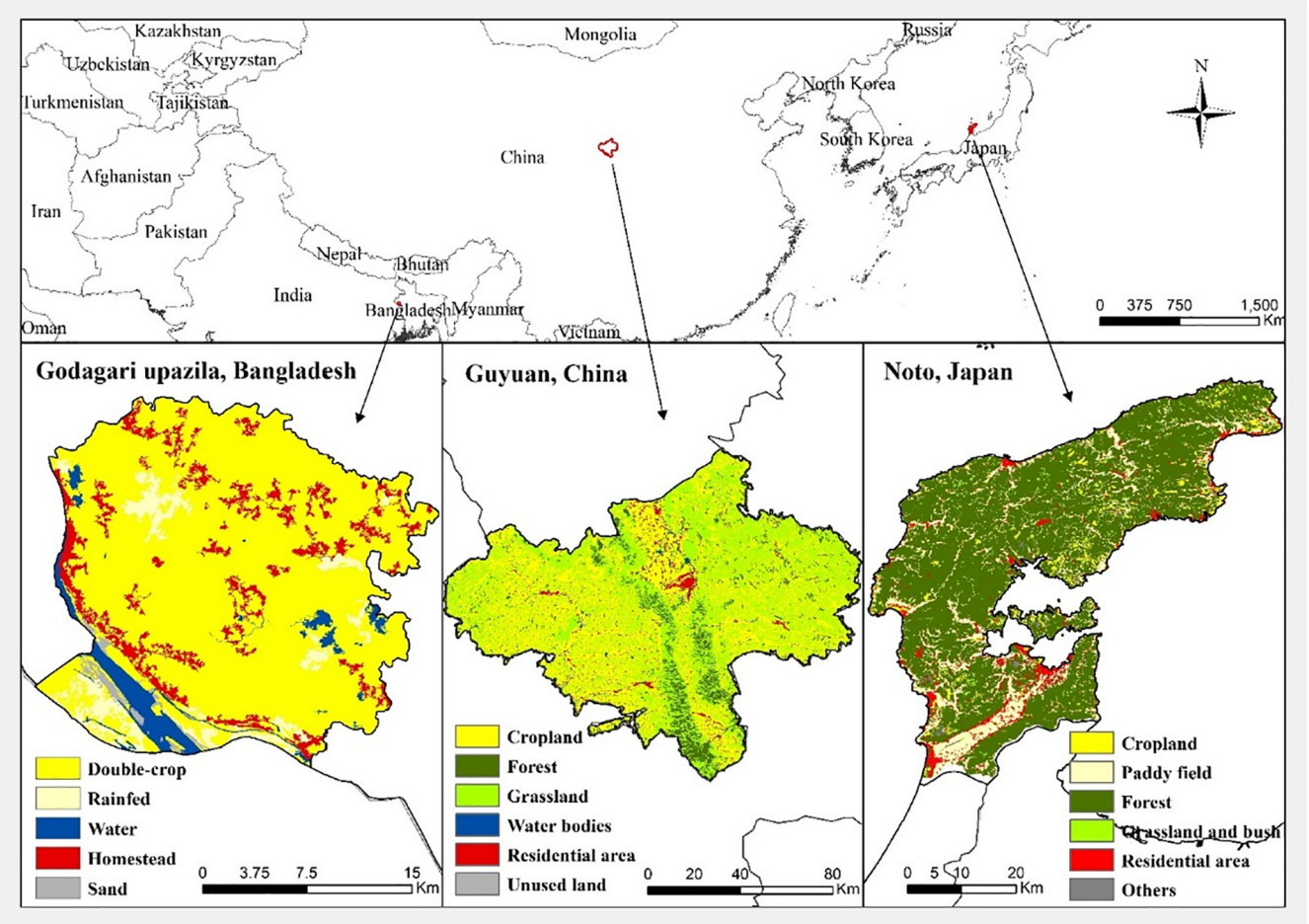

Fig. 1. Land use of the three study areas.

Table 1
Gradient difference of the study sites.

	Indicator	Godagari upazila, Bangladesh	Guyuan, China	Noto, Japan	Gradient difference
Common features	Landform	70.86% upland	41.64% with slope > 15°	49.60% with slope > 15°	–
Economic	Annual income of household farmer	$4773[a]	$5695[a]	$11,220[b]	↗
Social	Arable land per capita	0.10 ha[b]	0.25 ha[b]	0.097 ha[b]	↗↘
	Population trends	Increasing	Increasing	Decreasing	↘
Natural condition	Mean annual rainfall	1438 mm[c]	492 mm[b]	2100 mm[b]	↘↗
Land use problems[d]		• Food security	• Food security • Agricultural land abandonment	• Agricultural land abandonment • Low self-sufficiency rate	–

↗ increasing trend/↘ decreasing trend from Godagari upazila, Guyuan to Noto.
Exchange rate (as of 2018): 1 USD = 83.6351 BDT; 1 USD = 6.9065 CNY; 1 USD = 102,227 JPY.
[a] Based on the questionnaire.
[b] Based on the government agriculture statistics.
[c] Source: http://climate.barcapps.gov.bd/index.php?p=rainfall.
[d] Obtained from stakeholders participated workshop (FoPIA-preparation phase).

temporary cropped area, respectively (Bangladesh Bureau of Statistics (BBS), 2013). The daily average wage rate of agricultural labour in 2011 was 200 Taka for males (1 USD = 78.232 BDT, as of 2011), 160 Taka for females and 110 Taka for children (Bangladesh Bureau of Statistics (BBS), 2013).

Located in a peninsula of Ishikawa, Noto is an important socio-ecological landscape in Japan. The total area is 4185 km^2, with 1.15 million people and a mean annual rainfall of 2100 mm. According to remote sensing data, rice paddy fields and dry croplands account for 14% and 4% of the total area, respectively. The largest land use/cover types are forests (74%), including natural forests (3%), secondary forests (38%) and plantation forests (33%). Rice paddy terraces have been developed in steep fields for thousands of years, and other industries such as fisheries and primary industry-based tourism exist. In 2011, the northern part of the region was designated as a Globally Important Agricultural Heritage System (GIAHS) to enhance the sustainable agricultural activities.

2.2. Methods

2.2.1. Research group discussion

We conducted three discussions among the research team. The first one was at the beginning of our study, before the FoPIAs were implemented at the three sites, to build stable fundamentals for the success of FoPIA implementation at the three study sites. The second one was after the respective FoPIAs were implemented but before the field surveys were conducted, and the purpose of this discussion was to obtain a periodic summary and make any necessary adjustments. The last one was held after the field surveys at the three sites were conducted to complete the analyses of the results. The participants of the research group discussions included multifunction land use policy experts and regional sustainable development assessment experts from the three study sites, and each discussion contained four fixed experts. The experts attended all discussions during this research process, and there was also at least one consulting expert, which was dependent on the theme of the discussions. Detailed information about the experts is presented in Appendix I.

The first group discussion was held from November 3–5, 2016 in Beijing, China. Based on a thorough literature review beforehand, we drafted the land use problems and land use policies at the study sites and discussed them to determine the technical and administrative guidance necessary to facilitate integration. Rehearsals and trainings of the FoPIA processes, from its preparation to its operation, were also conducted. The second discussion was held from September 5–6, 2017 in Tokyo, Japan. We had an extensive and in-depth discussion focused on the LUFs, indicators, and scenarios at the three sites. A strict assessment was conducted to judge whether the FoPIA had been conducted correctly, and if not, a revised and updated FoPIA workshop would be needed. In addition to the issues raised and reflected regarding the FoPIA, a questionnaire survey was used to obtain a deeper understanding of the causes. Accordingly, the research group designed a field survey implementation plan. After the field survey, the last research group discussion was conducted from March 23–24, 2018 in Dhaka, Bangladesh. Researchers compared the scenario assessment results with the help of field survey data and provided policy recommendations.

2.2.2. FoPIA

(1) Implementation of the FoPIA

FoPIAs were conducted separately at the three study sites under the shared framework with three interrelated phases. First, we organized the preparation phase, which occurred at the first workshop, and gathered transdisciplinary experts to communicate regional land use problems, driving forces, and land management and policies (scenarios). Local LUFs were drafted and associated assessment indicators were obtained for the next phase. Second, we conducted the participatory evaluation phase, and evaluation workshops were held at each study site to accomplish four goals: a) determine the local land use scenarios, LUFs, and indicators; b) assess the weights of LUFs in terms of their importance for each respective study site; c) score the impacts of scenarios on each indicator with two-round paper-based assessments, in which researchers presented the average results of the first-round assessment and permitted the participating experts to revise or keep their assessment results in the second round on the basis of a face-to-face discussion of the first-round results. An additional round of assessments would be held to seek a consensus, and finally, the last goal was to d) provide further suggestions for researchers to complete an in-depth field survey, including the choice of a specific study site. Third, we analysed the results and refined recommendations based on the discussions during the preparation work and workshops.

The particular process and part of the results from Guyuan, China were published in 2018 by Xue and Zhen (Xue and Zhen, 2018) and Koenig et al. (König et al., 2014), and the detailed processes for Godagari, Bangladesh and Noto, Japan were similar. Table 2 shows the specific information of the FoPIAs for these three study sites.

(2) Stakeholders involved in FoPIA

The number of stakeholders who attended FoPIA workshops was designated to be manageable and effective, i.e., in the range of 10–15 stakeholders (Morris et al., 2011). The principles of the experts in the workshops were transdisciplinary and all were experienced in local land management, especially for the second workshop, in which the main definition and assessment work was completed. In Godagari upazila, Bangladesh, 7 of the 15 total stakeholders were government officers in charge of the relevant agricultural and forest department, while

Table 2
Implementation process of FoPIAs and field surveys.

Method			Godagari upazila, Bangladesh	Guyuan, China	Noto, Japan
FoPIA	Workshop I (preparation)		March 2017	September 2015	July 2017
	Workshop II (participatory evaluation)		May 2017	May 2017	July 2017
	Workshop II (revision)		–	–	Nov. 2017
	Stakeholders in (updated) workshop II (person)	Experts	6	5	5
		Government officers	9	5	2
		Farmer delegates	0	0	5
		Total	15	10	12
Field survey	Date		Oct. 2017-Feb. 2018	2–9 May 2017	Oct. 2017-Feb. 2018
	Sample size (household)		60	202	71

others were researchers or engineers engaging in crops, agroforestry or irrigation fields. In Guyuan, China, the first preparation workshop was conducted in September 2015 with ten policy makers (Wang and Zhen, 2017) who each had at least 8 years of local work experience. The second workshop was held in May 2017, with 5 policy makers and 5 researchers who were all experts on regional land use, and the local participants each had at least 9 years of work experience. In Noto, 12 stakeholders were engaged in the assessment process. Four of them were from the university and focused on agricultural and environmental research, while 6 were from government departments and local farm communities, and they were mainly in charge of policy making and agricultural management. Detailed information about the participants in each workshop can be found in Appendix II.

(3) Scenario development

According to the traditional development disciplines, the suitable scenario periods were independently chosen for the three study sites; the years 2030, 2025 and 2050 were used as the end points of the scenario prediction assessments for Godagiri upazila, Guyuan, and Noto, respectively.

Three types of scenarios were determined. The first one is the business as usual (BAU) scenario. Here, we put forth the hypothesis that there are no other new policies that could affect the local state of land use, and the problems and drivers that currently exist would continue. The second and third scenarios are both land management and policy scenarios. The second involves increasing the agricultural input (IAI). This scenario implies that the government should attempt to improve traditional local agriculture by increasing the investment in agriculture. For instance, the government should invest in agricultural infrastructure enhancement to defend and avoid land use issues. These initial and fundamental efforts are mostly based on financial input, e.g., farming subsidies and investments. The third scenario is the reform of the rural development mode (RRDM). Experts try to shift the perspective from enhancing current agricultural conditions to finding a new development method or building multifaceted agriculture to develop and improve local land management methods. These reforms are unprecedented and should already have successful cases. There is a need to evaluate their impacts on the sustainable development (i.e., LUFs) of this specific region. The specific hypotheses and definitions of each scenario for each study site are listed in Table 3.

(4) LUFs and associated assessment indicators

Following the three dimensions, the LUFs were defined in the FoPIAs (Table 4), and their associated assessment indicators were identified to evaluate the specific impacts under different scenarios. For example, in Guyuan, soil conservation was chosen as an indicator for the maintenance of ecosystem process functions in the environmental dimension because the most important environmental issue and the most fragile ecosystem process is soil erosion (Zheng et al., 2019; Chen et al., 2007; Shi and Shao, 2000). In principle, if the scenario improves regional soil conservation, it has a positive effect on the local maintenance of ecosystem process functions. Specific indicators for each study site can be found in Appendix III.

(5) Methods for scenario impact assessment

Table 3
Scenarios defined for the three study sites.

Scenario type		Godagari upazila, Bangladesh	Guyuan, China	Noto, Japan
Period		To 2030	To 2025	To 2050
Business as usual (BAU)	Name	Rainfed agriculture	Abandon, transfer and SLCP	Farmland abandonment
	Hypothesis	Rainfed agriculture as usual	30% farmland be abandoned and 20% be transferred	20% farmland abandoned
	Description	Single crop, production is mainly dependent on rainfall	Keep the trend of land abandonment, SLCP and the trial trend of rural land transfer	Continue the severe trend of farmland abandonment
Increasing agricultural input (IAI)	Name	Irrigated farming	Rural land transfer	Intensive farming
	Hypothesis	Cropping intensity increased to 125%	All the abandoned land will be rent and implemented with large-scale management (Xue and Zhen, 2018)	Abundant farmland will be converted by outside companies
	Description	Enhancing irrigation facilities. Following rice-rice or rice-others cropping pattern	Government would provide subsidies to encourage rural land transfer.	Enhancing effective use of the farmland, e.g., new crops and industrial plant for agriculture
Reform of rural development mode (RRDM)	Name	Irrigated and/or rainfed including tree-based farming	SLCP	Mountain agriculture conservation
	Hypothesis	Crop intensity + agroforestry: improved soil health and maintained groundwater table	Convert farmland on slopes above 25° into grassland and forest	Current farmland will be maintained
	Description	Reform the single plant and intensity crop into multiply with agroforestry. e.g., enhanced rainfed or irrigation facilities to develop the rice-legume crops or rice-trees for diversified production	Reform the single cultivated land into multiply with economic forests by make good use of the converted forest and grassland. For example, plant fruit tree and raise chickens under the tree	Reform rural farmer's communities with enhancing direct payment program for environmental services from mountain agriculture, and improve socioecological production landscapes

Table 4
Land use functions in three study sites.
Source: FoPIA workshops, 2017.

Dimension	LUF	Godagari upazila, Bangladesh	Guyuan, China	Noto, Japan
Environmental (ENV)	ENV1	Provision of abiotic resources	Provision of abiotic resources	Provision of biotic resources
	ENV2	Provision of biotic resources	Provision of biotic resources	Provision of abiotic resources
	ENV3	Maintenance of ecosystem processes	Maintenance of ecosystem processes	Maintenance of ecosystem processes
Economic (ECO)	ECO1	Land based production	Land-based production	Land based production
	ECO2	Artificial or non-land-based production	Residential	Non-land-based production
	ECO3	Infrastructure or transport	Infrastructure	Services: Tourism
Social (SOC)	SOC1	Provision of work	Provision of work	Provision of work
	SOC2	Quality of life	Quality of life	Quality of life
	SOC3	Food security	Food security	Food security
	SOC4	Cultural and aesthetic values		Cultural identity

The importance of the LUFs, which use weights from 0 (not relevant) to 5 (extremely important), and the impacts of the 3 scenarios, which use scores between −3 (most negative impacts) and 3 (most positive impacts) (Morris et al., 2011), at each site were scored by experts with two-round paper-based assessments (Xue and Zhen, 2018), and the assessment papers used in the FoPIA can be found in Appendix IV. The average score reported by all experts in the last round represents the final result.

We aggregated the impact assessment results (scores) of the three dimensions of sustainability (economic, social, environmental):

$$\begin{aligned} \boldsymbol{F_{k,d}} &= \left\{ \boldsymbol{F_{k,eco}} = \sum_{i=1}^{\boldsymbol{econ}} (\boldsymbol{w_i} \times \boldsymbol{f_{ki}}), (k = 1,2,3), \boldsymbol{F_{k,soc}} \right. \\ &= \sum_{\boldsymbol{i=econ+1}}^{\boldsymbol{socn}} (\boldsymbol{w_i} \times \boldsymbol{f_{ki}}), (k = 1,2,3), \boldsymbol{F_{k,env}} \\ &= \sum_{\boldsymbol{i=econ+socn}}^{\boldsymbol{n}} (\boldsymbol{w_i} \times \boldsymbol{f_{ki}}), (k = 1,2,3) \end{aligned} \quad (1)$$

$$\boldsymbol{F_k} = \sum_{i=1}^{\boldsymbol{n}} (\boldsymbol{w_i} \times \boldsymbol{f_{ki}}), (\boldsymbol{k} = 1,2,3) \quad (2)$$

where $F_{k,d}$ represents the assessment score by dimension. f_{ki} is the score for LUF i ($i = 1$ to n) in scenario k (k = 1 to 3). w_i is the weight of LUF i (i = 1 to n). $F_{k,eco}$, $F_{k,soc}$, and $F_{k,env}$ are the final assessment scores for the economic, social and environmental dimensions in scenario k (k = 1 to 3), respectively. *econ* and *socn* are the account numbers of LUFs in the economic dimension and social dimension, respectively. F_k is the final assessment score for scenario k (k = 1 to 3).

Different study sites resulted in different quantities of LUFs and indicators; to make the assessment results comparable between the three sites for each scenario, we conducted a normalization:

$$\boldsymbol{F_k^{'}} = \sum \left(\frac{\boldsymbol{w_i}}{\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \boldsymbol{w_i}} \times \boldsymbol{f_{ki}} \right) \times 100, (\boldsymbol{k} = 1,2,3) \quad (3)$$

where $F_k^{'}$ is the normalized assessment score of scenario k (k = 1 to 3) for further comparison.

Because the sustainable assessment should consider the balanced development of the three dimensions, we employed the standard deviation of the three dimensions for each of the scenario assessment results, and the equation is as follows:

$$\boldsymbol{\sigma} = \sqrt{\frac{1}{\boldsymbol{N}} \sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} (\boldsymbol{x_i} - \boldsymbol{\mu})^2} \quad (4)$$

where σ is the standard deviation, and μ is the arithmetic mean value of the three dimensions. N is 3 in this study and stands for three dimensions, while x_i is the value of dimension i.

2.2.3. Household questionnaire surveys

The field survey questionnaires were designed in three parts: basic information of households, land resources, and land policy perspective. Three sites shared the first two parts, and the third part about land use policy was designed for each site according to the actual land use scenarios defined in the FoPIAs. The basic information from each household included the gender, age, main occupation, and education level of each member of the household. The land resources included the area, location, gradient, quality, plant type, and the production of each patch. For the land use policy part, in Godagari upazila, the questions were designed to focus on the land use conditions, willingness to use land management methods, sustainable and environmental land usage, and food security. In Guyuan, questions were asked about their experiences with the RLT and SLCP programs, their willingness to transfer more land to other types and convert more land to forests or grasslands, and the reasons for the reported willingness. In Noto, the questions were about the number of subsidies already received, the willingness to abandon land, and whether an individual would apply for continuing subsidies.

To ensure the reliability and representativeness of the samples, we employed a random sampling method at each study site, and the sample size (number of households) was based on the suggestions of the local community managers and the information gathered from the FoPIAs. The field survey questionnaire was conducted by face-to-face interviews, which each took approximately 50 min. A total of 333 valid questionnaires were eventually collected. Quantitative and qualitative questionnaire data were recorded in Excel. Quantitative data were directly processed by Excel and PASW Statistics 18. Qualitative data were first analysed using text analyses, and the answers of farmers were compiled into numbers to make the statistical process more explicit.

The questionnaire data were mainly used as a supplement for the results of the FoPIAs, helping to explain the assessment results of the land use scenarios at each site, to assess the impact of land use change on the LUFs, to explore land use issues and to testify about the willingness of farmers and the help of researchers to extract land use suggestions on the basis of the FoPIA conclusions.

3. Results and discussions

3.1. Land use functions at the study sites

A synthetic analysis of the average weight for the three dimensions of LUFs from each site showed that the social dimension of the LUFs (SOC-LUFs) exhibited the lowest value at all study sites (3.54 in Godagari upazila, 3.39 in Guyuan and 3.33 in Noto) relative to the other two dimensions. In Noto, the economic dimension of the LUFs (ECO-LUFs) had the highest value (3.93), while in Godagari upazila and Guyuan, the environmental dimension of the LUFs (ENV-LUFs) had the highest value, with weights of 3.96 and 4.00, respectively. These results reflected the similarities and specific characteristics of

each study site (Fig. 2; specific scores for each LUF are shown in Appendix V).

For the ENV-LUFs, experts at both Godagari upazila and Guyuan assigned the highest scores to this dimension (3.96 and 4.00, respectively) but had very different reasons for doing so: in Godagari upazila, severe land degradation warned people to conserve land to improve environmental functioning. Additionally, water is a basic input for producing cereals and many other crops, particularly during the Rabi season, but the expansion of irrigated area led to the rapid depletion of groundwater (Dey et al., 2017); thus, a high priority has been given to the provisions of abiotic resources (4.40) by stakeholders. Another aspect is due to the application of fertilizers and agrochemicals, which represents approximately 25% of the total applied agrochemicals. Approximately 25% of the total applied agrochemicals are transported with run-off into soil and water bodies, affecting land fertility and causing declines in aquatic biodiversity (Alam et al., 2016). Thus, with these problems becoming more serious, the maintenance of ecosystem processes is more important than ever (3.84). However, in Guyuan, people continuously stress the environmental functions because they benefited from landscape protection in past decades by receiving compensation from participation in ecological protection projects (e.g., SLCP) and improving ecological conditions (e.g., regulating climate and retaining natural ecosystems (Xu et al., 2010)). Therefore, high priorities were given to the provisions of abiotic resources (4.17), the provisions of biotic resources (4.00), and the maintenance of ecosystem processes (3.83). In addition, in Noto, although the biodiversity loss and deterioration of ecosystem functions are critically concerning in rural areas due to less land management throughout the country, with traditional and naturally good conditions of sufficient quantities of rainfall and forests, the ENV-LUFs have not been stressed nearly as much as those in Godagari upazila and Guyuan, having an average score of 3.63.

The ECO-LUFs were given the highest score in Noto and Godagari upazila and Guyuan gave moderate scores. These disparities are closely related to their traditional backgrounds. First, the three study sites are all rural agricultural regions, and although land management methods have changed over time, land-based production has always been the fundamental income of the local people. According to our survey data, approximately 88.3%, 29.5% and 18.5% of farmers in Godagari upazila, Guyuan, and Noto, respectively, obtained more than half of their household income from farming. Thus, land-based production received high scores of 4.62, 4.33, and 4.00 at these sites, respectively. In addition, unlike the other two sites, Noto had non-land-based activities, such as the manufacturing of agricultural and fishery products, which have existed for hundreds of years; thus, Noto provided a score of 4.00 to non-land-based production. Because the land was designated as a GIAHS site, nature and culturally based tourism is a dominant industry, and tourism services have become important, with a score of 3.80. Thus, the economic functions of land use in Noto have an especially high value for regional development.

In the social dimension, the coincidental lowest rankings at the three study sites reflected the decreasing dependence of farmers on their land. However, the direct reasons and the degree of decrease was not uniform among the three sites. The population of Bangladesh increased by 10.7%, from 149 million in 2009 to 165 million in 2018, and the immense pressure of the growing population has caused food security functioning to receive the highest importance, with a score of 4.38 in SOC-LUFs. The diversified income sources, including rice mills, handy crafts, cottage industries, and bamboo and cane industries, act as an increasingly key driving force for the insignificance of land function for providing work (3.38), quality of life (3.05) and cultural and aesthetic values (3.33). The implementation of national ecological restoration projects and the "rural labour transfer" policy relocated approximately 27.7% of the total agricultural workers for the purpose of gaining employment in the cities in Guyuan in 2015 (Xue and Zhen, 2018). This land grabbing process is perhaps the reason why the land provision of work functions received the lowest score (2.50) of all land use functions in Guyuan. Despite the diverse selection of biocultural activities (e.g., crop variety, traditional craft skills) in Noto, due to the trend of the ageing society (during the 2010–2015 period, the percentage of the population aged 65 and over increased from 23.0% to 26.7% (Statistics Bureau of Japan, 2015)), the decreased participation of young people is causing the enervation of the communities; furthermore, cultural identity received a score of 3.00 and food security was as low as 3.00, exhibiting that the land dependence in Noto was much weaker.

3.2. Impacts of land use scenarios on LUFs

3.2.1. Scenario impacts on LUFs in three dimensions

1) Scenario impacts on ENV-LUFs

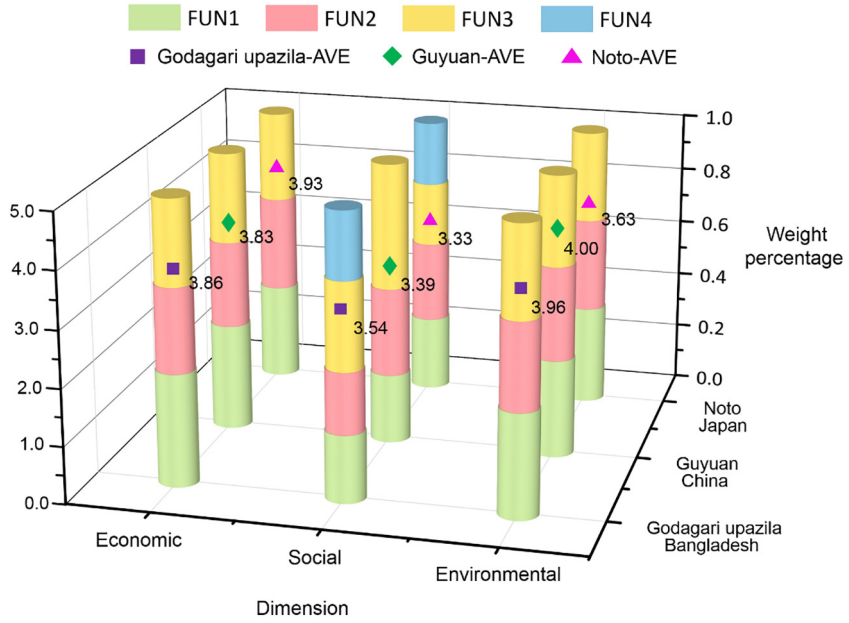

Fig. 2. Weights of the LUFs at the three study sites. (FUNn ($n = 1$ to 4) refers to the nth function at each dimension, and specific functions are listed in Table 4. AVE represents the average score of the LUFs in the dimension of each study site.)

The IAI scenarios in Godagari upazila and Guyuan received the lowest impaction scores; however, Noto received the highest score (3.70) among the three scenarios. The results reflected the degree to which each country appreciates the local ecosystems and environments. In Godagari upazila, all scenarios had negative impacts on ENV-LUFs. Under the BAU scenario (−11.48), the arbitrary rainfall patterns (Mondol et al., 2018) lead to unstable soil moisture, which severely affects the maintenance of ecosystem processes; in the IAI scenario, as noted by the experts, irrigated farming directly threatens the groundwater and its replenishment. According to the questionnaire survey, all the farmers reflected that they are already observing the decrease of the groundwater table due to the installation of pumps compared with the level 20 years ago. In the RRDM scenario (−5.91), while coping with the problems of soil moisture and groundwater availability, farmers have continuously added foliage from fruit trees to replenish the organic matter content of the soil and thus have higher positive contributions to nutrient cycling (Weinbaum, 1999). The rural land transfer in the IAI scenario had the least positive impact (2.81) on environmental LUFs in Guyuan. Some of the experts believe that the uncertain impact of RLT is due to homogenization by cultivating a single crop on a large scale, which might bring potential risks to the maintenance of ecosystem processes (Xue and Zhen, 2018). However, the trees and grasses planted during the SLCP, as defined in the RRDM scenario, will gradually mature and enhance the provision of biotic resources and the maintenance of ecosystem processes (Wang et al., 2005). In addition, only mountain agriculture conservation in the RRDM scenario suggests positive impacts (3.70) on environment LUFs, mainly due to the sustainable maintenance of the agricultural landscape. Experts indicated there was a loss of biodiversity caused by decreased land management throughout the country. The intensive land use in the IAI scenario, such as building industrial plants or photovoltaic systems, would disturb the local ecosystem processes and further block the provision of abiotic resources by the local land. Thus, experts have provided a negative impact assessment result (−3.30).

2) Scenario impacts on ECO-LUFs

The scores of ECO-LUFs in Godagari upazila and Noto are increasing in the BAU, IAI, and RRDM scenarios. The impact scores are as follows: BAU: 14.23 < IAI: 22.11 < RRDM: 26.88 in Godagari upazila and BAU: -2.10 < IAI: 11.8 < RRDM: 17.70 in Noto. In Guyuan, the IAI received the highest score of 10.80. In particular, ECO-LUFs in Godagari upazila received the highest scores among all scenarios (Fig. 3). This result reflected that, in agricultural areas of Godagari upazila, more attention is paid to land-based production and its economic effects; furthermore, both irrigation infrastructure and agroforestry land reform could effectively improve the economic functions, with increases of 55.38% and 88.90%, respectively. The statistical results from the field survey data showed that the incomes from per-hectare rainfed land, irrigated land, and fruit tree-based farming were 452.0 BDT, 1014.7 BDT, and 1324.7 BDT, respectively. These results reflected that irrigation systems and agroforestry systems could improve the land income, with increasing income rates of 225% and 293% per acre, respectively. In Guyuan, rural land transfer in the IAI scenario is more effective for improving economic land use functions (10.80) than SLCP in the RRDM scenario (9.22). One of the reasons for this difference is that the transferred land in rural areas will always be applied to modernized agriculture, as it is large-scale, market-oriented, information-based, and productive (Xue and Zhen, 2018). In Noto, either intensive farming or mountain agriculture conservation could effectively release the negative impact on land-based production by land abandonment in the BAU scenario (−2.10), especially in the IAI scenario, which improves the economic land functions by 9.43 times relative to the value in the BAU scenario. This increase is mainly due to the development of the outside industry to develop crops and plants, which are normally benefit-oriented. The statistical data suggest that paddy fields cover 80.4% of the total farmland; however, the income from paddy fields per area is less than that from intensive crop fields. Thus, crop conversion and intensive use of farmland is a plausible scenario under a depopulating society.

3) Scenario impacts on SOC-LUFs

The IAI scenario has positive impacts on the social LUFs of Guyuan (12.57) and Noto (11.00), while the RRDM scenario was the best for

Study site	scenario	ENV-LUFs						ECO-LUFs						SOC-LUFs								Integrated assessment		
		ENV1		ENV2		ENV3		ECO1		ECO2		ECO3		SOC1		SOC2		SOC3		SOC4		Wenv	Weco	Wsoc
		w	i	w	i	w	i	w	i	w	i	w	i	w	i	w	i	w	i	w	i			
Godagari upazila, Bangladesh	S1	4.40	-1.14	3.65	-0.88	3.84	-0.86	4.62	1.30	3.47	1.14	3.50	1.22	3.38	1.10	3.05	-1.60	4.38	1.52	3.33	-1.64	-11.48	14.23	0.03
	S2		-0.77		-2.12		-0.99		1.74		2.20		1.84		1.24		-1.26		1.76		-0.72	-14.91	22.11	5.66
	S3		-0.40		-0.27		-0.83		2.34		2.25		2.36		1.48		0.28		2.00		-1.40	-5.91	26.88	9.95
Guyuan, China	S1	4.17	0.29	4.00	1.14	3.83	1.57	3.67	-0.43	4.33	1.00	3.50	1.14	2.50	-1.71	3.17	1.71	4.50	-0.57	-	-	11.79	6.74	-1.42
	S2		0.00		0.29		0.43		1.86		0.57		0.43		0.86		0.86		1.71		-	2.81	10.80	12.57
	S3		0.57		1.14		1.29		1.43		0.57		0.43		0.00		1.29		0.86		-	11.88	9.22	7.96
Noto, Japan	S1	3.80	1.00	3.60	-1.00	3.50	-1.00	4.00	-0.50	4.00	-0.50	3.80	0.50	3.50	0.50	3.80	-2.00	3.00	1.00	3.00	-0.50	-3.30	-2.10	-4.35
	S2		1.00		-1.00		-1.00		1.50		1.50		1.50		1.50		-2.00		1.50		-1.00	-3.30	17.70	-0.85
	S3		1.00		-1.00		1.00		1.00		1.00		1.00		1.00		0.00		1.50		1.00	3.70	11.80	11.00

w : Weight of LUFs
i : Score of LUFs' indicator
S1: Busness as usual (BAU)
S2: Increasing agricultural input (IAI)
S3: Reform of rural development mode (RRDM)

Wenv: Integrated assessment result for environmental dimension of LUFs
Weco: Integrated assessment result for economic dimension of LUFs
Wsoc: Integrated assessment result for social dimension of LUFs

Negative value
Positive value

Fig. 3. Scenario impacts on LUFs at the three study sites.

Godagari upazila's social LUFs, with a score of 9.95. The results reflected that, in the BAU scenario in Godagari upazila, SOC-LUFs would not develop much, and the quality of life and cultural and aesthetic values would even decrease, with impact scores of −1.60 and − 1.64, respectively. Because precipitation in this region is unstable and decreasing (with concentrated rainfall from July to September in the Rajshahi district and a decreasing trend from 1670 mm in 2000 to 1248 mm in 2013 (Bangladesh Bureau of Statistics (BBS), 2013)), the traditional rainfed farm approach is hard to utilize to ensure a stable and sufficient supply of food, and these changes further affect the quality of life of local farmers. With irrigation and agroforestry systems, land use efficiency could be improved, and these structures will potentially bridge the gap between conservation and commodity production (Mukul and Saha, 2017). In Guyuan, the rural land transfer would release household labour to develop more business, thus improving quality of life (0.86) with the premise of ensuring food security (1.71) (Xue and Zhen, 2018). However, SCLP converted farmlands into grassland or forestry, which reduced the area of agricultural land, threatening the food security in these regions (Feng et al., 2005). Thus, it received a lower impact score (7.96) on social LUFs than did the IAI scenario (12.57). In Noto, only the mountain agriculture conservation (RRDM) scenario resulted in a positive impact on local social LUFs because in the BAU scenario, the rapid depopulation and ageing of the local community is gradually breaking down the balance between humans and nature; additionally, land use problems, including the abandonment of farmland and forests, are increasing (Hashimoto et al., 2014), and farmland abandonment threatens food security and cultural identity in Noto. Furthermore, considering that Noto is a traditional paddy region and has even developed into a GIAHS, land abandonment would turn this paddy land into a natural recovery region and would result in a loss of traditional cultural heritage; thus, these developments lead to the synthetically negative impact of −4.35. In addition, in the IAI scenario, which is intensive farming in Noto, the outside company would be responsible for the crops, photovoltaic systems and industrial plants, bringing new technology and management ideas into the local region but also threatening the local traditional land use culture, indicating a negative impact score of −0.85 on local social LUFs.

3.2.2. Aggregate impacts of land use scenarios on LUFs

1) Impacts of the BAU scenario on LUFs

With the normalized scenario impact results (Fig. 4), under the BAU scenario, the order of magnitude of the three study sites was as follows: Guyuan (50.80) > Godagari upazila (7.39) > Noto (−27.08), implying that all of the study sites have limited and even negative developments if no land management measures are taken. From the balance of the three dimensional perspective, the order of standard deviations (SDs) are Noto (2.55) < Guyuan (16.17) < Godagari upazila (27.96). The smallest SD in Noto reflected that the environmental, economic, and social dimensions all had similarly restrained negative impacts. The results from the land cover data suggest that the farmland in Noto decreased from 45,213 ha in 1978 to 33,664 ha in 2014, with a rate of decrease 0.7%. Thus, local governments need to cope with this negative trend. Godagari upazila received the most imbalanced results, with a standard deviation of 27.96. The main reason for this imbalance is that, while assessing the impact of each scenario on local LUFs, experts focused more on economic indicators, and land-based production and making good use of the agricultural land were still the fundamental and primary issues.

2) Impacts of the IAI scenario on LUFs

The magnitude of the impact of the IAI on the three study sites is as follows: Guyuan (77.75) > Noto (37.64) > Godagari upazila (34.19). The results reflected that the IAI scenario could release land management problems in all three sites and improve land use efficiency. From the balanced LUFs in three dimensions, the ranking is as follows: Guyuan (12.61) < Noto (26.04) < Godagari upazila (40.26), indicating that all of the sites obtain relatively imbalanced results among the three dimensions, especially in Godagari upazila, due to the higher positive impacts on ECO-LUFs and the lower negative impacts on ENV-LUFs compared to those under the BAU scenario; thus, the polarization is more distinct. This result possibly implies that, although the land management measures in the IAI scenario seem to have an aggregated positive impact on local development (77.75 in Guyuan, 37.64 in Noto and 34.19 in Godagari upazila), the excessive extraction of underground water for irrigation in Godagari upazila could have severe impacts on environmental conservation, which represents an unsustainable development pattern. The IAI scenario also has a high SD, and experts note that for intensive land management, although it might improve the local environment and economic development through industrial plants or photovoltaic systems, it would definitely disturb the local original and traditional balance between human society and the natural environment, and the impact is uncertain, especially in the context of technological change.

3) Impacts of the RRDM scenario on LUFs

The aggregate impacts of the RRDM scenario in LUFs at the three study sites are as follows: Guyuan (86.31) > Godagari upazila (82.19) > Noto (73.61), with an SD order of Guyuan (4.86) < Noto (10.12) < Godagari upazila (35.59). In Guyuan, the RRDM scenario had the highest aggregated impact with the minimum SD. Experts of FoPIA stressed the subsequent effects of the SLCP, especially in ENV-LUFs and ECO-LUFs. Since the implementation of the SLCP in 2000, Guyuan has increased its area of forests and grasslands by 3.11×10^5 ha, of which 1.69×10^5 ha was provided by the conversion of cultivated land, which accounted for 44.9% of the total cropland (3.76×10^5 ha) in 2015 (Guyuan Bureau of Forestry, 2015; Guyuan Bureau of Statistics, 2016). The trees and grasses planted during this program will gradually mature and enhance the provision of biotic resources and the maintenance of ecosystem processes of LUFs (Wang et al., 2005). In addition, villagers have currently developed multiple industries to make full use of forests, such as raising chickens or bees under trees, which provides economic benefits and could improve the quality of life of local residents (Osmaston, 1967). However, with the great promotion of the SLCP in Guyuan from 2000 to 2010, there is not much potential for converting more croplands into grasslands or forests, and therefore, combining SLCP with RLT to promote balanced local development might be a better choice (Xue and Zhen, 2018). In Noto, with the relevant higher positive aggregated impacts and the relevant balance between the three dimensions, the RRDM seems to have a superior impact on local development. Local experts stressed that in the RRDM scenario, it is worth paying subsidies for local residents to continue mountain farming both from the aspect of land-based production on food security and from the aspect of cultural inheritance. However, the most severe problem at the present time is that even though there are some subsidy policies for farming, it is difficult for farmers to apply for these programs. Through interviews with local farmers, the possible reasons include the complicated application process and multiple livelihood choices.

4. Conclusions

By combining the FoPIAs with field surveys to include multilevel stakeholders, the impacts of different land use policy scenarios on remote agricultural areas were comprehensively assessed. We carried out a comparative study on the LUFs in typical remote agricultural areas in Bangladesh, China, and Japan, which showed gradient

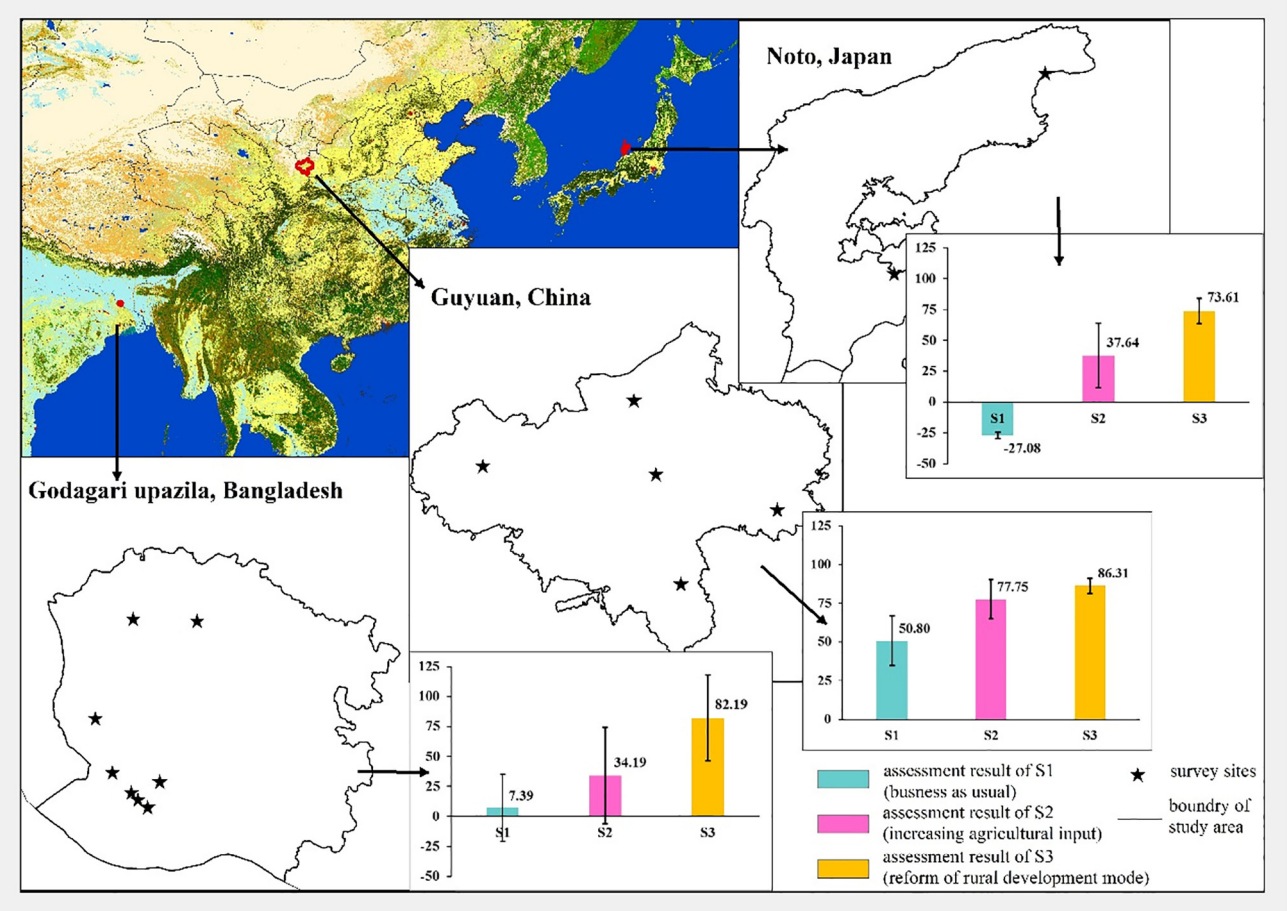

Fig. 4. Scenario impacts on LUFs and the standard deviations of the dimensions under each scenario.

differences in their economic, social, and natural conditions as well as in their main land use problems. We reached the following conclusions:

(1) The three study sites had indifferent responses of SOC-LUFs. Although they attached importance to ENV-LUFs, the rooted reasons were different and sometimes opposing. Farmers assigned the lowest weights to the social LUFs at all sites, reflecting their decreasing dependence on their land. The main reasons for this change included increasingly diversified income sources, rural labour transfer, and ageing societies in Godagari upazila, Guyuan, and Noto, respectively. ENV-LUFs are highly respected, especially in Godagari upazila and Guyuan, due to the opposing factors of warning residents about land degradation and the benefits obtained from land restoration.

(2) A positive aggregate impact result might not represent a sustainable development pattern when considering the balance of the three dimensions simultaneously. In Godagari upzila, the land management measures in the IAI scenario seemed to have an aggregated positive impact (34.19) on local development. However, the high SDs for environmental, economic and social dimensions reflected that, with the excessive extraction of groundwater for irrigation, local environmental development, especially groundwater conservation, might be severely threatened. Thus, combining the integrated impacts and coordinating the three dimensions is necessary when evaluating the aggregated rationality and sustainability of land use management measures.

(3) Combining multiple land uses with land management measures tailored to local conditions, including the natural conditions, economic and social development stages, is the most important task for local sustainable development. Noto has the highest economic development level among the study sites, highest per-capita agricultural land, and sufficient precipitation. They are paid subsidies directly and provide consideration for converting extra farmland into forests, which could obtain aggregated and balanced benefits. Meanwhile, Guyuan has a medium level of economic development, a medium amount of per-capita agricultural land and limited precipitation; therefore, combining the RLT in the IAI scenario with the SLCP in the RRDM scenario could maintain the environmental goodness of the SLCP, develop a forestry economy, and improve land use efficiency through the RLT. Godagari upazila has the lowest economic development level, the least amount of per-capita agricultural land and decreasing precipitation, and therefore, agroforestry could greatly improve soil health, maintain groundwater and enhance land-based production. Thus, protecting traditional agriculture and carrying out appropriate agricultural reforms could inject new vitality into agricultural development, thereby avoiding the loss of traditional culture and promoting regional sustainable development simultaneously.

There are some limitations in this study. First, more types of land use conditions should be included, especially for those that have already been successfully tested. In this study, only two policy scenarios were built for each study site. However, land management measures are continuously being explored and implemented, and many other policy scenarios should be considered for further study. Second, in the FoPIAs, we mainly invited experts in fields relevant to land management; however,

transdisciplinary experts should also be involved to provide a more comprehensive assessment process. Third, although we have developed a two-round paper-based score process, a round-interim discussion and a research discussion to weaken the subjectivity of the research, there are potential limitations from the stakeholders in the participatory assessment method (Reed et al., 2009). Their participation and knowledge have greatly contributed to the enhancement of understanding these regional land use issues and improving land management methods. Fourth, as a multi-country study, the errors introduced because of different languages are inevitable. We have made many efforts to minimize this error, e.g., we organized frequent research group discussions (Section 2.2 Methods, Section 2.2.1 Research group discussion) throughout the whole research process to ensure that the researchers had a consistent understanding from the beginning to end. We also shared the same template materials for the FoPIA and the same basic information from the questionnaires; the other parts of the questionnaires were consensual during the group discussion. However, we acknowledge that it is not realistic to keep all communication with stakeholders consistent; in this comparative study, the results are comprehensive and meaningful for further research.

Author contributions

Lin Zhen conceived the framework of the research and this paper. Zhichao Xue, Giashuddin Miah and Kikuko Shoyama performed and adjusted the implementation at each study site. Zhichao Xue wrote the draft of the manuscript. All the authors contributed to the interpretation of the data, discussion of results and writing of the manuscript.

Declaration of competing interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2019.133689.

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