ASIA-PACIFIC NETWORK FOR
GLOBAL CHANGE RESEARCH

Final Technical Report
CRRP2016-04MY-Zhen

Assessing Land Use Functions for Sustainable Land Management in Asian Countries

The following collaborators worked on this project:

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Project Overview

Project Duration	:	01 August 2016 to 31 December 2018
Funding Awarded	:	US$ 42,000 for Year 1; US$ 42,000 for Year 2 USD 67,200, received by August 1, 2016.
Key organisations involved	:	- Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, China, Prof. Dr. Lin Zhen, Ms. Xue Zhichao. - Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh, Prof. Dr. MD Giashuddin Miah. - United Nations University, Institute for the Advanced Study of Sustainability, Japan, Dr Kikuko Shoyama.

Project Summary

A combination of natural condition and human activities caused significant effects on land use in Asia and brought challenges for decision making on sustainable land management. Land use function (LUF) approach has been developed for assessing policy impact on the performance of multi-functions attached to land use, and economic, environmental and societal impacts of land use changes have on sustainability. LUF is a crosscutting but less studied issue. This project addresses questions of what are the policy impact on LUF and sustainability, and how to mainstream the results into land use decisions. It aims to a place-based comparative study in China, Bangladesh and Japan by selecting remote rural areas and linking to local policy/program/plan and international best practices, to develop a framework, indicator system and scenarios for quantitative assessment of policy impact on LUFs, and enhance regional partnerships with Global Land Project (GLP)/Future Earth (FE)/IPBES/APEC and APN through joint activities, shared data/findings and dissemination materials. Quantitative data will be developed from intensive field surveys using professional tools like Participatory Rural Appraisal (PRA), Key Informant Interview (KII), Framework for Participatory Impact Assessment (FoPIA), satellite images and statistics. The study highlights stakeholders' participation/skill improvement; proposed activities and expected outputs are closely relevant for APN goals and agenda in various ways.

Keywords:
Land use function (LUF); Sustainable Land Management; Asian Countries

Project outputs

- Reviews of existing land-use problem and land use policy in three study sites, collected international best practices on land use and management, interviewed stakeholders to gather background data and information.
- Conducted data collection in 3 remote agricultural areas in China, Bangladesh and Japan, using Framework for Participatory Impact Assessment (FoPIA), household survey, and Key Informant Interview (KII). Besides, Statistics and maps were gathered.
- Defined Land Use Functions (LUFs) and indicators in each site, developed land management scenarios and assessed their impacts on regional LUFs.
- Simulated LUFs' change by Agent-based modelling (ABM) and statistical analysis, conducted the visualisation for scenario assessment results. Young scientists in three sites had been trained on the modelling.
- Expert consultations have been conducted for comments on the research progress and scenario development.

- Three workshops were held in China, Bangladesh and Japan for the kick-off meeting, progress reporting, and result in analysis and comparative for better promotion and understanding of the research topics.
- Participated in an international conference to disseminate research findings and develop networks.
- Drafted policy brief and reported by public media to share and demonstrate the results, and enhance regional collaboration and partnerships with other global change and sustainability networks and organisations.

Project outcomes

- Develop a LUF analytical framework, identified key LUFs and assessment indicators characterising each LUF.
- Assess and simulate scenario impacts on LUFs in three study site and compared the results and provide a recommendation.
- Capacity building of young scientists and stakeholders in the studied areas. About 7 young scientists including post-graduate students have been involved in the research activities, and training for research methods and several meetings were held in the survey sites, which are significant for improving their knowledge on LUFs, sustainable land management and land use policy issues.
- Networking. Research and collaboration network have been established among the research countries, GLP, IHDP, IGBP, WFP, IUCN and UNEP, as well as NGOs and local governments of the study countries. Relations with institutions in Germany (Leibniz Central for Agricultural Landscape Research, ZALF), UK (Oxford University) and Holland (Wageningen University) have been stressed.
- Reporting and publications: Final report is prepared, and about seven journal papers are under review, in preparation or published, which are essential for dissemination of the findings.

Key facts/figures

- 6 FoPIA workshops were conducted in three study sites (1 in China, 2 in Bangladesh and 3 in Japan)
- 37 local experts, government officers and farmer delegates were involved in FoPIA (10 in China, 15 in Bangladesh and 12 in Japan)
- 333 Questionnaires were implemented in three study sites (202 in China, 60 in Bangladesh and 71 in Japan)
- 24 Key informant interviews were carried out in three study sites (9 in China, 9 in Bangladesh and 6 in Japan)
- About 7 young scientists including post-graduate students have been involved in the research activities and training for research methods
- About seven journal papers are under review or published
- A policy brief is under preparation to be published from UNU

Potential for further work

In China, loess hilly and gully region is typical and historical ecosystem fragile region. In this study, we have evaluated LUFs' change in the past 20 years and assessed the land management measures impacts on LUFs in the future. However, the specific study site is limited in Guyuan in this study. The field survey collected data which included typical landform of the whole loess hilly and gully region. As the next step, we will expand our results for the assessment and visualisation simulation for whole hilly and gully region considering the current results. Another issue is that it is needed to conduct further

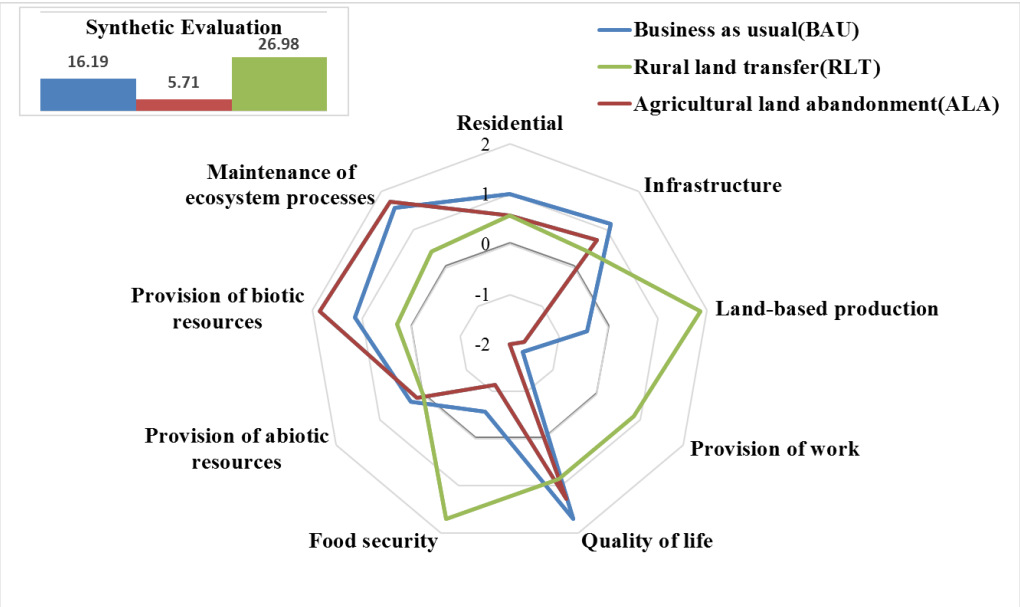
studies on the comparative of LUFs change under the same land management measures. For instance, we have assessed the impact of rural land transfer (RLT) on LUFs in Loess hilly and gully region focus on the release effect of RLT on local agricultural land abandonment. However, land abandonment is common in other parts of China with different natural conditions, and RLT has also been attended to implemented to improve land use intensity and release land abandonment, the relevant effect should be conducted to obtain a further understanding of impacts from land use policy. The results and data gained from this research will be useful for future comparative studies.

Drought is one of the most earnest problems in Bangladesh that substantially impacted on the water availability, food, health, livelihoods, and migration of the peoples over the last few decades. Plenty of research findings have been published with particular focus on drought and drought impacts in Bangladesh, including the most drought-prone area of the country, especially in the northwest region. Unfortunately, limited work examines what will be the future impacts of existing land use practices in the drought-prone area of Bangladesh. Moreover, investigations about how a land provides multiple functions, including socio-economic and environmental aspects, and how these LUFs act as key stimuli to change their land use in the drought-prone area are still elusive. In this study, we determined the potential impacts of existing major land uses on land use functions in Godagari of Barind tract in Bangladesh. We also visualised the possible impacts of alternative land use systems through farmer's knowledge and experiences. However, Barind tract covers a greater area, but we have covered only one. Therefore, further studies are much needed to cover the whole Barind tract region to get deep insights into the assessment and visualisation of agricultural management practices as well as their associated LUFs in respect of social, economic and environmental aspects. Based on LUFs assessment, policymakers will able to focus on the best eco-friendly agricultural practices at the drought-prone areas with emphasising on improving it sustainably. Furthermore, keeping Barind tract results as a reference, policymakers can advocate doing similar studies in almost the same land topography especially in the hill tract region of Bangladesh.

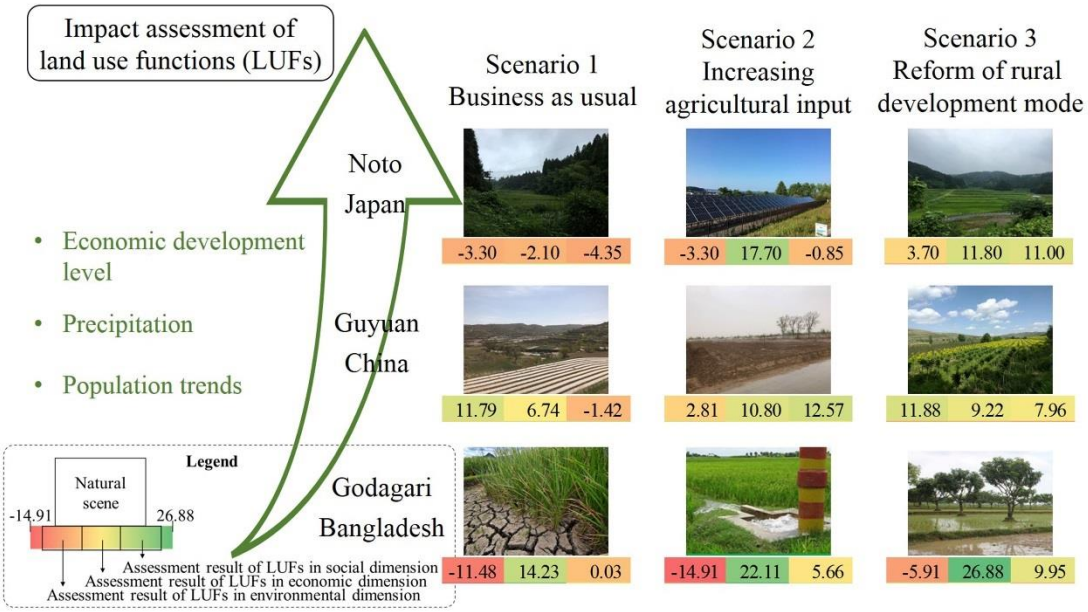
In Japan, we collected agricultural census data and created a platform to develop an agent-based model. Further research, e.g., to analyse full policy impact on each farmers group, various land use policy impact on the remote area will be necessary.

Publications

Xue Z, Zhen L. Impact of Rural Land Transfer on Land Use Functions in Western China's Guyuan Based on a Multi-Level Stakeholder Assessment Framework[J]. Sustainability, 2018, 10(5).



Xue Zhichao, Zhen Lin, Giashuddin M, Shoyama K. Impact assessment of land use functions on sustainable regional development of representative Asia countries – a comparative study in Bangladesh, China and Japan. Science of The Total Environment. It is under review, with cover image/graphical abstract as follow:

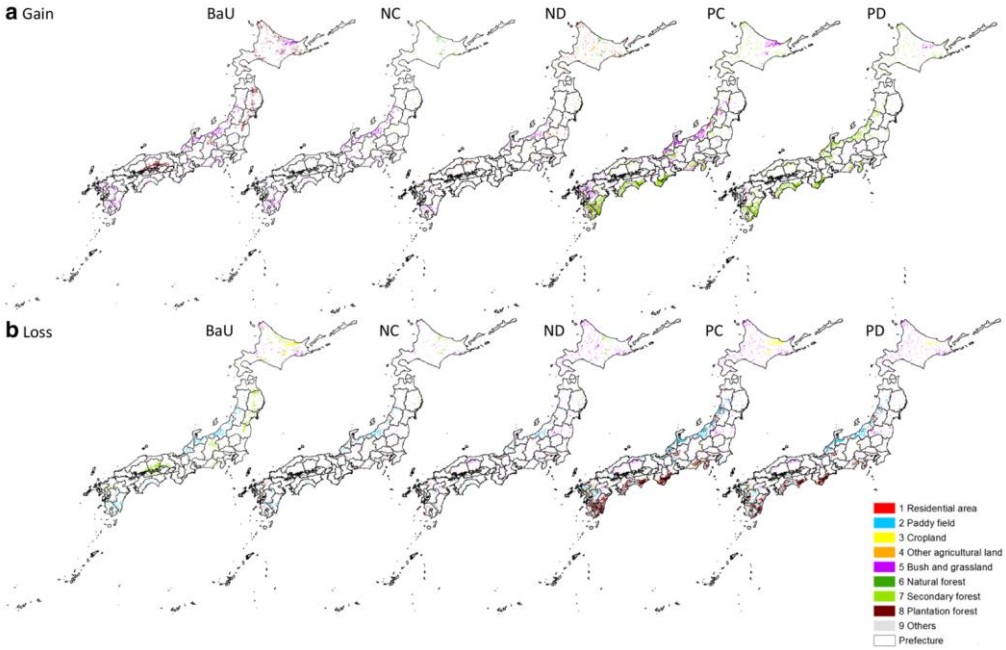


Xue Zhichao. Analysis on multifunctional land use in Loess Hilly and Gully Region: A case study in Guyuan, China. 2019. PhD thesis, Chinese Academy of Science, Beijing, China.

Xue Z, Zhen L. Factors Affecting Farmers' Choice of Abandoning Agricultural Land in Loess Hilly and Gully Region: A Case Study in Guyuan, Western China. Preparation paper.

Shoyama K., Kamiyama C., Morimoto J., Ooba M., Okuro T., (2017) A review of modeling approaches for ecosystem services assessment in the Asian region. Ecosystem Services 26: 316-328.

Shoyama, K., Matsui, T., Hashimoto, S., Kabaya, K., Oono, A., Saito, O. (2018) Development of land use scenarios using vegetation inventories in Japan, Sustainability Science, https://doi.org/10.1007/s11625-018-0617-7.



Miah. M. G., M. M. Rahman, M. A. Rahman, H. M. Abdullah. Land use functions assessment for sustainable land management: A case study in Barind Tract of Bangladesh. Annals of Bangladesh Agriculture, 2018, 22(1): 1-16.

Awards and honours

2018	Outstanding paper of youth in 2018 Annual Conference of China Society of Natural Resources, Ms Zhichao Xue Title: Factors Affecting Farmers' Choice of Abandoning Agricultural Land in Loess Hilly and Gully Region: A Case Study in Guyuan, Western China (in Chinese)
2017	Excellent presentation in the 10th Postgraduate Geography Academic Forum in Beijing, Ms Zhichao Xue Title: Research progress, prospect and application of multifunctional land use in China (in Chinese)
2017 - 2018	Merit Student in University of Chinese Academy of Sciences, Ms Zhichao Xue
2015 - 2016	Merit Student in University of Chinese Academy of Sciences, Ms Zhichao Xue
2017	First-class Academic Scholarship by Chinese Academy of Sciences, Ms Zhichao Xue

Pull quote

- ✧ Prof Jiyuan Liu, a leading scientist in land use and cover change, the Formal Director General of the Institute of Geographic Sciences & Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS)

In the study area of China, the research group of Prof Zhen had finished this project in line with the objectives and major contents in the proposal. Through literature review, field surveys and data analysis, they have understood the primary land use problems currently in Loess Hilly and Gully region and the impacts of land use management measures on LUFs and regional sustainable development from future perspectives. The results have provided valuable information about how land use transfer, sloping land conversion program and land abandonment affect the LUFs in Loess plateau of China. In addition, by applying the multiagent model, they have simulated the spatial and temporal changes of LUFs in the future under the influence of different policy scenarios, the results will provide a scientific basis and support for decision making. The study is significant for both methodology development on LUFs research and land use decision making of the study area.

- ✧ Prof Zhen Lin, the project leader, Institute of Geographic Sciences & Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS)

For the study site in Bangladesh, as an over-populated country, the land uses of Bangladesh, especially in drought-prone areas being changed dramatically within a short period, which is aggravated by climate change and inappropriate anthropogenic activities. Prof Giash led a team to conduct their study in line with the project objectives at the Barind Tract of Bangladesh; characterised by its unique soil topography, which made it ecologically vulnerable. Through secondary sources (e.g. reports, articles and newspapers) as well as field surveys and key informant interview, they have identified the existing land use scenarios and their exerting effects on associated land use functions (LUFs). It is worth mentioning that the LUFs were assessed through some LUFs indicators. LUFs indicators provided comprehensive information regarding how land use was transmuted based on climate change and necessities, and what were the exerted impacts on the environment that threaten our sustainable agriculture and future food security. In crux, this study helped to understand the socio-economic setting, people’s observation on LUFs, socio-economic causes behind the land use changes, and finally discovered the potential socio-economic benefits of LUFs assessment. The study is the first kind of such research in Bangladesh, which has both theoretical and practical values on land use.

Furthermore, in Noto of Japan, the research group of Dr Shoyama conducted LUFs assessment to examine the consequences of intensive/extensive land-use interventions. The derived scenarios can be used to assess the policy impacts on agricultural ecosystems in the rural area. Through the research process, they involved various experts and farmers in the assessment, which turns out to have vital effect for the comprehensiveness of their research and benefit to the knowledge sharing among researchers, experts and local communities.

Acknowledgements

Overall, we would like to express our heartfelt thanks to APN for its financial support to this valuable research, as well as APN's continuous very kind support and comments during the implementation process of this project.

We are grateful for the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences for the managing the project. We are thankful for the help from local government, institute, village heads and households to help us to accomplish the stakeholders research and achieve a thorough understanding of local conditions. Gratitute goes to the Guyuan National Career Technical College, Guyuan Water Affairs Bureau, Guyuan Water Conservation Station, Guyuan Bureau of Land and Resources, and Guyuan Municipal Development and Reform Commission. Thank you also for the support and comments from Prof Jiyuan Liu and Huimin Yan.

In Bangladesh study site, we highly acknowledged Prof. Dr. Lin Zhen, Institute of Geographic Science and Natural Resources Research, Chinese Academy of Sciences, Beijing for her dynamic leadership and technical support. We are incredibly thankful to Mr. Md. Mezanur Rahman, Research Assistant of this project for supervising the whole activities and drafting the report. We are also thankful to colleagues and MS students of the Department for their active involvement in conducting key informant survey, questionnaire survey and workshops. We are profoundly grateful to the local authority and participants of the workshop as well as respondents in the Godavari, Bangladesh for their helpful cooperation.

In the study site of Japan, the field survey and workshops were conducted with the help of local government, community office and participation of local farmers in the Noto region, Japan.

1. Introduction

A combination of natural condition and human activities caused significant effects on land use in Asia and brought challenges for decision making on sustainable land management. Land use function (LUF) approach has been developed for assessing policy impact on the performance of multi-functions attached to land use, and economic, environmental and societal impacts of land use changes have on sustainability. LUF is a crosscutting but less studied issue. This project addresses questions of what are the policy impact on LUF and sustainability, and how to mainstream the results into land use decisions? It aims to a place-based comparative study in China, Bangladesh and Japan by selecting remote rural areas and linking to local policy/program/plan and international best practices. As well as to develop a framework, indicator system and scenarios for quantitative assessment of policy impact on LUFs, and enhance regional partnerships with Global Land Project (GLP)/Future Earth (FE)/IPBES/APEC and APN through joint activities, shared data/findings and dissemination materials. Quantitative data will be developed from intensive field surveys using professional tools like Participatory Rural Appraisal (PRA), Key Informant Interview (KII), Framework for Participatory Impact Assessment (FoPIA), satellite images and statistics. The study highlights stakeholders' participation/skill improvement; proposed activities and expected outputs are closely relevant for APN goals and agenda in various ways.

2. Methodology

2.1 Detailed data collection methods

2.1.1 In Guyuan, China

2.1.1.1 FoPIA

We structured the FoPIA approach, as described by Morris et al. (Morris et al., 2011), into three phases: preparation (problem definition and choice of LUFs and indicators), participatory evaluation (definition of the context for the scenarios and impact assessment), and analysis of the results followed by preparation of recommendations (Figure 1).

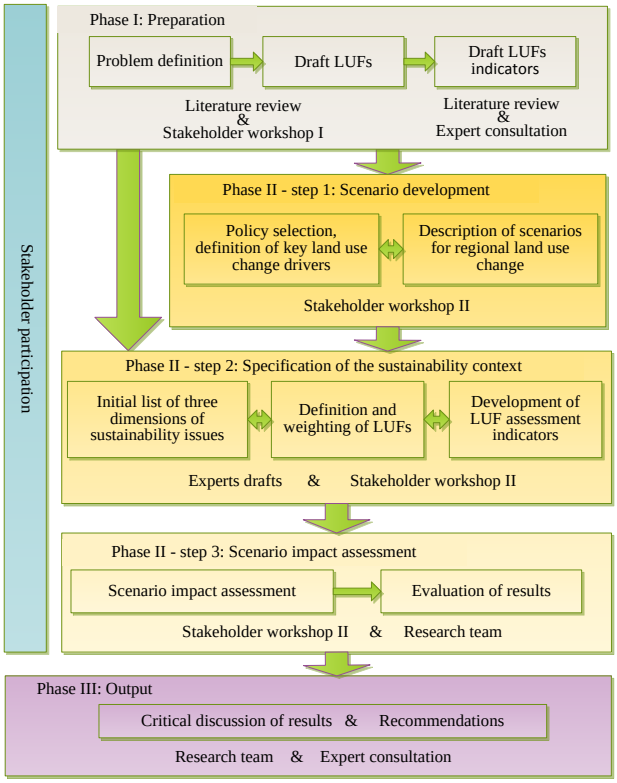


Figure 1. The framework used for participatory impact assessment to identify and assess the land use functions.

In the preparation phase, we held the first workshop and gathered experts from many disciplines (agriculture, hydrology and water resources, economic, regional planning, human resources and social security, forestry, environmental) to define and discuss the current land use problems, the causes and driving forces of these problems, and the implementation of relevant policies (scenarios). We described the main LUFs and associated assessment indicators in preparation for the next phase. In the participatory evaluation phase (Figure 2), we conducted a second workshop to initiate a discussion which covers the scenarios, the LUFs and their associated assessment indicators, and develop a paper-based assessment. Each participant weighted the LUFs in terms of their importance and scored the indicators in each scenario in terms of the impacts, so that we could reach a consensus on LUFs' relative importance and the scenarios impactions on LUFs. In the final phase, we analysed the results and prepared recommendations which includes the summary of the previous workshops and final discussions, followed by the preparation of policy recommendations based on these results.

Figure 2. FoPIA in Guyuan

2.1.1.2 KII

We interviewed the key informants (i.e., village managers) to obtain information on natural environmental conditions, the livelihoods of farmers, and the willingness of local farmers to continue farming in the future in each village. Our goal was to use this information as a reference for the assessment responses of the decision-maker and decision-taker groups. To choose these key respondents, we used the following principles:

1) The final group must contain at least one village manager and one farmer to represent the roles of leader and implementer in the village, and describe their different willingness for taking and supporting the decision-making exercise.

2) Village managers should have a minimum of 5 years of work experience and had handled the overall operation of the village.

3) The farmers should have a minimum of 10 years of experience in the village, were familiar with village conditions, and were not young people with long-term work outside the village or housewives who only worked at home.

Figure 3. KII in Guyuan of China

We developed a semi-structured interview process from 2 to 9 May 2017 (Figure 3), with questions focused on the LUFs conditions in each village and three key informant interviews in each village. Interviews with village managers included questions about the land use changes that had occurred in the last 20 years and the possible abandonment or transformation trends in the future, as well as land use problems in the village and the willingness of farmers. We collected and extracted the background information through the statements of key informants, and used it as a fundamental basis for the analysis and explanation on the results of FoPIA and questionnaires.

2.1.1.3 Questionnaire

The questionnaire was designed to obtain basic information on the respondent's family, the status of agricultural land abandonment and their willingness to abandon their land, and the willingness to attend the RLT program and opinions on RLT. The basic family data included the gender, age, main occupations, and education levels of members of the household. The second part asked about whether they had abandoned agricultural land and the reason. The last part asked about their experience with the RLT program, their willingness to transfer more land with the local government coordination, and the reasons for this willingness. Each questionnaire took around 50 min to finish.

Figure 4. Questionnaire in Guyuan of China

We referred to the specific LUFs in each dimension that were defined during the FoPIA workshops and classified farmers' understanding of the LUFs for the economic dimension of land usage (rents, land-based income, higher yields), the social dimension (employment, maintaining basic living conditions, and two kinds of income (i.e., income from farming and rent) to improve the quality of life), and ecological dimension (more sustainable use of the land, land quality improvement, good for the environment). We normalized the impact assessments from the RLT program scenario in the FoPIA by calculating the percentage values of each dimension ($F_{k,d}$, where k = 1, represent RLT scenario) in the synthetical value (F_k, where k = 1, represent RLT scenario), and we also normalized the questionnaire data from farmers by analysing the percentage of farmers who mentioned the factors in each dimension. So that they would all in 0 to 1, and represent the importance degree of LUFs dimensions in RLT for farmers and experts, respectively. This lets us compare the views of these two groups for the three dimensions.

Households samples were choose randomly in each village, and the final sample size (number of households) were based on the suggestions of the village managers, to ensure reliability and representativeness of the data. Questionnaire survey were conducted from 2 to 9 May 2017 (Figure 4) in each village using face to face interviews. A total of 202 valid questionnaires were collected.

2.1.1.4 Statistic and spatial data

We also collected the land use/cover data (1 km resolution ratio, the year 2000, 2010 and 2015), digital elevation model data, and administrative data of the whole area of Guyuan from Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (http://www.resdc.cn/). The statistical data were downloaded through CNKI (http://oversea.cnki.net/kns55/default.aspx) and from the Guyuan Bureau of Statistics.

2.1.2 In Godagari, Bangladesh

2.1.2.1 FoPIA

Participatory rural appraisal (PRA) method was used to assess LUFs in Godagari in July 2017 (Figure 5). Two stakeholder workshops were conducted with the aim to judge the LUFs on three prominent farming systems of the study area. The research has been conducted in four phases: literature review and preliminary site-selection survey; specification of the LUF context; ranking of priorities and weighting of LUFs; and visualisation and discussion of the results according to the methodology of Chao and Lin (2017). Necessary precaution has been taken during participatory rural appraisal workshop to get the ground-truth information. Involvement of many people in the workshops made the discussion too complex. Therefore, 14 participants from different stakeholders includind five agricultural officers, two university teachers, one irrigation specialist, two public representatives, two

forest personnel and two personnel from research organisations (BRRI and ICRAF) were present in the workshops. Workshop procedure was followed according to the methods of Chao and Lin (2017). At the end of each workshop, scoring on different LUFs and LUFs-indicators were amassed and analysed, and afterwards, final scoring and/or decision have been made keeping in mind the suggestions as well as constructive arguments.

Figure 5. FoPIA in Rajshahi

2.1.2.2 KII

Before FoPIA, one key informative interview (Figure 6) was done with two government officers, one university teacher and one researcher to get an overview about the existing social, economic and environmental factors that affecting cropping systems of the locality in order to identify some key LUFs indicators. Before starting the field survey in each union, we interviewed one public representative, one college/school teacher, and one progressive farmer to obtain information on the livelihood pattern of the locality, agricultural crops and cropping in the area, changes of agricultural practices over time, constraints and prospects of the farming systems as well as some recommendations. The gathered information was then used to explain the outcome of the FoPIA and questionnaires.

Figure 6. KII in Godagari of Bangladesh

2.1.2.3 Questionnaire

Through the pre-tested and pre-structured questionnaire face to face, interviews were conducted with the 60 local farmers in November 2017 (Figure 7). In brief, the questionnaire covers the basic demographic/household's data, basic information of land types/cropping patterns, reasons behind the land/cropping pattern transformations, opinion on environmental sustainability and status of economic solvency of the respondents.

Figure 7. Questionnaire in Godagari of Bangladesh

2.1.2.4 Statistic and spatial data

Geographic Information Systems (GIS) and Remote Sensing (RS) were used as key techniques with 30-m2 resolution to determine the land use and land cover changes of Godavari in the year of 1993, 2004, and 2016. The entire data was classified into different thematic areas, e.g. agricultural land, homestead vegetation/orchard, water bodies, char land, and fallow/chance crop. Spatial data including administrative division map, transportation map and digital elevation model data were developed. Agricultural statistics data were collected from the Agriculture Information Service (AIS) and the

Bangladesh Bureau of Statistics Department, and union wise data were collected from the Agricultural Office.

2.1.3 In Noto, Japan

2.1.3.1 FoPIA

Two stakeholder workshops were conducted in Suzu and Nanao cities, in July and November 2017 (Figure 8), with 12 participants including 4 researchers, 2 agricultural officers, 2 officers from the regional planning council, 4 representatives of the community association. Through the workshop process, LUFs and indicators were selected then each LUFs were weighted based on the perceived importance of each function in the study area.

Figure 8. FoPIA in Noto of Japan

2.1.3.2 KII

Before FIPIA, key informative interviews were conducted in June 2017 (Figure 9) to identify the issues at the local scale and discuss the social, economic, and environmental aspects relating to land management. 2 researchers, 2 government officers and 2 staff of community centre in Suzu and Nanao cities were selected as the interviewee.

Figure 9. KII in Noto of Japan

2.1.3.3 Questionnaire

Face to face interviews conducted against local farmers from Oct. 2017 to Feb.2018 (Figure 10). 47 farmers in Suzu city and 24 farmers in Nanao city responded to the questionnaire.

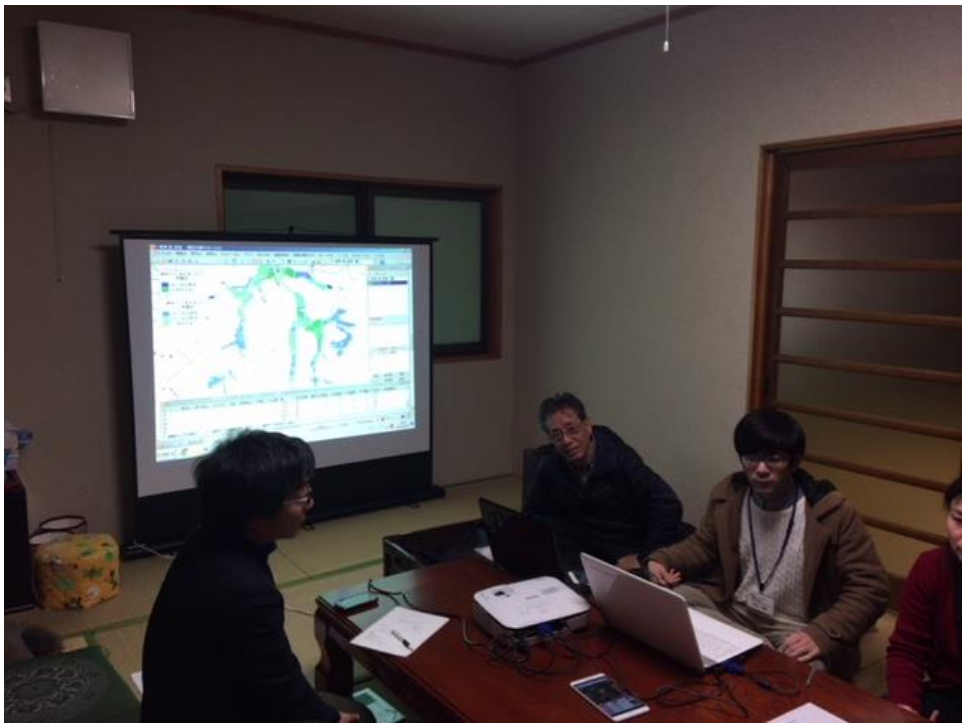


Figure 10. Questionnaire in Noto of Japan

2.1.3.4 Statistic and spatial data

Based on the national scale GIS-based vegetation maps, we derived land use maps at 1987, 1998 and 2014 with 9 categories (1) residential area; (2) paddy field; (3) cropland; (4) other agricultural land; (5) bush, grassland, and other vegetation; (6) natural forest; (7) secondary forest; (8) plantation forest; and (9) others. Spatial data set including (1) elevation; (2) slope; (3) annual temperature; (4) precipitation (5) distance to a stream; (6) distance to a main paved road; and (7) population density was created at 1 km sq. resolution. Agricultural statistic data in 2015 was used to identify farmers' characteristics and their land status.

2.2 Detailed data analysis methods

2.2.1 In Guyuan, China

2.2.1.1 Detailed data analysis methods on LUFs change in the past 20 years (FoPIA + Statistic and spatial data)

Impact Data and information for LUFs change in the past 20 years from FoPIA were analysed using the qualitative descriptive method. Data from household questionnaire and statistic books were analyzed by SPSS software. For land use/cover data in GIS format, ArcGIS tools are used to analyse land use/cover change process and land use/cover conversions. The reasons for each land use change were analysed using descriptive method mostly.

2.2.1.2 Detailed analysis methods for the impact of scenarios on LUFs

We assessed the importance of the LUFs using a two-round assessment, in which participants assigned weights from 0 (not important) to 5 (extremely important) in the first round, then discussed and resolved any differences in the second round. If the stakeholders did not agree on any result, we

used an additional round of discussion to seek consensus, and then, used the following equation for calculating the mean weight of each LUF:

$$w_i = \frac{1}{n}\sum_{j=1}^{n} w_{ij} \quad (1)$$

where w_i is the weight of LUF i (i = 1 to 9), n is the total number of participants, j is the j^{th} participant in this workshop, and w_{ij} is the weight that expert provided for LUF i.

A two-round assessment of the impacts of the three scenarios were conducted and possible trade-offs on the selected LUFs at a regional level, in which participants score the impacts of the scenarios to each LUF between −3 (most negative impacts) to 3 (most positive impacts) (Morris et al., 2011) in the first round. Discussion followed to resolve differences in the second round. If the stakeholders did not agree on any result, an additional round was conducted. We assessed the scenarios one by one and calculated the final score for each scenario using the following equation:

$$f_{ki} = \frac{1}{n}\sum_{j=1}^{n} f_{kij} \quad (2)$$

where f_{ki} is the score for LUF i (i = 1 to 9) in scenario k (k = 1 to 3), and f_{kij} is the last-round score for expert j.

We aggregated the impact assessment results (scores) for each LUF, for the three dimensions of sustainability (economic, social, ecological), and synthesized using the following equations:

$$F_{ki} = w_i \times f_{ki}, \qquad (k = 1,2,3) \quad (3)$$

$$F_{k,d} = \begin{cases} F_{k,eco} = \sum_{i=1}^{3} (w_i \times f_{ki}), (k = 1,2,3) \\ F_{k,soc} = \sum_{i=4}^{6} (w_i \times f_{ki}), (k = 1,2,3) \\ F_{k,ecg} = \sum_{i=7}^{9} (w_i \times f_{ki}), (k = 1,2,3) \end{cases} \quad (4)$$

$$F_k = \sum_{i=1}^{9} (w_i \times f_{ki}), \qquad (k = 1,2,3) \quad (5)$$

where F_{ki} is the final assessment score for LUF i (i = 1 to 9) in scenario k (k = 1 to 3), $F_{k,d}$ represent the assessment score by dimensions. $F_{k,eco}$, $F_{k,soc}$, $F_{k,ecg}$ is the final assessment scores for economic dimension, social dimension and ecological dimension in scenario k (k = 1 to 3), respectively. F_k is the final assessment score for scenario k (k = 1 to 3). Using F_k to compare the alternative scenarios, we ranked the scenarios to provide possible implications for land management and decision support for policy recommendations.

2.2.1.3 Agent-based model about LUFs' change

The model would consist of four sub-models with four kinds of agents. Sub-models including individual status transferring sub-model, households' classification sub-model, spatial environment distribution sub-model and households' farmland use decisions sub-model. Agents are individuals, households, household group and government. At least three scenarios will be designed and simulated which included baseline scenario, land abandonment scenario and land use policy scenario.

(1) Sub-models

Individual status transferring sub-model

In this model, one individual agent corresponds to one farmland plot. The individual agent behaviours include birthing, educating, farming, migrant working, retiring and dying. Individual status would change along with the year passing.

Households' classification sub-model

According to the household's economic sources and the household's livelihood demand for farmland and non-agricultural labourers, it is divided into different groups. The present group classifications are subsidy-dependent, pure-farming, part-farming, non-farming and pure-outworking groups.

Spatial environment distribution sub-model

This sub-model is designed to describe farmland quality. For example, when households choose to plant at reduced scales, they will rent out or abandon farmland plots with inferior qualities. The quality factors of land would be majorly initialised with remote sensing data.

Households' farmland use decisions sub-model

Farmland use decision behaviours of the household groups include renting out, renting in, and abandonment of farmland. The households within a group have similar farmland use behaviours. The percentage of each type of household to abandon or transferred their farmland were extracted from the data.

(2) Agents

The individual agent refers to the family members of a household. The household agent is comprised of individual agents, and the corresponding relationship between the household agent and the individual agent is one-to-many. Households in the same households group would prefer similar land use decision. Government agents would mainly have macroscopic activation, for example, making rules that land above 25 degrees has to be transferred into forest land.

This model will be developed with Java language and RePast simulation platform. The baseline year will be 2010, model results for 2015 will be validated to adjust the model.

2.2.2 In Godagari, Bangladesh

2.2.2.1 Detailed data analysis methods on LUFs change in the past 20 years (FoPIA & Statistic and spatial data)

Data from the past 20 years on population changes, peoples scope to engage in agricultural activities, income generation from agriculture, agricultural mechanization, irrigation facilities, fertilizer and pesticide using tendency, soil health status, road and transportation facilities, infrastructure development, and migration tendency to town were collected from the Agricultural Information System (AIS) department as well as from the Agricultural Office. The data were validated through the experts' perception during the process of FoPIA and analysed through qualitative description method. Data from the questionnaire survey were analysed through SPSS software to get an overview of the locality.

2.2.2.2 Detailed analysis methods for the impact of scenarios on LUFs

In Bangladesh particularly in Barind Tract area, historical rainfed farming system was predominant where once single rice crop (Aman rice grown using rainwater) was the main crop. With the gradual expansion of groundwater irrigation after the 1980s, two crops having high yielding varieties (HYV) of rice including vegetables were introduced in this area. However, over-extraction of groundwater due to the expansion of irrigated area led to rapid depletion of groundwater level at present. This is the critical issue to the farmers, researchers and policymakers, while recently multi-functional farming system, i.e., agroforestry – tree (particularly fruit trees) based crop production has been scattered introduced. Giving priority on socio-economic and environmental sustainability, we developed three scenarios namely

irrigated farming and irrigated and/or rainfed including tree-based farming up to 2030, while rainfed was considered as business as usual (Table 1). In the case of irrigated farming, irrigation facilities increased the cropping intensity to 125% by replacing only one season rice into rice-rice or rice-other vegetables systems. In case of tree-based farming, crop intensity, e.g. rice-pulse/legume crops/trees could be increased even in rainfed condition due to conserving soil moisture by trees, and irrigation facilities in tree-based farming boost the crop performances remarkably. After consultation with teachers of the university, researchers, policy makers and agriculture officers; these scenarios were developed and assessed the LUFs against each scenario in the study area.

Table 1. Scenario development of three prominent farming systems in Godagari, Bangladesh

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

In brief, methods for scenario impacts assessment on 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 scoring, the mean and rankings were calculated and shared with the participants. After the discussion, the participants' understanding of the importance of each LUFs were improved. A second scoring was done and the result modified the rankings. To explore the capacity of each land use type on LUFs, participants were asked to score each land use type from 0 (least capacity) to 100 (most capacity). Then the results were presented to the participants. After the 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 necessary to make the participants reveal their arguments for the different scorings. The research team through open discussion recorded all arguments and then a second scoring round was completed.

The results of the LUFs assessment were then evaluated according to the following formula of Chao and Lin (2017).

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

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=10).

2.2.2.3 Agent-based model about LUFs' change

For the visualisation and simulation of LUFs' change in Godagari, Bangladesh, we designed an agent base model contained two key parts: one is the agents, another is the context, i.e., the environment.

Agents in this model including farmers in Godagari, they are divided into three groups, rainy farmers whose only own rainfed farmland, irrigated farmers with irrigation infrastructure, and agroforestry farmers employed the multi structure of farmland usage. The behaviour of each farmer agents group is analysed from questionnaire data.

The context in this model included the land use and land cover data, digital elevation model and administrative divisions of Godagari. The context is the area where farmer agents would live and conduct the agricultural activity.

With the increasing of running round, the income and preference of a different group of agents would change, the LUFs for each land spot would also have a difference. The result would reflect the different of LUFs in a different kind of land use model directly in spatial

2.2.3 In Noto, Japan

2.2.3.1 Detailed data analysis methods on LUFs change in the past 20 years (FoPIA & Statistic and spatial data)

National census data from 2000 to 2015 was collected to identify population change, the number of farmers for each community. Through the process of FoPIA, the data was reviewed by experts to discuss the socio-economic change in the area.

2.2.3.2 Detailed analysis methods for the impact of scenarios on LUFs

In Japan, national-scale future scenarios were developed for exploring potential changes in natural capital and ecosystem services up to 2050. The developed scenarios were named as "Natural capital-based society (NCS)" and "Produced capital-based society (PCS)" with business as usual scenario (BAU). Natural capital basis indicates the direction to promote ecosystem-based infrastructure development, disaster risk reduction, land management, and ecotourism, while produced capital basis depends more on conventional human-made infrastructure and technologies (Saito et al. 2018). These scenarios were developed based on perspectives of researchers, experts, and policymakers; thus we applied these upper scenarios in our land use function assessment to explore the scenario impacts on local situations (Table 2).

Table 2. Scenario development of three prominent farming systems in Godagari, Bangladesh

Scenario	Description
BAU (Business as usual)	20-50% farmland abandoned to 2050
Scenario 1: NCS (Natural capital-based society)	Current farmland will be maintained with the direct payment program
Scenario 2: PCS (Produced capital-based society)	Abundant farmland will be converted into industrial use (e.g., crops, photovoltaic system and industrial plant) by outside companies

2.2.3.3 Agent-based model about LUFs' change

To develop future land-use scenarios, we used the land change modeler (LCM), which is a spatially explicit cellular automata-based modelling tool available in IDRISI software (Eastman 2016). For further research, we collected agricultural census data and created a platform to develop an agent-based model to analyse full policy impact on each farmers group.

2.2.4 Methods for scenario impact assessment

The importance of the LUFs, which use weights from 0 (not relevant) to 5 (extremely important), and the impacts of the three scenarios, which use scores between -3 (most negative impacts) to 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 in the last round of all experts is the final result.

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

$$F_{k,d} = \begin{cases} F_{k,eco} = \sum_{i=1}^{econ} (w_i \times f_{ki}), (k = 1,2,3) \\ F_{k,soc} = \sum_{i=\text{econ}+1}^{\text{socn}} (w_i \times f_{ki}), (k = 1,2,3) \\ F_{k,ecg} = \sum_{i=\text{econ}+\text{socn}}^{n} (w_i \times f_{ki}), (k = 1,2,3) \end{cases} \quad (1)$$

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

where Fk,d represents the assessment score by dimensions. fki is the score for LUF i (i = 1 to n) in scenario k (k = 1 to 3). wi is the weight of LUF i (i = 1 to n). Fk,eco, Fk,soc, and Fk,ecg are the final assessment scores for the economic, social and ecological dimensions in scenario k (k = 1 to 3), respectively. econ and socn are the account number of LUFs in economic dimension and social dimension, respectively. Fk is the final assessment score for scenario k (k = 1 to 3).

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

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

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 scenario assessment results, and the equations are as follows:

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

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 xi is the value of dimension i.

2.3 Description of study areas

2.3.1 Guyuan, China

2.3.1.1 Criteria for selection of the study area

Located in the hilly and gully region of the Loess Plateau (Figure 11 and Figure 12), Guyuan is an environmentally fragile and economically underdeveloped area of China. It has a semi-arid continental monsoon climate. The annual precipitation is limited and highly spatially and temporally variable. Based on the meteorological data and land cover and land change data provided by the Data Centre for Resources and Environmental Sciences, Chinese Academy of Sciences (http://www.resdc.cn/), the

mean annual rainfall ranges from 431.4 ± 197.9 mm in 2005 to 463.9 ± 150.8 mm in 2015 (Guyuan Bureau of Statistics, 2016a), which is not sufficient to support rainfed farming. The mainland use types are cultivated land (44.7% of the total land use) and grassland (44.9% of the total). Around 41.6% of the total area has a slope greater than 15°, and 12.1% has a slope greater than 25°, which makes cultivation difficult and makes the fine-grained loess soils highly vulnerable to erosion.

2.3.1.2 Detailed description of the study areas with maps

The major crops are winter wheat in rotation with summer maize and potato, which account for 48.0% of the total cultivated area. The agricultural population is 1.11 million, and these workers account for 74.4% of the total population. However, the disposable income of rural households is 7002.1 CNY, which is lower than the provincial average of 9119.0 CNY and the national average of 11,422.0 CNY in 2015 (Guyuan Bureau of Statistics, 2016b). The approximate conversion rate in 2015 was about 6.4 CNY per U.S. dollar.

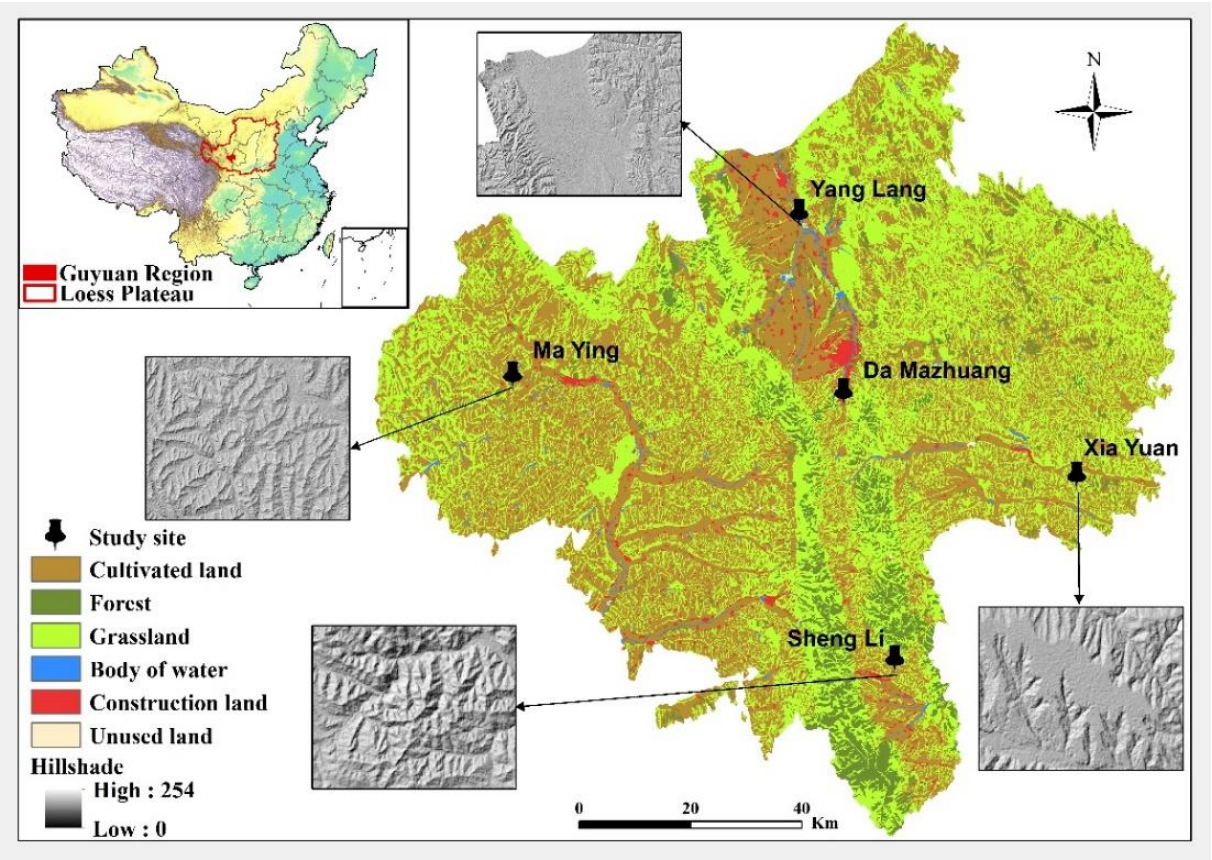


Figure 11. Location of Guyuan and the study sites, and the associated topography and land use.

Figure 12. Scenarios in Guyuan, China

Since implementation of the SLCP in 2000, Guyuan has increased the area of forest and grassland by 3.11 × 105 ha, of which 1.69 × 105 ha was provided by conversion of cultivated land, which accounted for 44.9% of the total crop area (3.76 × 105 ha) in 2015 (Guyuan Bureau of Forestry, 2015; Guyuan Bureau of Statistics, 2016a). However, younger residents of Guyuan have increasingly been leaving agriculture in search of jobs that provide a better income, leading to ageing of the agricultural workforce. Although the SLCP has restored vegetation in a large amount of the abandoned arable land (1.41 × 105 ha), local experts report that nearly 25% of the land remains abandoned.

The abandoned agricultural land significantly threatens local food security (Holden and Shiferaw, 2004; Scherr and Yadav, 1996; Zhen et al., 2010). Also, because nearly half of the cultivated land is on steep slopes with fine-grained loess soils, the abandoned land is highly vulnerable to erosion, and its variable distribution has led to problems related to land use fragmentation historically (Jiao et al., 2005).

Local experts told us that RLT, which could consolidate small fields into larger areas to improve the efficiency of management, would simultaneously improve the usage of abandoned land and the economic development, as it has done in successful implementations in other parts of China (Du and Sun, 2011). In Guyuan, the primary land use type in rural areas is cultivated land, so RLT mainly refers to the exchange of usage rights for cultivated land or the transfer of cultivated land among households, companies and communities. The current land transformation conditions in Guyuan can be summarised as follows (Agriculture and Animal Husbandry Bureau of Guyuan, 2016):

1) The scale of the transfers is increasing but remains small. The total exchange of contracted cultivated land in 2008 was 6706.53 ha, versus 49,642.73 ha in 2015, which represents only 13.2% of the total cultivated area.
2) The plant types on the transferred land have expanded from the original types (mainly crops) to tree seedlings produced for afforestation or trade, fruit trees, and cash crops. The area for food crops after the abovementioned exchanges was only 2.08 × 104 ha, accounting for 41.9% of the total transferred area. This suggests that land exchanges have not well-supported the original goals of the RLT, which is to improve the production and efficiency of cultivated land.
3) The form of RLT is evolving from spontaneous private exchanges to more organised flows, but the regulations to support this evolution are insufficient. The transfer form in Guyuan mainly includes rentals, subcontracting and exchanges; the most popular form is rentals, which affected 38,165 ha (76.9% of the total transferred land). However, owing to the official statistic data by local government, the amount of land transferred under formal contracts was 39,302 ha, accounting for 79.2% of the total transferred land. However, local experts stressed that the real contracts proportion would be even less with many individual transactions, suggesting the unsound of the transfer system.
4) The rental fees for transferred land vary widely owing to differences in the land conditions. The high-quality land rents for a higher price of around 33.3 CNY/ha annually and annual rents can increase by 0.7 CNY/ha annually. In contrast, the lowest price is 2 CNY/ha annually for hilly and dry land. In 2017, to promote RLT, the government of Guyuan introduced shareholding systems, based on successful experiences elsewhere in China, to account for the dry climate and local conditions for labour mobility, with the goal of promoting land transfers.
5) The RLT is usually related to a single type of plant in a large area. These plants are typically cereals, vegetables, and wolfberry (Lycium chinense) in Guyuan, owing to that they are suitable for this region to improve earnings. For example, in Yang Lang village, the biggest household interviewed has rented 66.47 ha of land, which is nearly 13.8% of the entire village's crop area. This household chose to plant only wolfberry and pumpkins in 2016. This condition has the potential to threaten the biodiversity and the maintenance of ecosystem processes.

In summary, the current conditions for transferring land use rights in Guyuan represent an exploratory stage, with many problems that remain unsolved. Because the government officials are unsure of the local suitability of RLT and its prospects, a feasibility study is much needed on RLT based on land location, geomorphology, quality and accessibility to water resources to decide whether the land transfer is possible. At the same time, willingness and perceptions of the farmers on RLT should also be evaluated. Based on such studies, politicians can further improve current policies and regulations related to land transformation.

Guyuan has a wide variation in landforms. Based on suggestions from local experts, we selected four villages to represent plain land in the valley (Yang Lang), loess tableland (Xia Yuan), plateau hills (Ma Ying), and stony mountains (Sheng Li), and one village (Da Mazhuang) to represent a peri-urban village. This will let us compare the factors that constrain sustainable agricultural management in each region.

The characteristics of the selected villages, as well as their locations, topography, and land uses can be found in Table 3 and Figure 11 respectively.

Table 3. Characteristics of the study villages and survey details in Guyuan, China

Village	Feature	Slope of Cultivated Land [1]	Agricultural Land Abandonment	Livelihood	Questionnaires	Key Informant Interviews	
						Village Manager	Farmer
Yang Lang	Valley plain	99.6% with slopes <5°	Before RLT, 14.3% After RLT, 0% 85% of farmland is irrigated; other land abandoned mostly due to drought	Mainly work in town	49	2	1
Ma Ying	Plateau hills	72.6% with slopes >25°	10% but increasing, most land difficult to access from farmer homes; no participation in SLCP	Mainly farming, with part-time jobs in town	33	2	1
Xia Yuan	Tableland and hills	64.6% with slopes <15°	Before SLCP, 20.0%. After SLCP, 14.3% mainly living and farming on tableland; steepness and faraway hill land would be abandoned	Mainly farming and livestock breeding, with part-time jobs in town	37	2	1
Sheng Li	Stony mountains	65.8% with slopes >15°	Before SLCP, 13.3% After SLCP, 0% (replaced by tree nurseries and the forest economy)	Mainly work in town	40	2	1
Da Mazhuang	Peri-urban village	62.4% with slopes <5°	Before SLCP, 50.0% After SLCP, 15%	Mainly work in town (convenient transportation)	43	2	1

[1] Statistical data from questionnaires. RLT: rural land transfer; SLCP: Sloping Land Conversion Program.

2.3.2 Godagari, Bangladesh

2.3.2.1 Criteria for selection of the study site

Barind Tract is an agrarian upland in the northwest region of Bangladesh, located above 20 m from the sea level and characterised by low rainfall, which makes it meteorological and hydrological drought-prone area. The reasons behind these droughts include short duration of monsoon rainfall, prolonged dried-spell, and intensive groundwater use for Boro rice (winter rice) cultivation. Historically, the cultivable land was dominated (84%) by single cropped rainfed-rice (Aman rice). With the availability of irrigation facilities, most of the area converted to double crops mainly rice-rice/vegetable. Continuous practising high inputs based intensive farming and overuse of groundwater, the sustainability of this farming is in question because of the degradation of soil and water. However, conversion of agricultural land to non-agriculture uses like industrial exploitation reduces the rice and other crop field's area in this region. Most importantly, the highly unfavourable man-land ratio and extremely high population density, gradually increasing land degradation, unplanned or misuse of land could not be able to support the agro-based economy in the near future. With the increasing demand for agricultural produces, the relevant and sustainable 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 the deterioration of production environments and natural resources. To address the challenges of land use change, the researchers, policymakers and stakeholders' need adequate information on the key determinants of land use change and its consequences to formulate a sustainable land management strategy.

2.3.2.2 Detailed description of study areas with maps

The study site is located in Godagari (a good representation of Barind Tract) under the Rajshahi district in the northwestern region of Bangladesh (Figure 13, 14). There are 9 unions and 415 villages

having a total population of 3, 30,924 with a population growth rate of 1.68%. Godagari lies on the northern bank of the Padma River, and the land is predominantly highland and medium highland. 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 conditions of the rest of the country (Hasan and Mahmud-ul-islam, 2018). The region is designated as drought-prone zone and adversely affects the cultivation of crops. Rice dominate the cropping pattern of Barind area, which suffers from drought in the dry season. Historically, single crop (Aman paddy) in the rainy season was cultivated in Barind. With the rapid expansion of groundwater irrigation after the 1980s, high yielding varieties (HYV) of rice were introduced in this area. Now, most of the areas of Barind tract produces two and/or more crops in a year with the use of groundwater. However, the groundwater level is being decreased significantly because of its intensive use for irrigated rice production. It is now a great concern to all levels of stakeholder. It is fascinating to note that recently orchard especially mango, litchi, and guava based farming system has been expanding rapidly because of good income and relatively resistant to natural hazards.

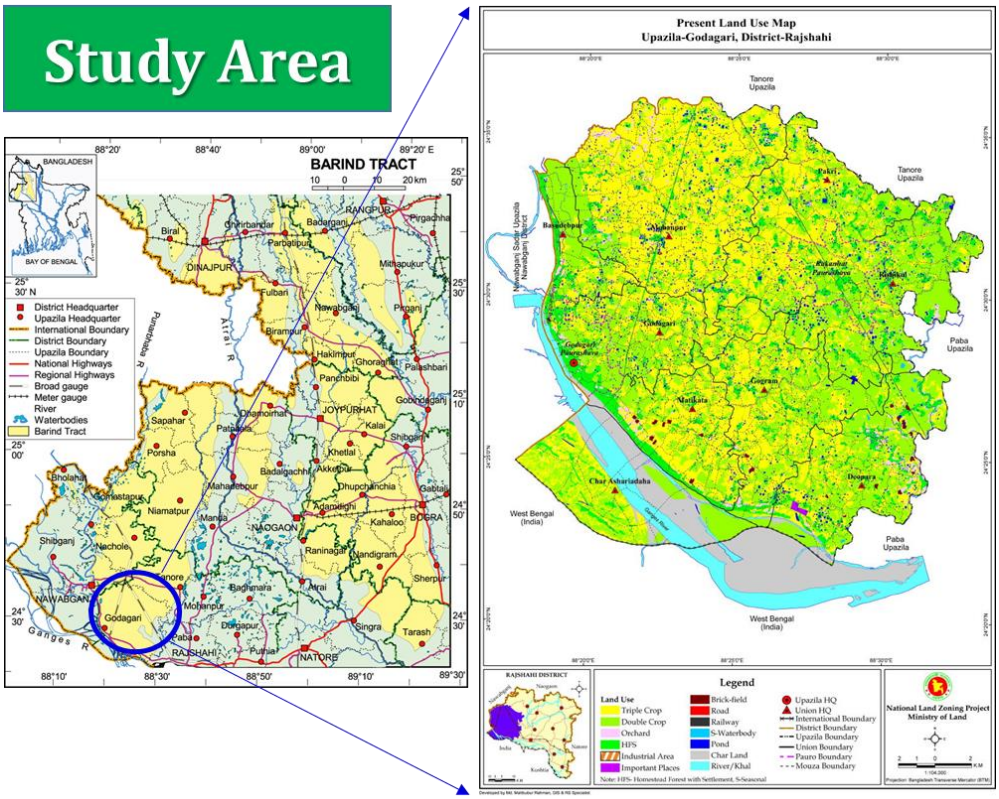


Figure 13. Location of Godagari and associated land use-land cover change map. Source: National land zoning report: Godagari, 2016.

Nevertheless, environmental issues that concern the are monsoon floods, rivers/canals siltation, fog, hails-storm, wetland degradation, improper agricultural practices, unplanned expansion of housing, infrastructure, unplanned growth of brickfields, losses of biodiversity, sand extraction and climate change. Furthermore, overexploitation and lack of replenishment of groundwater including elevated temperature and decreased precipitation led to the decline of groundwater availability (avg. rate 0.10 m/year) and the area is being turned hydro-meteorologically into a semi-arid zone with low to moderate groundwater potential zone. Drought and cold wave creates a negative impact on the diversification of crops and biodiversity. Bricks are made by collecting topsoil from agricultural land that impoverishes land, which is alarming. According to farmers' opinion, "brick kiln black emission hampers mango pollination process notably. Besides, wetland habitats are badly damaged mainly through soil pollution

and land degradation. Agricultural labour crisis in the winter season, inadequate surface irrigation facility, soil pollution, prolonged drought, fog etc. have been creating land management barriers. Mostly river erosion affects vast area; as a result, the migration of rural people is increasing. Agricultural land converted to non-agriculture uses reduces rice field area in this region.

Sustainable land management requires knowledge of goods and services provided by different land uses regarding social, economic and ecological dimensions (Helming et al., 2011). The Land Use Functions (LUFs) framework designed by Perez-Soba et al. (2008) may help 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 regarding environmental, economic and social aspects of agricultural land use. Furthermore, the 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.

Figure 14. Scenarios of Godagari, Bangladesh

2.3.3 Noto, Japan

2.3.3.1 Criteria for selection of the study site

The Asian countries are expected to contribute to the population growth until 2050 (UN 2017). However, Asian population growth is estimated to fall around 2050. The depopulation trend has already

started in Japan since 2010 (Statistics Bureau 2016), and thus Japan has experienced depopulation earlier among other countries in Asia. Noto region was selected as a typical rural landscape facing depopulation and abandoned farmland.

2.3.3.2 Detailed description of the study site with maps

In particular, depopulation and ageing have been a critical concern in the rural area throughout the country. The population of the Noto region has decreased since the mid-1950s due to the limited job opportunities caused by stagnating agriculture and forestry and immigrating to cities. The ongoing trend of ageing in the rural area has further caused this situation and resulted in a rapid increase in abandoned forests and farmlands. These situations have changed the flow of ecosystem services including provisioning, regulating and cultural services in the Noto region (Hashimoto et al. 2015).

The study site, Noto peninsula is located in Ishikawa prefecture, Japan (Figure 15). Noto is an important socio-ecological landscape in Japan. The total area is 4185km² with 1.15 million people, mean annual rainfall is 2100mm. The dominant land cover is a forest (76%, mostly planted forest and secondary forest) followed by paddy field (13%) and residential area (4%) (Hashimoto et al. 2018). The rice paddy terraces have been developed in the steep fields for hundreds of years; rests are fisheries and primary industry-based tourism. In 2011, the northern part of the region was designated as a Globally Important Agricultural Heritage Systems (GIAHS) aiming to enhance sustainable agricultural activities and the tourism based on traditional agricultural use, e.g., terrace paddy fields.

In this study, we focused on the issues of Direct Payment in Hilly and Mountainous Areas (hereafter, payment program), which has implemented by Ministry of Agriculture and Forestry since 2000. This payment program was designed to maintain and enhance various land functions, in light of the Agricultural Basic Law implemented in 1999. The payment program has supported farmland management activities by local communities. However, some communities have begun to drop out of the program due to the absence of young agricultural successors. This situation accelerates the increase of abandoned farmland. Some agricultural companies converted abandoned cropland to economic crop fields, and immigrant farmers contribute to utilising the abandoned cropland. However, less productive paddy fields in mountain area tend to be abandoned due to the ageing of landowners and no successors. Thus, maintenance of mountain landscape with complex secondary forest and paddy field and keeping community functions are a topmost concern in the rural area.

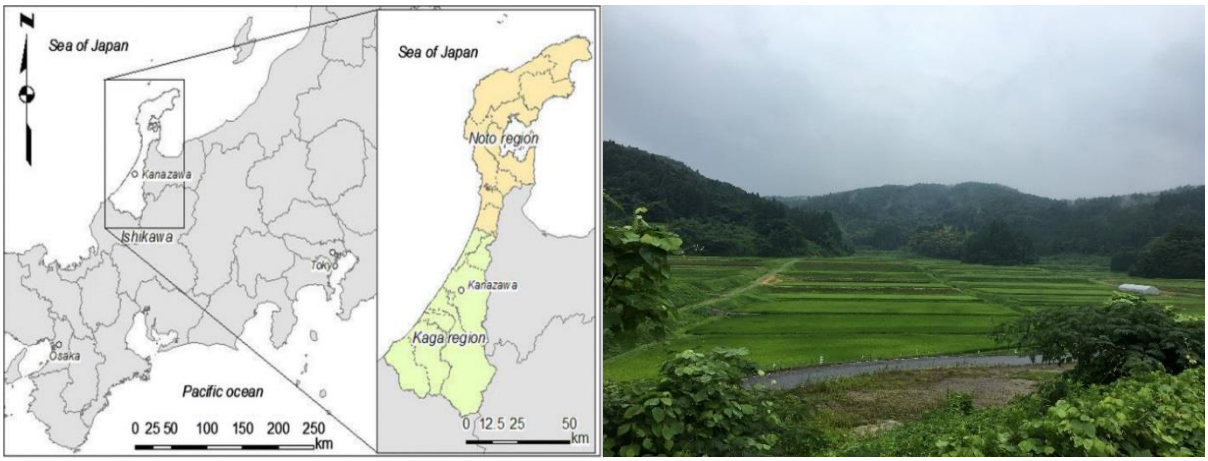


Figure 15. Noto region in Japan (Left, Hashimoto et al. 2015) and agricultural landscape in the study area (Right)

3. Results & Discussion

3.1 LUFs and indicators in the three sites

3.1.1 Guyuan, China

3.1.1.1 LUFs

We defined the nine most important LUFs in Guyuan in the workshop of FoPIA. The LUFs are the same in all three stakeholder evaluations (Table 4).

Table 4. Land use functions and indicators in Guyuan, China

Dimension	No.	Land Use Functions	Definition
Economic	1	Residential or non-land-based activities	Provision of space where residential, social and productive human activity takes place
	2	Infrastructure	The quantity and quality of roads as a means to connect rural regions with other regions
	3	Land-based production	Provision of land for economic production, including agricultural and forest products
Social	4	Provision of work	Employment opportunities for activities based on natural resources
	5	Quality of life	A good living standard in rural regions related to factors that should improve the quality of life
	6	Food security	Access to and availability of a sufficient quantity and quality of food
Ecological	7	Provision of abiotic resources	The land's role in regulating the supply and quality of soil and water
	8	Provision of biotic resources	Provision of habitat and biodiversity, and factors affecting the capacity of the land to support them in regions
	9	Maintenance of ecosystem processes	The land's role in the regulation of ecosystem processes, the regulation of natural processes related to the hydrological cycle, and ecological supporting functions such as soil formation

Source: Framework for Participatory Impact Assessment (FoPIA) workshop, 2017.

3.1.1.2 Indicators

We defined the corresponding indicators in the second workshop in FoPIA. We divided these indicators into economic, social, and ecological dimensions (Table 5).

Table 5. Land use functions and associated assessment indicators in Guyuan, China

Dimension	No.	Land Use Functions	Regional Relevance	Indicators
Economic	1	Residential or non-land-based activities	Construction land, and especially the residential land, to meet the basic needs of farmers	Percentage of construction land
	2	Infrastructure	For remote rural areas, the road infrastructure strongly influences the potential for economic development	Density and quality of the transportation network
	3	Land-based production	Provide a basic income for farmers	Output value of primary agricultural and forest industries
Social	4	Provision of work	Basic and traditional forms of employment for farmers	Proportion of agricultural employees
	5	Quality of life	The satisfaction of farmers with their land	Per capita public green space
	6	Food security	Local farmers would not abandon land because it was necessary to ensure that they received a sufficient quantity and quality of food	Per capita grain output
Ecological	7	Provision of abiotic resources	Water and soil are both essential in this semi-arid area	Per capita water resources

	8	Provision of biotic resources	Vegetation cover and diversity indicates an improved environment in this semi-arid region	Vegetation cover of forests and grasses
	9	Maintenance of ecosystem processes	Undisturbed land is the basis for a local environment-friendly life	Soil conservation

Source: Framework for Participatory Impact Assessment (FoPIA) workshop, 2017.

3.1.2 Godagari, Bangladesh

3.1.2.1 LUFs

Based on literature review, 10-land use functions were identified under three major dimensions. Preferred land use functions were the provision of work (SOC1), quality of life (SOC2), food security (SOC3), and cultural and aesthetic values (SOC4) under social dimensions. Economic dimension included land-based production (ECO1), artificial or non-land based production (ECO2), and infrastructure or transport (ECO3). Whereas, the environmental dimension covered the provision of abiotic resources (ENV1), provision of biotic resources (ENV2) and the maintenance of ecosystem processes (ENV3).

3.1.2.2 Indicators

Depend on preliminary surveys and consultation with experts, assessment indicators were identified for each land use functions (Table 6).

Table 6. LUFs and corresponding assessment indicators in Godagari, Bangladesh

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
	SOC4. Cultural and aesthetic values	Local land use techniques, e.g. ploughing, broadcasting etc. methods	Use of traditional land use techniques
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 take place	Income from product processing facilities
	ECO3. Infrastructure or transport	Mainly focus on rural transportation as a 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, biodiversity, and factors affecting the capacity of the land to support regional biodiversity.	Water quality Biodiversity
	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

3.1.3 Noto, Japan

3.1.3.1 LUFs

Based on literature reviews (indicators for monitoring sustainable society and policy measures in the master plan) and preliminary surveys, assessment indicators were identified for the LUFs. Selected LUFs were ECO1. Land-based production, ECO2. Non-land based production, ECO3. Services: Tourism, SOC1. Provision of work, SOC2. Quality of life, SOC3. Food security, SOC4. Cultural identity, ENV1. Provision of biotic resources, ENV2. Provision of abiotic resources, ENV3. Maintenance of ecosystem processes.

3.1.3.2 Indicators

The assessment indicators were selected according to primary industries and target indicators in the local action plan; i.e., Agricultural production amount, Income from agriculture, Crop variety (for ECO1), Production amount, Income from fishery, Number of catch species (for ECO2), Number of tourist, Income from tourism, and Capacity of tourism facilities (for ECO3), Number of population in Agriculture, Fishery and Tourism (SOC1), Number of Children/Schools (SOC2), Self-sufficiency rate (SOC3) and Number of cultural event (SOC4), Vegetation area (ENV1), Per capita water resources and Water quality (ENV2), Landscape Index (ENV3).

3.2 Weights of LUFs in each site

3.2.1 In Guyuan, China

The LUFs in the ecological dimension had the highest score, at an average of 4.00 (Figure 16). This shows recognition of the importance of the ecological environment and the effectiveness of the promotion and protection work that has been conducted in the past several years. For example, in Yuanzhou County, the forest cover has increased from 11.0% in 2009 to 14.0% in 2015, representing a 27.8% increase. The local government has also stressed the importance of these programs to maintain good environmental conditions. The economic dimension was rated second, with an average score of 3.83. Therefore, residents recognised the importance of factors that would let them earn a satisfactory living. Analysis of the specific economic functions showed that food security had the highest weight (4.50), followed by land-based production (4.33). Because 74.4% of Guyuan's population works in agriculture, the primary livelihood is farming, so the quality and quantity of the land's production were important. The lowest score was for the social dimension, with an average score of 3.39. Of the specific functions, employment had the lowest score (2.50), possibly because more and more farmers would like to work in the city, and they, therefore, placed less value on the employment provided by their land. In addition, with the desire of farmers to move to the city to find off-farm jobs ("rural labour transfer"), the local government also has organised technical training to prepare farm workers for these new jobs and help them escape poverty. This program benefited 193,177 people from 2005 to 2015. Government statistics suggest that the number of rural workers who moved to cities increased from 180,000 people in 2003 to 308,800 in 2015, a 71.6% increase that amounted to 27.7% of the total agricultural workers in 2015. The income from this transferred employment accounted for 44.3% of the regional average per capita disposable income of farmers (Human Resources and Social Security Bureau of Guyuan, 2017). Thus, with the irresistible trend of rural labour transfer, the importance for employment functions of their land would be continuously decreasing.

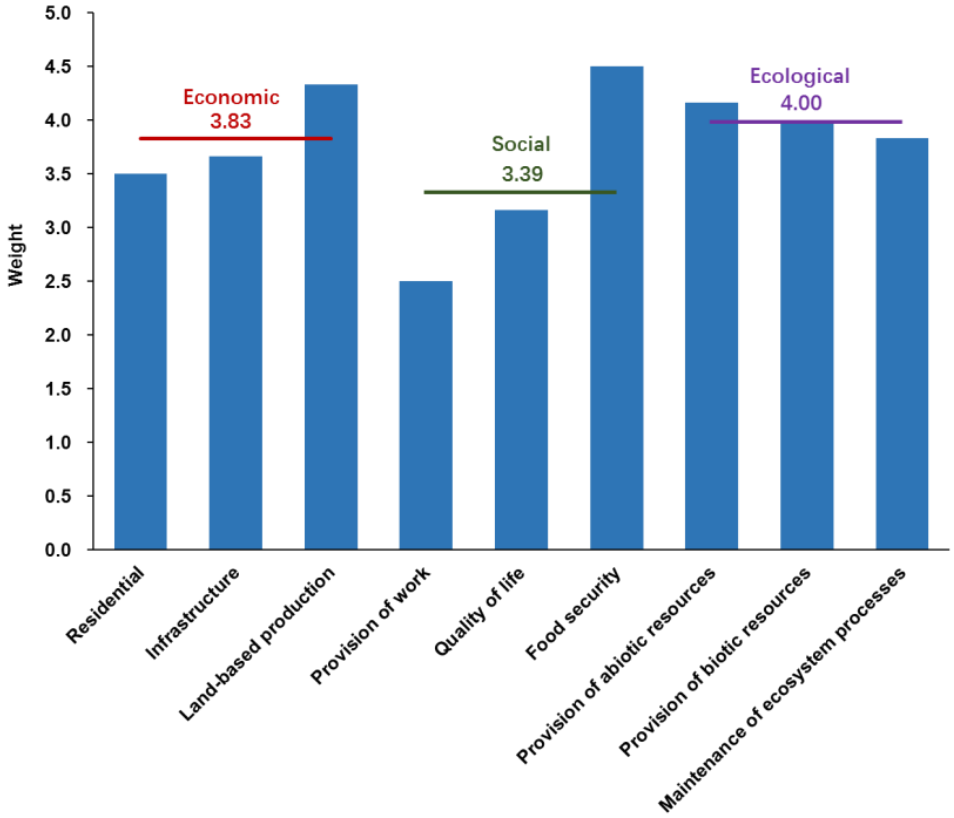


Figure 16. Land use functions in each of the three dimensions of Guyuan, China.

3.2.2 In Godagari, Bangladesh

Priorities of LUFs by the participants

Policymakers/ experts considered most of the social and economic land use functions as most important in the past land use system (20 years back) compared to present time, while environmental land use functions perceived higher preference at present (Figure 17).

Social function priorities

Given social function priorities, SOC1 was considered to be moderately important (3.38) because people have the opportunities to work in rice mills, handy crafts, cottage industries, bamboo and cane industries, and poultry farms. Higher income from the diversified sources acts as a key driving force for the scoring of SOC2 at present (3.05). At present, despite considerable progress in food grain production in the Godavari, immense pressure of growing population and sustainability of irrigated rice production have been made SOC3 higher importance (4.38). Instead of tremendous advances in modern cultivation technology, participants thought that local land use technology as a means of cultural and aesthetic values (SOC4) was convenient to save the environment, though they did not forget to recognise the sanctify of modern technology. Therefore, the scores given by the participants on SOC4 at present (3.33) seemed logical.

Economic function priorities

Based on the survey and workshops, land-based production (ECO1) was considered much more important at present followed by infrastructure and transport (ECO3) and artificial or non-land based production (ECO2). At present, most of the people in the study area are dependent on modern agriculture. Therefore, opportunities for higher involvement in various activities believed that modern farming especially cereals crops obtained from their field had higher importance (4.62) for their daily consumption and income sources. At present, agricultural production is pretty well, which need to export other parts of the country even in abroad that closely linked to good communication and transport systems. Therefore, the scores (3.50) on ECO3 seemed rationale. The diversified production from the

agricultural field needs to process well. Therefore, the establishment of the various agro-processing centre, food industries, fruit industries, etc. are an imminent need. Thus, the moderate priority (3.47) given by the participants on ECO3 LUF is justifiable.

Environmental function priorities

It is interesting and worth mentioning that in case of environmental functions, policy makers/ experts have given much priority to those land use functions that need to maintain an urgent basis for a sustainable environment. 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, for the present time, water was considered as a basic input for producing cereals and many other crops, particularly during the Rabi season. The sharp increase of irrigated area supports the notion of this agreement. Therefore, the higher priorities (4.40) given by the participants for present land use system regarding ENV1 LUF seemed accurate. 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. Moreover, overuses of agrochemicals terminated the aquatic habitats. All of these factors had influenced participants to give the higher importance (3.65) in respect of ENV2. Correspondingly, participants gave the higher priorities (3.84) to ENV3 at present. Application of fertiliser and agrochemicals have increased agricultural production, and it has been reported that 25% of the total applied agrochemicals are being a runoff and mixed into soil and water bodies of the study area, and are responsible for declining the aquatic biodiversity including land fertility. On the other hand, hot summer with undulating 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 had immense importance on agricultural production in the near future, it will lead to meteorological and hydrological droughts in the surrounding environment as the sign has already been noticed. Based on all issues, the highest priorities given by the participants on ENV3 at present seemed plausible.

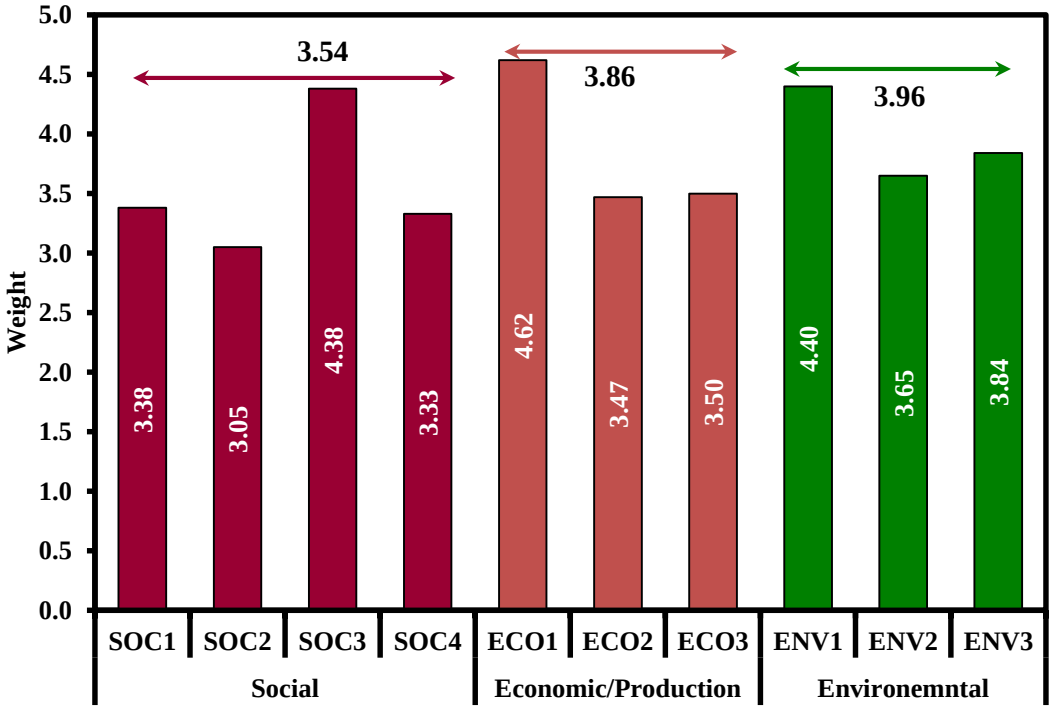


Figure 17. The priorities of LUFs assigned by policymakers in Godagari, Bangladesh

3.2.3 In Noto, Japan

Overall, the participants considered the economic LUFs as most important (3.8 – 4.0), followed by the social LUFs (3.0 – 3.8) and the environmental LUFs (3.5 – 3.8) because the economic dimension is the basis of the livelihood (Table 7).

Economic function priorities

The functions of land-based production (ECO1) and non-land based production (ECO2) were highly perceived (4.0) in the region because land-based agricultural activities and non-land based activities such as the manufacture of agricultural and fishery products have been centred more than hundreds of years regarding economic, social and cultural in this area. Since the land was designated as GIAHS site, nature and cultural based tourism is a central industry in the area. Thus tourism services (ECO3) was also recognised as land-based and/or non-land based economic function (3.8).

Social function priorities

Based on the review of policy measures in the master plan, quality of life (SOC2) was selected as essential functions as well as the provision of work (SOC1), food security (SOC3) and cultural identity (SOC4). Due to the trend of ageing society, less participation of young people is causing the enervation of the communities. During key informative interviews and workshops, most participants mentioned that maintain rural communities with some children is the ideals of future society. Thus the quality of life (SOC2) was highly perceived (3.8) as well as the provision of work (3.5). The area is well known as traditional agricultural district based on diverse bio-cultural activities (e.g., crop variety, traditional craft skills), the functions of food security and cultural identity are also perceived by the participants (3.0).

Environmental function priorities

As environmental dimension, provision of abiotic resources (ENV2) was highly perceived (3.8) followed by provision of biotic resources (ENV1) and maintenance of ecosystem processes (ENV3), which are weighted as 3.6 and 3.5 respectively. The area has a sufficient quantity of rainfall, but some parts of the area are limited to access to water resources to maintain paddy field production. Biodiversity loss and deterioration of ecosystem functions are a critical concern in the rural area due to less land management throughout the country. Thus ENV1 and ENV3 are also perceived by the participants.

Table 7. LUFs and corresponding assessment indicators in Godagari, Bangladesh

Dimensions	Land Use Functions (LUFs)	Weight	Explain	Indicators
Economic	ECO1. Land-based production	4.0	Provision of land for economic production from land including agricultural and forest products.	Agricultural production amount Income from agriculture Crop variety
	ECO2. Non-land based production	4.0	Fishery and product processing	Production amount Income from fishery Number of catch species
	ECO3. Services: Tourism	3.8		Number of tourists Income from tourism Capacity (Number of tourism facilities)
Social	SOC1. Provision of work	3.5	Employment opportunities for economic activities based on natural resources.	Number of population in Agri. Number of population in Fishery Number of population in Tourism
	SOC2. Quality of life	3.8	A ‘good’ living standard with families	Number of Children/Schools
	SOC3. Food security	3.0	Access to and availability of sufficient quantity and quality of food.	Self-sufficiency rate
	SOC4. Cultural identity	3.0	Local activities, e.g., traditional craft, harvest festival	Number of cultural (traditional) event

Environmental	ENV1. Provision of biotic resources	3.6	Provision of habitat and biodiversity and factors affecting the capacity of the land to support regional biodiversity.	Vegetation area
	ENV2. Provision of abiotic resources	3.8	The role of land in regulating the supply and quality of soil and water	Per capita water resources Water quality
	ENV3. Maintenance of ecosystem processes	3.5	The role of land in the regulation of ecosystem processes related to the production of food, biodiversity conservation, soil health and ecological supporting functions	Landscape Index

3.3 Changes of LUFs in the past 20 years

3.3.1 In Guyuan, China

3.3.1.1 Changes of LUFs in the past 20 years

In the past 20 years, LUFs in economic dimension and environmental dimension have got positive assessment result (Figure 18). However, LUFs in the social dimension, especially SOC1 (provision of work, -2.00) and SOC3 (food security, -0.14) seem negative in the past 20 years. The most import reason might be that the increasing trend of young generations choose to work off farm and land use efficiency is induced owing to the loss of labour. Furthermore, the trend of agricultural land abandonment is more and more severe in Guyuan, where initially have bad quality of soil and high deep slope. Thus, the job opportunities agricultural land could provide is significantly decreased, and the following food security has been threatened. Accordingly, ECO3 (land base production) and ECO1 (provision of abiotic resources) also resulted in a low score in 0.57 and 0.43 respectively.

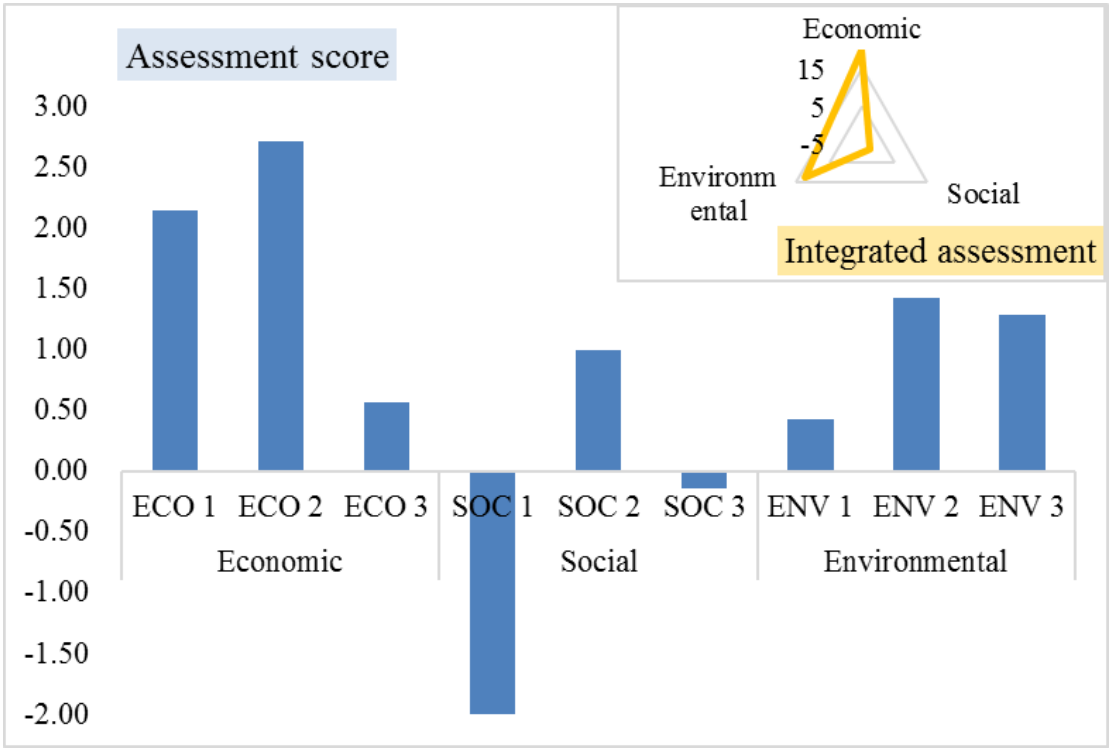


Figure 18. Impact assessment in the past 20 years in Guyuan, China

In summary, the loss of labour force in the rural area and the increasing agricultural land abandonment is tough problems arisen in the past 20 years and has reflected the negative impact on regional LUFs, especially for social dimension. Effective measures and land policy are urgently needed to release the problems and keep the regional balance development.

3.3.1.2 Analysis the impact and consequence of land use policy

In China, the Chinese government has attempted to deal with widely distributed severe soil erosion and land degradation and to relieve the pressure on ecosystems by implementing a nationwide program since 1999, namely the Sloping Land Conversion Program (SLCP). Under this program, the government has attempted to convert cultivated land or barren land on steep slopes into grassland and forests, thereby protecting the land against soil erosion and further degradation. However, implementation of the SLCP has removed much agricultural land from production, thereby significantly decreasing grain production in many regions, especially in western China, the region that has the largest area of cultivated sloping land, and the grain loss was expected to reach 50% (Feng et al., 2005; Zhen and Du, 2017). Furthermore, with rising wages for non-agricultural work and an increasing number of ageing workers on farms, abandonment of agricultural land is accelerating (Liu et al., 2014; Zhang et al., 2014), thereby jeopardising China's food security. In 2011 and 2013, 13.5% and 15.0% of China's agricultural land was idle (Gan et al., 2015). Another serious problem is that the land which is not entirely abandoned (i.e., set the land as their fundamental safeguard, or because of the need to feed themselves) is usually cultivated and managed by women and elderly family members (Gu et al., 2009). Just as Bachelet stressed [36], women are the backbone of the development of rural and national economies. They comprise 43% of the world's agricultural labour force, which rises to 70% in some countries. It is a fact that rural women are the main contributors to food production. This is not, however, sufficient to meet future needs (Ajadi et al., 2015; Saquina Mucavele, 2015). Increasing involvement of women and aged people in land cultivation practice in rural China is potentially a serious problem inhibiting further improvement in agricultural production (Gu et al., 2009; Zhao, 1999). Faced with these problems, the government has proposed a program of rural land transfer (RLT) to promote more rational and effective utilisation of agricultural land and prevent agricultural abandonment (Du and Sun, 2011; Wu et al., 2008).

RLT refers to the rural agricultural land use right circulation (i.e., change) in China. It was proposed in the 1980s to mitigate the inefficiency of decentralised land operation and has evolved from individual and irregular land management to regional and organised management (Table 8). Under RLT, people who accept responsibility to manage land must do so under the collective ownership of the land (the government still owns the land but the agent of land management is changed under contract) and must not change the land use away from agriculture. If they meet these conditions, they can subcontract, lease, exchange, or otherwise to circulate the land usage right (Ministry of Agriculture of the People's Republic of China, 2005; State Council of the People's Republic of China, 1995). The process is voluntary rather than imposed. RLT does an excellent job of meeting the requirements of modernised agriculture, as it is market-oriented, large-scale, mechanised, and information-based. However, while promoting the RLT in a region, little attention has been paid to the influence of this program on land use and regional sustainable development.

Table 8. Evolution of rural land transfer programs in China

	I: Spontaneous	II: Exploratory	III: Standardized
Period	1980s	Late 1980s to the 21st Century	Since the 21st Century
Region	Coastal regions and the areas surrounding large cities	Expansion to central and western China	Across the country
Form	Land contracts awarded to households, Individual consultation and collective adjustment	Spontaneous transfers of land, Transfers of land organised by village committee	Development of large farm households, Development of agricultural enterprises, Collective management
Main regulations	Household responsibility system	A system of contracting separately for grain-production fields (take	Abolishment of the agricultural tax,

	agricultural tax) and responsibility fields (take agricultural and contract fee)	Law of Rural Land Contracts

3.3.2 In Godagari, Bangladesh

3.3.2.1 Changes of LUFs in the past 20 years

According to the expert's opinion, environmental land use functions got a positive assessment in all cases (Figure 19). However, social land use functions particularly SOC2 (quality of life) and SOC3 (food security) seemed negative in the past; ECO3 (infrastructure or transport) also got a negative assessment. Predominantly, farmers in the past practised mainly rainfed agriculture, which solely depends on rainfall and used to limit the crop yields as well as the intention to cultivate diversified crops, which leads to food insecurity and less income; thus the quality of standard life could not be maintained. Peoples in the past used traditional methods like a yoke to cultivate their land as well as practised broadcasting seed sowing method, and therefore, the positive assessment given by the experts seems credible. Product processing centre development is intricately associated with crop production and transportation facilities. However, some traditional rice-processing centres were developed then but few people were engaged with, and the transportation and infrastructure were bad in the past. Therefore, the assessment given by the expert seems plausible. Even though irrigation facilities had been started at more than 20 years ago, but not explored much like the present, and people had some other opportunities to irrigate their fields from different water sources like bees, canals, ponds, and rivers, which put less pressure on groundwater usage. Similarly, peoples used no/fewer agro-chemicals as they produced crops only one season (due to rainfed nature); therefore, the aquatic environment remained ecologically sound. Due to fewer disturbances to the land and limited infrastructural development, the overall environment in the past was good, and thus the higher positive scores were given by the participants on environmental land use functions seemed rationale.

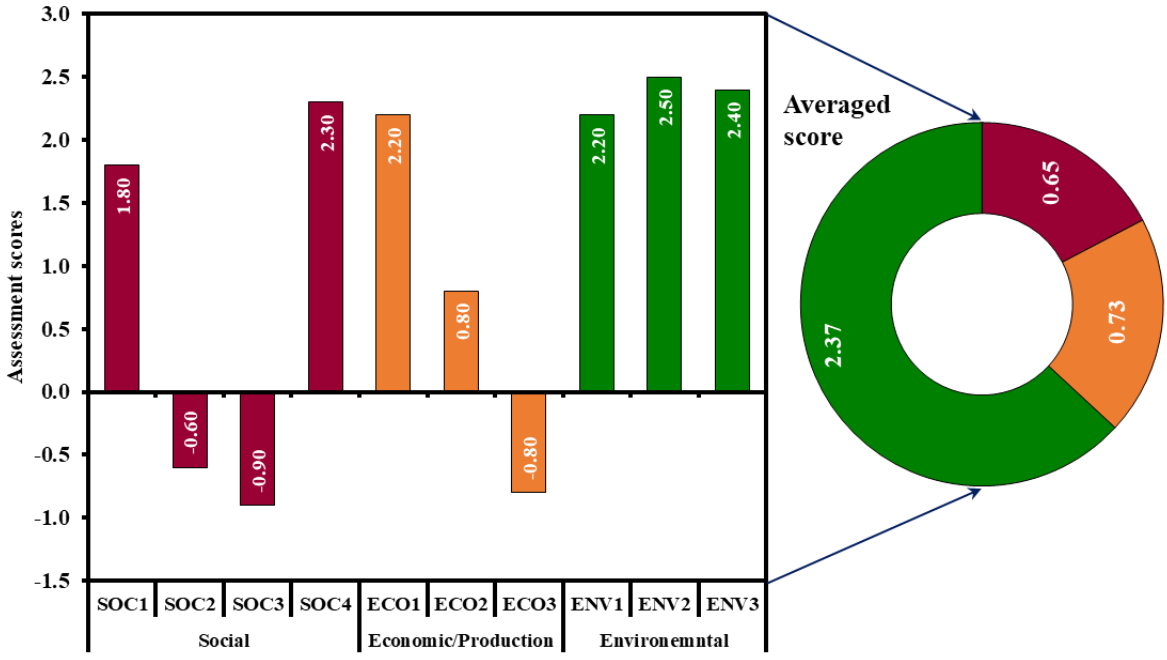


Figure 19. Impact assessment in the past 20 years in Godagari, Bangladesh

3.3.2.2 Analysis the impact and consequence of land use policy

In respect to assessing the land use policy in Godagari, the questions were designed to focus on the land usage conditions, willingness to use land management methods, sustainable and environmental land usage and food security.

Before 1985, the potential for the agricultural development in High Barind Tract (HBT) was considered almost zero and area was considered not suitable for development. About 55 % area of HBT is rainfed (Ali, 1998). A few private deep tube wells were available but buying water from these was very expensive for the farmers. It used to cost 3,000 to 3,500 BDT to irrigate one 'bigha' (approximately 0.13 hectare). Transplant Aman (T. Aman) rice was the major crop in case of rainfed farming in the past, which regularly suffered due to early or late drought and planting of the post-rainy crop. Nation-wide rice production losses due to drought in 1982 were about 50% more than losses due to flood in the same year, particularly in the HBT >80% T. Aman rice production was lost (Islam et al., 2010). The 1997 drought caused a reduction of around 1 million tons of food grain, of which about 0.6 million tons were T.Aman, entailing a loss of around $ 500 million ((Islam et al., 2010)). Thus, the livelihood of the area was vulnerable to climate change particularly to drought (Ali et al. 2007). It was also evident from our survey that peoples were not willing to practice rainfed agriculture (T.Aman) as it gave a lower annual income of BDT 37, 800-2, 55, 000/= from 0.40-2.29 ha of land.

Today, agriculture is the main occupation in the region, and approximately 80 per cent of people in HBT are involved in farming due to the development of an underground irrigation system. In recent years, the irrigation facilities have further expanded, which created the opportunity to cultivate modern varieties of different crops with modern method of cultivation which increased yields. It was also manifested in our survey that people now cultivated T. Aman, Boro, Aus, Maize, Wheat, along with other crops with the augmented facilities of irrigation. It is worth noting that in 1985, cropping intensity of HBT was 117% and 166% in 1992-93, whereas present (2016-17) cropping intensity of this area is 223%. The survey results showed that people could earn BDT 13, 200-10, 20, 000/= from 0.03-5.26 ha of land.

Although about 1.5 million farmers are benefited from the irrigation systems, the over-extraction of groundwater from deep tube wells have created concern among farmers as well as the research community and policymakers. Earlier, the depth of tube-well was 35 feet, but now it required to go 120 to 140 feet deep to get water level in the area. The water level had gone down 20 feet in 1985, 30 feet in 1995, 66 feet in 2010 and 135 feet in 2017. Moreover, survey results indicated that extensive use of pesticides and fertilisers for intensive rice crops, poor sanitation, rapid industrialisations, brickfield instalment, poor drainage facilities, and intensive crop cultivation lead to deteriorating air, water and soil quality of the locality. Therefore, though it gives good yields and income at present, it will not be sustainable.

On the other hand, fruit tree-based farming systems have come of age to solve the on-going problem at a certain level as it conserves soil moisture, improve soil fertility and water holding capacity, besides proving year-round source income and nutrients. Our survey results also depict that peoples could earn BDT 1, 43, 000-13, 04,000/= from 1.52-7.21 ha of land.

3.3.3 In Noto, Japan

3.3.3.1 Changes of LUFs in the past 20 years

The scores of indicators in past decades in the region were assigned with stakeholders (Table 9). Most stakeholders mentioned the decrease in the number of children and personal relationship with young peoples in the communities, which affect primal industries, cultural events at the local scale, while tourism industry and accessibility to the cities were well improved by developing infrastructures in the past decades.

Table 9. Scores of indicators in the past 20 years of Noto, Japan

LUFs	Scores (-3 – +3)
Quality of life/Family	-2.0
Community environment	-1.0
Culture	-0.5
Primary industry	-0.5
Secondary industry/ Tourism	+1.0
Provision of work	+1.0
Provision of abiotic resources	+1.0
Provision of biotic resources	-1.0
Agricultural landscape	-1.0

3.3.3.2 Analysis the impact and consequence of land use policy

In the questionnaire survey, over half of respondents responded as the positive effect of payment system for Agriculture (Figure 20). However, about 20% of respondents mentioned that the current payment system is effective on land maintenance but not on crop production. Considering the negative scores in social and environmental aspects, improvement of the payment system was highlighted during the workshops.

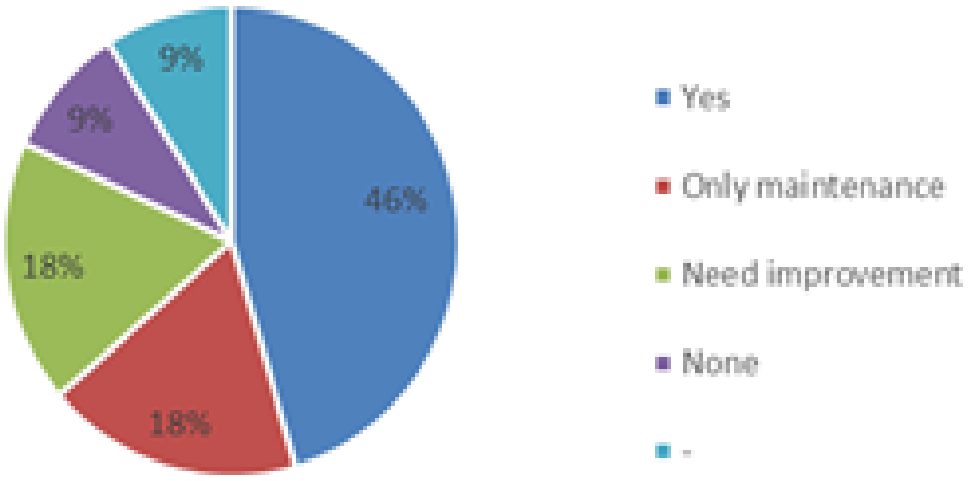


Figure 20. Effect of the payment system (% of the respondents) in Noto, Japan

3.4 Scenarios impact on LUFs

3.4.1 In Guyuan, China

3.4.1.1 Impact Assessment of the LUFs in FoPIA

When we synthesised the results, the order of impacts was RLT scenario (26.98) > BAU scenario (16.19) > ALA scenario (5.71). RLT earned the highest score; it reflected the superiority of this approach for achieving sustainable regional development. Regarding the three dimensions (Figure 21), RLT got the highest score in the economic and social dimensions, but the lowest score in the ecological dimension (2.79). In contrast, the ALA scenario earned the highest score in the ecological dimension, but the lowest score in the economic and social dimensions. The BAU scenario had intermediate values for all three dimensions.

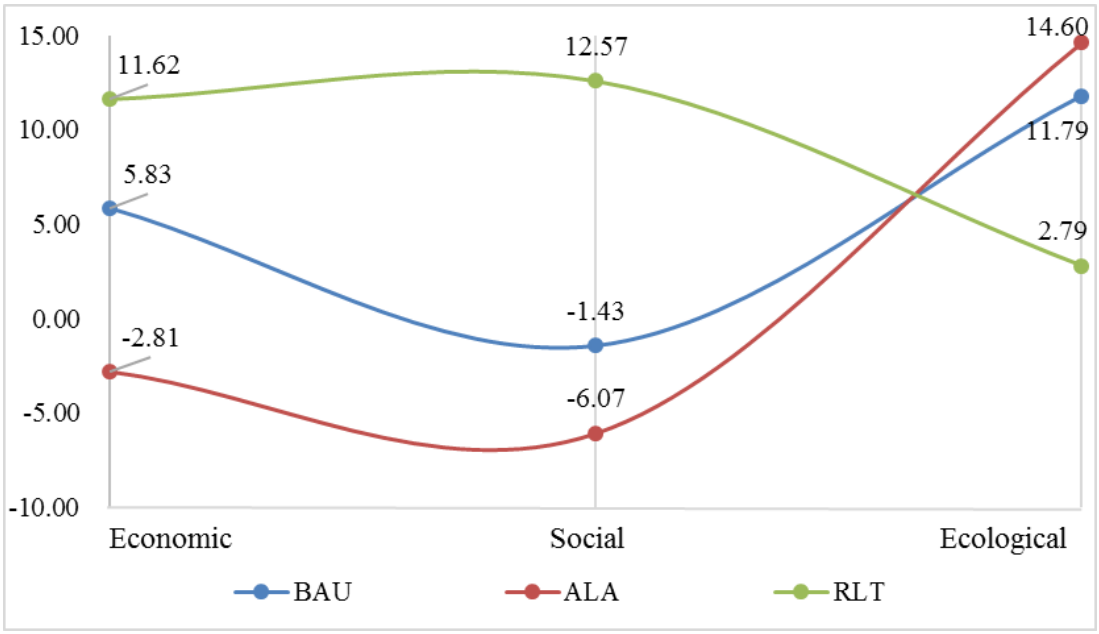


Figure 21. Impacts of the three scenarios on the land use functions' three dimensions (predicted values in 2025) in Guyuan, China. Scenarios: ALA, agricultural land abandonment; BAU, business as usual; RLT, rural land transfer.

Figure 22 synthesises the impact assessment results and the key informant interview results to clarify the details of our assessments further. In the economic dimension, the most contributing function is land-based production, followed by infrastructure and residential. RLT could improve this function from negative under BAU and ALA to positive, with the most dramatic increase reaching 208.8% compared with ALA. This is because the transfer of cultivated land in the RLT program and start the concentrate using of cultivated land, and allocated with irrigation facility and machines by big farming households or companies who rent the land, would significantly improve the quality of the land, especially in the aridest areas. For example, in Yang Lang Village, implementation of RLT increased the proportion of irrigated land from 50.0% to 86.1%, decreased the proportion of abandoned land from 13.9% to 4.0‰, and at least doubled the crop yield in irrigated land compared to that in rainfed fields.

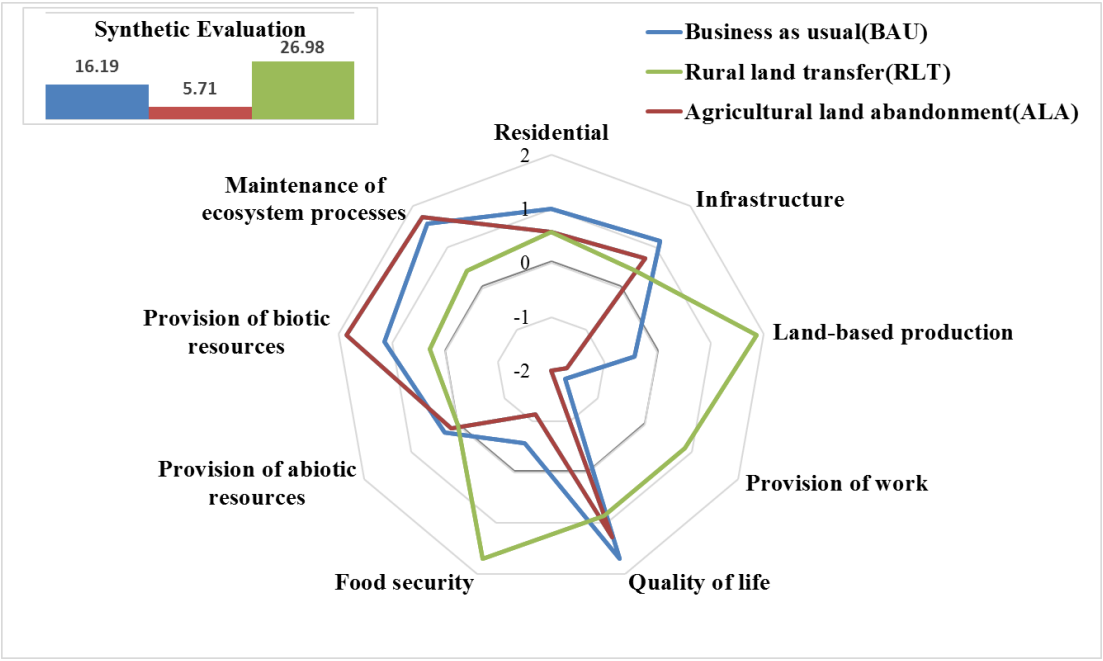


Figure 22. Impacts of the three scenarios on the land use functions (predicted values in 2025) in Guyuan, China

In the social dimension, the impacts in the BAU and ALA scenarios were all negative, and the ALA scenario produced a 148.3% worse outcome than the RLT scenario. The most important reason is likely to be the trend of increasing numbers of farmers wanting to leave their village, leading to increasing amounts of land being abandoned. One driver of this trend is that the income from rural employment transfer has increased tremendously in Guyuan, from 0.64×10^9 CNY in 2003 to 4.62×10^9 CNY in 2015, representing an average annual increase of 51.8% (Human Resources and Social Security Bureau of Guyuan, 2017). This had been a significant way for farmers to earn more disposable income. The low benefits and high costs for farmers on poor-quality land provide a strong motivation to work less in agriculture or even abandon their land. Another driver is the increasing value attributed to education. In Guyuan, 67 middle schools were all built in the region's city centres (Guyuan Bureau of Statistics, 2016a). To attain a good education, parents tended to move to cities to accompany their children and also get a temporary job. With less strength in agricultural work and more abandonment of their land, the importance of the provision of work function would weaken and food security would be threatened. However, in the RLT scenario, farmers would be willing to continue working on their land, because with the help of machines, the work would become easier, they could finish the work faster, and they could double their income from renting the land and wages. This is profit for the provision of work function and could ensure or even improve the quality of life and food security functions.

In the ecological dimension, the BAU and ALA scenarios would benefit from the environmental protection projects and natural recovery that occurs after the abandonment of land under these scenarios, which is why they had higher positive impacts than in the RLT scenario. Since 2000, the SLCP has increased the regional forest cover from 35% to 73% and has increased the regional grassland cover from 12.8% to 22.2%, for a total increase of 3.11 × 105 ha in the whole Guyuan. The trees and grasses planted during this program will gradually mature and enhance the provision of biotic resources and the maintenance of ecosystem processes LUFs (Wang et al., 2005). At the same time, the abandonment of land in the ALA scenario will permit natural recovery of the ecosystem, which would promote the maintenance of ecosystem processes LUF (Sulieman, 2013; Zhang et al., 2015). Also, some of the experts expressed uncertainty about the impact of RLT owing to the homogenization, i.e., to cultivate a single kind of plant in a large scale, which might not be good for the maintenance of ecosystem processes. However, some of the experts were optimistic about the balance between economic development and the short-term use of single plant types, since they argued that this approach is ecologically beneficial because it makes better use of the land than abandoned farmland (Keenleyside and Tucker, 2010).

Although the experts affirmed the positive synthetic impact of the RLT scenario on regional sustainable development, they also emphasised the provision of employment function. Some believed that although farmers can continue to work on their own land, with the improvements permitted by mechanised farming, the requirement for human labour would be limited (Wang et al., 2016). National statistics show that both the area of cultivated land and the area of land harvested by machines increased by 4% and 9% annually, respectively, from 1990 to 2012 (National Statistical Bureau of China (NSBC), 1985-2013). That is, fewer workers can produce more food because of increased productivity. Therefore, this trend does not provide employment compared with the period dominated by individual farming with a heavy reliance on manual labour. Others believed that direct employment provided by the land is generally decreasing, but that the dependence of farmers on this LUF is also decreasing owing to the transfer to other forms of employment. According to our household survey in the five villages, 32.6% of family members had an off-farm job, and this proportion was increasing. Thus, the existing provision of employment LUF appears able to meet the current employment needs of farmers.

3.4.1.2 Stakeholder Perceptions of rural land transfer and Comparison with Expert Assessments

Details of the assessments of the RLT program's impacts on the LUFs varied among the five villages owing to the different landforms and local conditions (Figure 23b–f).

Ma Ying village (Figure 23e) had the maximum weight (0.72) in the economic dimension because it is located in a hilly area, so that most of the cultivated land is in steep slope or far from the farmers' homes; as a result, farmers here engaged more on lands while gaining little benefit. For example, the average maize yield was 1500 kg/ha, which is 27.4% of the average yield (5467.48 kg/ha) for Guyuan as a whole in 2015 (Guyuan Bureau of Statistics, 2016a). Thus, the economic functions that the land provides so they can meet the basic needs for life are the primary dimension.

Xia Yuan village (Figure 23d) had the most significant proportion of impacts on the social dimension (0.33). This can be explained by the fact that the tableland in this village is much easier to manage than hilly land; as a result, 93.8% of the farmers preferred to plant the tableland by themselves, and 59.4% of the households choose to work simultaneously in town according to our survey. Considering the off-farm jobs that helped the villagers to meet their economic needs, the tableland was preferred to provide the food security LUF and to ensure the quality of life, both of which belong to the social dimension.

Da Mazhuang village (Figure 23c) reflected the high impact of the RLT on both the economic (0.53) and the social (0.23) dimensions. This can be explained by two common phenomena in this suburban village. First, due to the short distance from the village to the nearest city (around 8 km), farmers were used to working in the city and cared more about the economic function when they transferred land. In our survey, 76.7% of the households had part-time jobs in the city, and 67.4% received most of their income from off-farm work. As a result, they relied less on the land, even though the income and production from the land remained fundamental elements of their livelihood. Second, our key informant interview revealed 400 households in Da Mazhuang, but more than 120 of these families had moved into cities temporarily. The main reason was that they worked in the city so that they could accompany their children to school, but they will return to their village and work on the land after their children graduate from high school. Therefore, they considered their land as the final insurance for their work and livelihood, and they paid more attention to the social functions of the land.

In Yang Lang village (Figure 23b), with relatively good economic conditions, villagers also considered the ecological impacts of land transfers. The majority of the farmers thought that the RLT program had improved the land quality and ecological function.

In Sheng Li village (Figure 23f), which had the smallest land size because it was mainly located on stony mountainous land, the villagers cared less about the RLT. However, they believed that if the government promoted the RLT, they would think highly of the ecological LUFs because of their relatively good environmental experience due to a long period of planting trees under the SLCP and tree nurseries for trade.

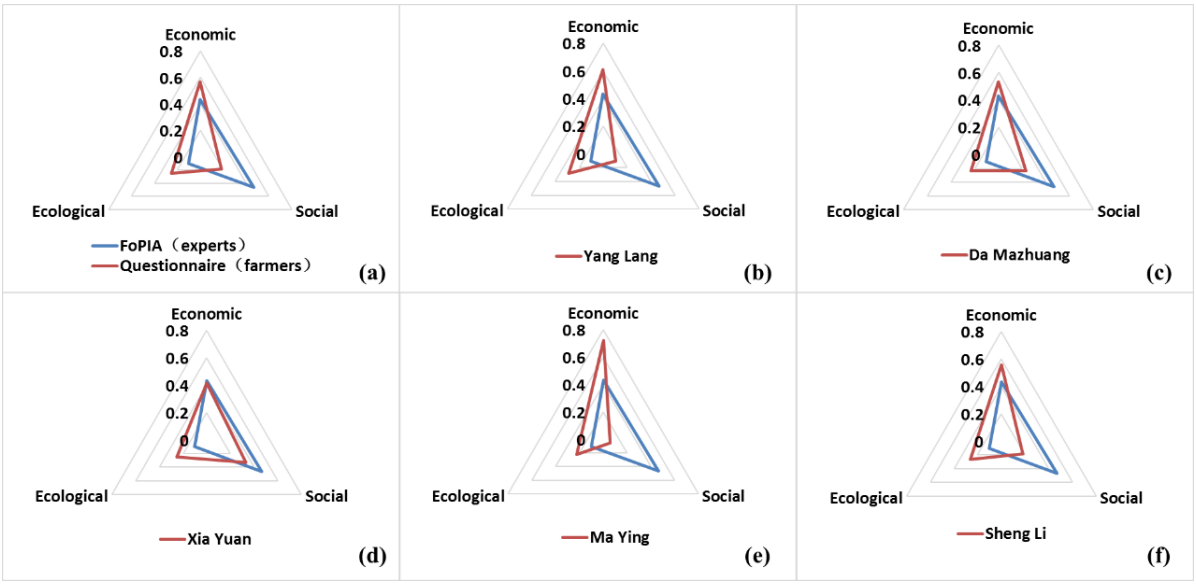


Figure 23. Comparison of the perceptions of the rural land transfer impacts between experts and farmers in Guyuan, China

The experts in the FoPIA (Figure 23a) assigned the highest weight to the social dimension, with a total impact score of 0.47, which was nearly five times the value (0.10) they assigned to the ecological dimension and slightly higher than the value (0.43) they assigned to the economic dimension. However, the rates reflected in the farmer questionnaires were different: the farmers assigned the dimension rankings in the following order: economic (0.57) > ecological (0.25) > social (0.18). Therefore, there were two obvious differences between the experts and the farmers: the experts gave more than twice the weight assigned by farmers to the social dimension, whereas the farmers gave more than twice the weight experts assigned to the ecological dimension.

This may be because experts had more of a regional than local perspective, and therefore believed that the RLT program could solve the problem of land abandonment and improve the food security LUF. For example, Yang Lang village is a typical successful test site, since the transferred cultivated land, which used to suffer from frequent drought, has been turned into irrigated land. As a result, the yield of potatoes from these lands increased from around 5247.38 kg/ha to 14,992.50 kg/ha, an increase of 185.7%. It is also possibly because the farmers emphasised the ecological dimension based on their experiences. For example, Sheng Li village assigned the highest rate of the five villages to the ecological dimension in the RLT scenario (0.26). This village has been planting trees for 15 years under the SLCP and has developed tree nurseries for more than 10 years. As a result, farmers experienced visible improvement in their environment, and 62.9% of the farmers expressed the belief owing to the afforestation, the number of animals and plants had increased. In addition, due to the implementation of irrigation and land restoration under the RLT program, the land's ability to maintain ecosystem processes was much greater, especially when compared with the land that was about to be abandoned. The quality of 160.33 ha of cultivated land had improved from "bad" or "medium" to "good" according to the questionnaire results for Yang Lang village, which accounts for 33.3% of the total land in the village.

We identified three issues related to the implementation of the RLT program. First, not all of the farmers were willing to practice RLT. In Sheng Li village, for example, the average land area cultivated by a household was only 0.44 ha, and they preferred to develop tree nurseries, as this consumed less time and energy. Thus, the RLT is meaningless for them. Second, not all of the agricultural land could be transferred. For example, in Ma Ying village, 84.0% of the farmers favoured the RLT, and their willingness to transfer related strongly to the rent. However, because they mostly had access to inferior

quality hilly land, few companies or households wanted to rent their land, and the rent they would have received was low. Third, with relatively good quality tableland, farmers preferred to plant by themselves using machines, without disturbing their urban employment, and they were able to consume their own organic cereals, thereby making good use of the land's ability to improve their quality of life.

3.4.2 In Godagari, Bangladesh

The evaluation results of three major land use dimensions showed that social functions (Wsoc) were not adequately supported by the rainfed farming system (0.03), while highly supported (9.95) by fruit tree based farming system and moderately supported (5.66) by the irrigated farming system. Poor impact of rainfed farming system to these social LUFs might be attributed to the limited access to the market for buying food, and use of traditional land use techniques. Comparative evaluation of different economic LUFs indicated that fruit tree based farming provided more support (LUFs=26.88), compared to irrigated (LUFs=22.11) and rainfed farming systems (LUFs=14.23). The higher positive impact of fruit tree based farming on economic LUFs might be due to the higher economic return obtained from the year-round diversified crops as well as from exporting of harvested crops/fruits to other areas including abroad. Similar to the economic LUFs evaluation, the fruit-based farming system also efficiently supported the environmental LUFs (Wenv) (-5.91) compared to irrigated (-14.91) and rainfed farming systems (-11.49). Fruit tree-based farming systems had a moderately positive impact on soil fertility by adding leaf litter, which might have accelerated in close and efficient nutrient cycling system and, thereby, augmented soil fertility status. Moreover, litterfall might have accelerated floor cover to the soil surface that helps conserve soil moisture (Rahman et al., 2018).

In crux, all of these land use dimensions results manifested that fruit tree-based farming systems (30.92) provided more support to land use functions compared to irrigated (12.86) and rainfed farming systems (2.78) (Figure 24).

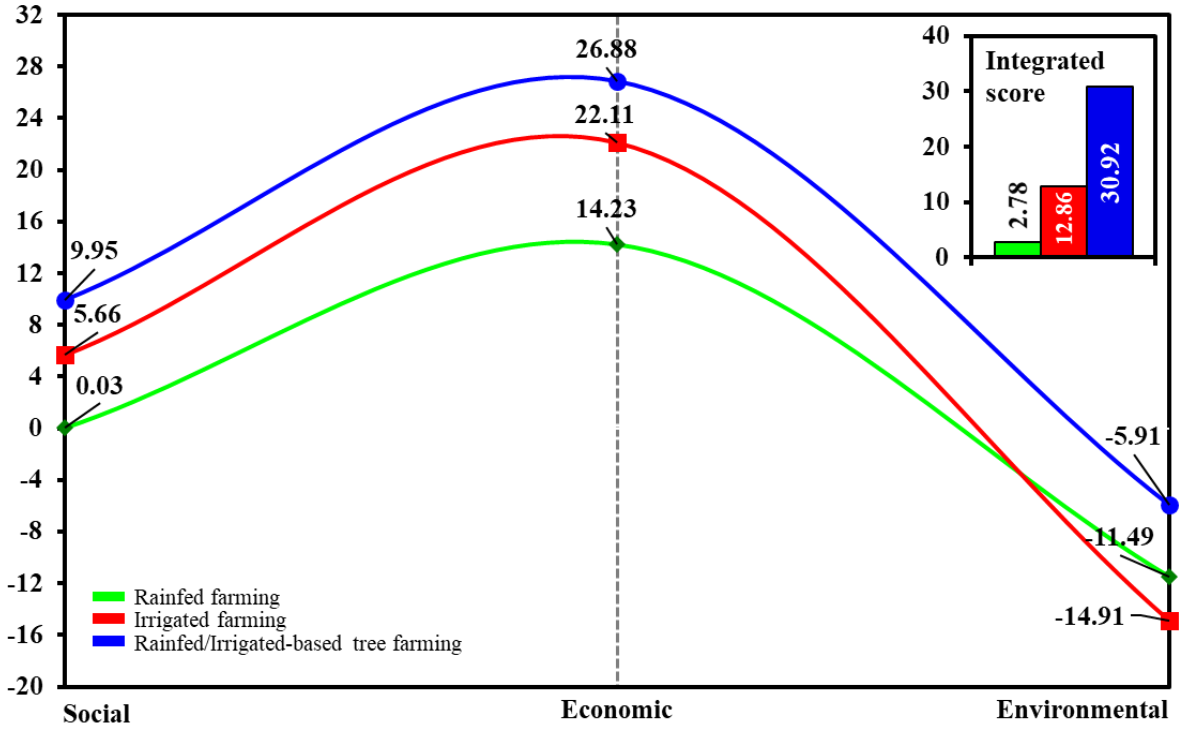


Figure 24. Impacts of the three scenarios on the land use functions of three dimensions in Godagari, Bangladesh

In order to get insights into the rationale of the impacts of three scenarios on each land use function under three dimensions of land use, we also assessed perception-based scores on each land use function indicators.

In respect of social functions indicators, practising fruit tree-based farming system received a higher benefit (1.48) compared to irrigated (1.24) and rainfed farming systems (1.10), given the percentage of employment in agriculture (Figure 25). Predominantly, rich and educated farmers practised year-round fruit farming system, which required a higher number of labour for both fruit harvesting and processing including crop management compared to the other two systems. Therefore, the higher values attained in tree-based farming seemed rationale. Experts opined that fruit tree-based farming system had many opportunities (2.00) in providing diversified food items, for instances fruits, cereals, vegetables, etc., therefore, had greater prospect to enhance per capita food availability in tree-based farming compared to irrigated (1.76) and rainfed farming systems (1.52). Fruit tree-based farming system had a great opportunity to enhance income, and, therefore, have relatively high opportunity (0.28) to access the market for their daily needs. While farmers practising crop farming in rainfed condition have relatively low income due to the paucity of rainfall and use of traditional varieties. Traditional farming methods like use of yoke, broadcasting seed sowing method also severely hampered the rainfed farming (-1.64) relative to irrigated (-0.72) and tree-based farming (-1.40). Lower negative scores in irrigated farming systems regarding the traditional way of farming might be associated with mechanisation in agriculture and water in irrigated farming acts as a key driving force towards boosting crop yield either it is local or HYV.

Scoring of economic land use function indicators as affected by three farming systems showed (Figure 25) that fruit tree-based farming system presumed 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 a higher value for the potential of exports of fruits and ultimately higher income generation compared to that obtained from irrigated (1.74) and rainfed farming systems (1.30). Establishment of several fruit-based industries and good transportation facilities may play a promising role in processing and export agricultural commodities and the socio-economic improvement of the area, which have been reflected in the present study by showing higher positive impact in fruit farming system (2.25 and 2.36, respectively) as compared to irrigated (2.20 and 1.84, respectively) and rainfed land use systems (1.14 and 1.22, respectively).

Scoring of environmental land use function indicators showed that fruit tree-based farming system had a moderately 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 (Figure 25). Continual foliage addition from the fruit tree-based system may have enhanced the microbial activity of the soil and, therefore, might have improved the soil fertility status as observed by Miah et al. (2017). The irrigated farming system had an extremely negative impact (-2.74) on groundwater indicator as 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 a lower negative impact on soil moisture (-0.32) indicator due to the scope of applying irrigation water. Whereas, higher negative affect regarding soil moisture (-2.32) in the rainfed farming system was found because of arbitrary rainfall pattern, while 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 had a high negative impact (-2.40) on water quality because of extensive application of agrochemicals in irrigated crop fields as compared to rainfed (-0.97) and fruit tree-based farming systems (-0.16). Similarly, higher negative impact (-1.83) on ecosystem biodiversity 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). The land of 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 practised irrigated farming was

chosen for brickfield installation and bricks were made by collecting the fertile topsoil from a depth of about 1 to 2 m, where farmers could grow two or three crops in a year. 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 used to uptake nutrients from the soil and use them for metabolic processes; in turn, plants return nutrients to the soil naturally either as litterfall or deliberately as pruning or through root senescence. Soil microorganisms decompose these plant parts and then release nutrients bound in them into the soil. The nutrients then become available for plant uptake (Rahman et al., 2018).

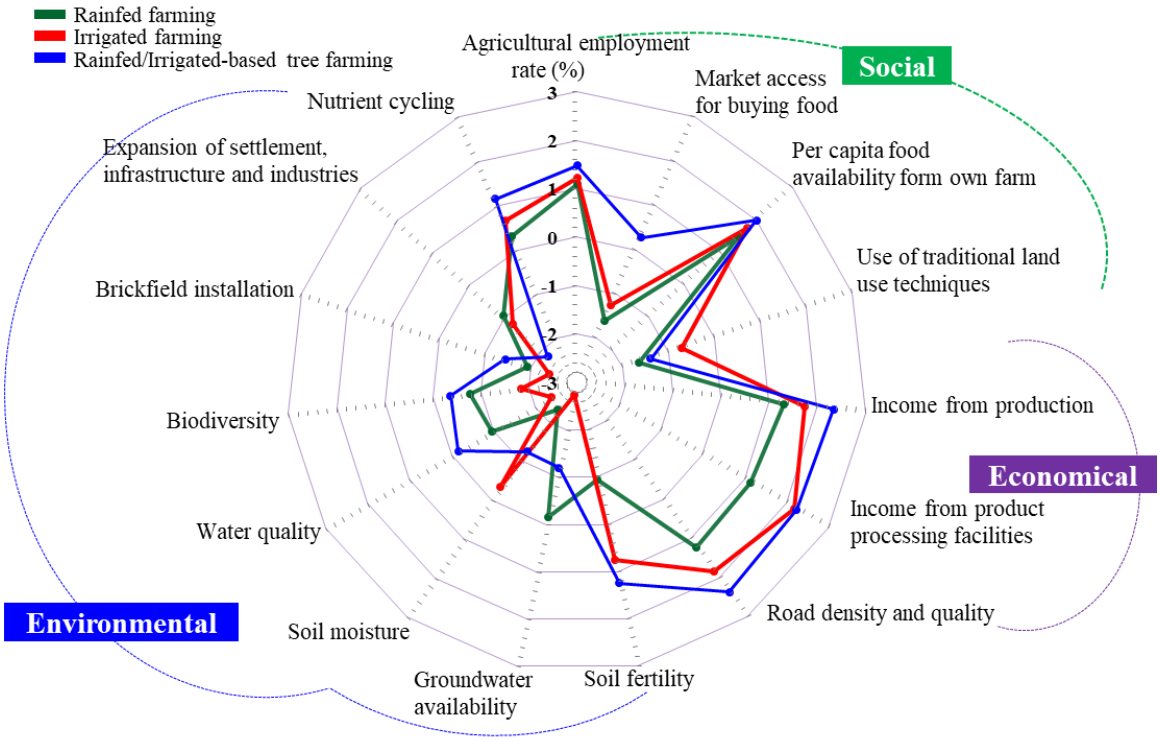


Figure 25. Indicators for scoring of social, economic and environmental land use functions as affected by three farming system in Godagari, Bangladesh

3.4.3 In Noto, Japan

The impacts of scenarios were assessed with stakeholders (Figure 26). NCS scenario aims to improve societal functions as well as keeping the agricultural landscape. PCS scenario aims to improve economic functions. Changes in biotic and abiotic resources are unpredictable due to global environmental changes, e.g., changes in species. Both alternative scenarios developed by experts and policymakers are recognised to improve the economic LUFs; however, PCS scenario tends to be recognised to decline the social LUFs.

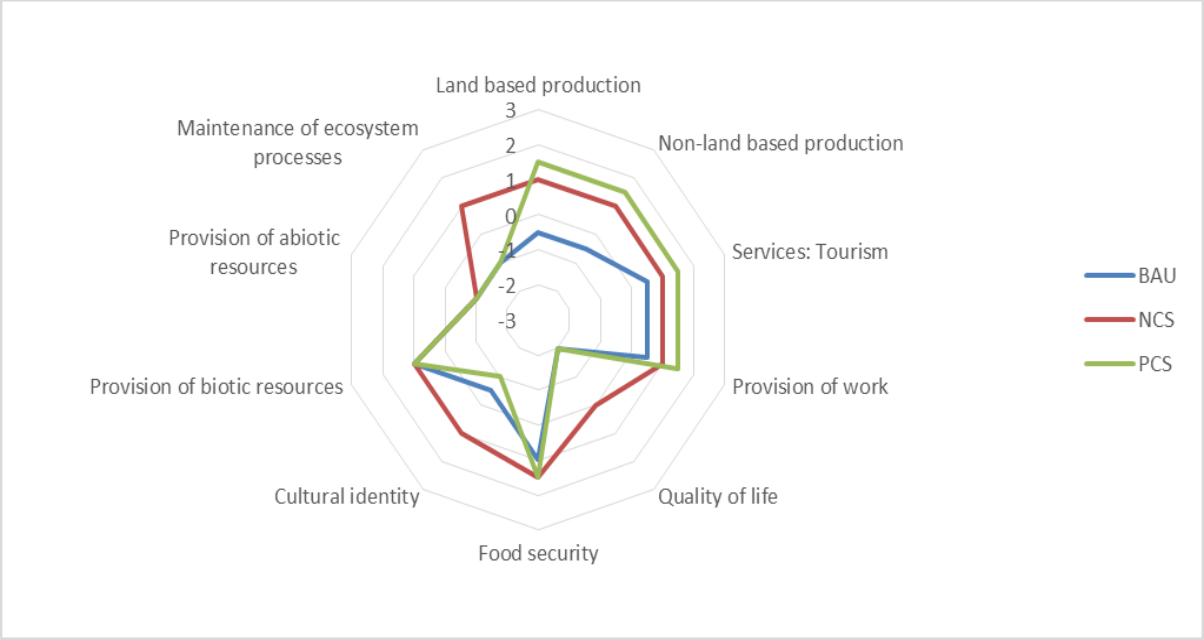


Figure 26. Three policy scenarios impacts on land use functions in Noto, Japan

3.5 LUFs simulation by ABM

3.5.1 LUFs simulation in Guyuan, China

The output of ABM in Guyuan China including the land use land change map, the LUFs visualisation in spatial period, the income from cultivated land, land use states (rent, plant or abandoned) and the working states for farmers (including work off farm or work in the farm). The running and output interface of ABM in Guyuan China is shown in Figure 27.

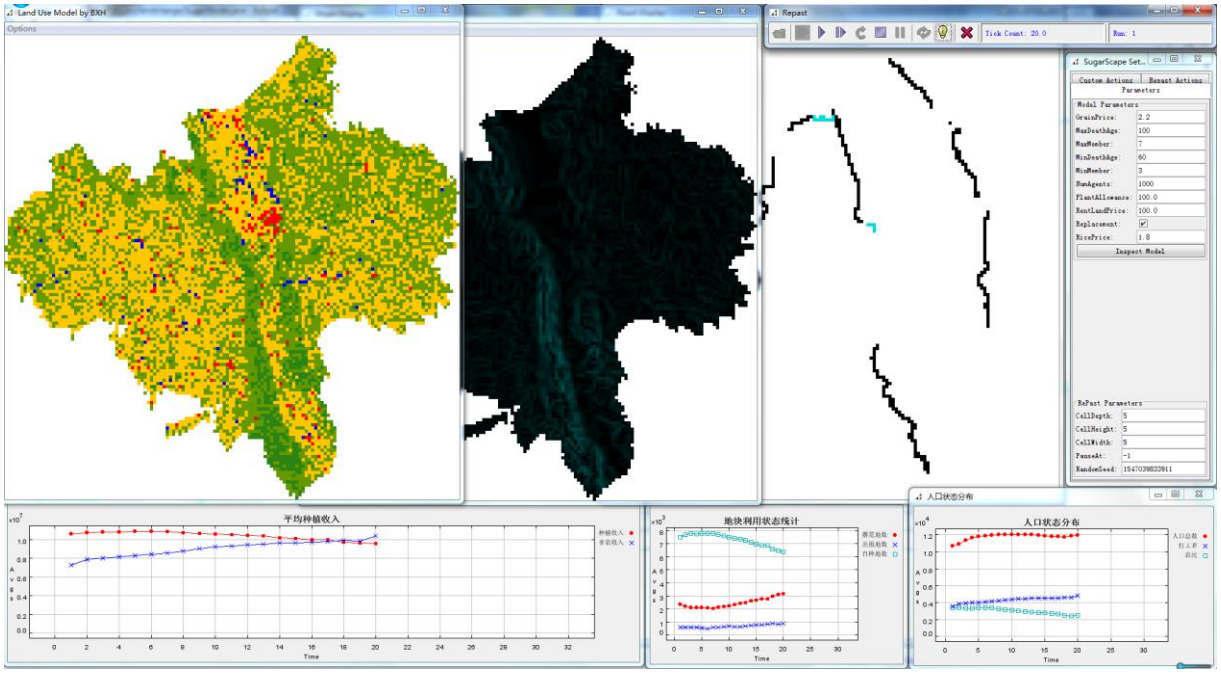


Figure 27. The running and output interface of agent-based model for Guyuan, China

The contribution matrix of land use type and LUFs provide the relationship between the LUFs and its spatial distribution. Figure 28 shows the contribution matrix contained in ABM in Guyuan, China, where cultivated land has the greatest contribution for food security, land-based production and provision of work functions, forests are prominently good in LUFs in environmental dimension,

including provision of abiotic resources, provision of biotic resources and maintenance of ecosystem process, and also reflect an outstanding influence in quality of life function. Also, construction land shows to have great contributions to local residential or non-land based activities and infrastructure, which benefits the manufacturing features.

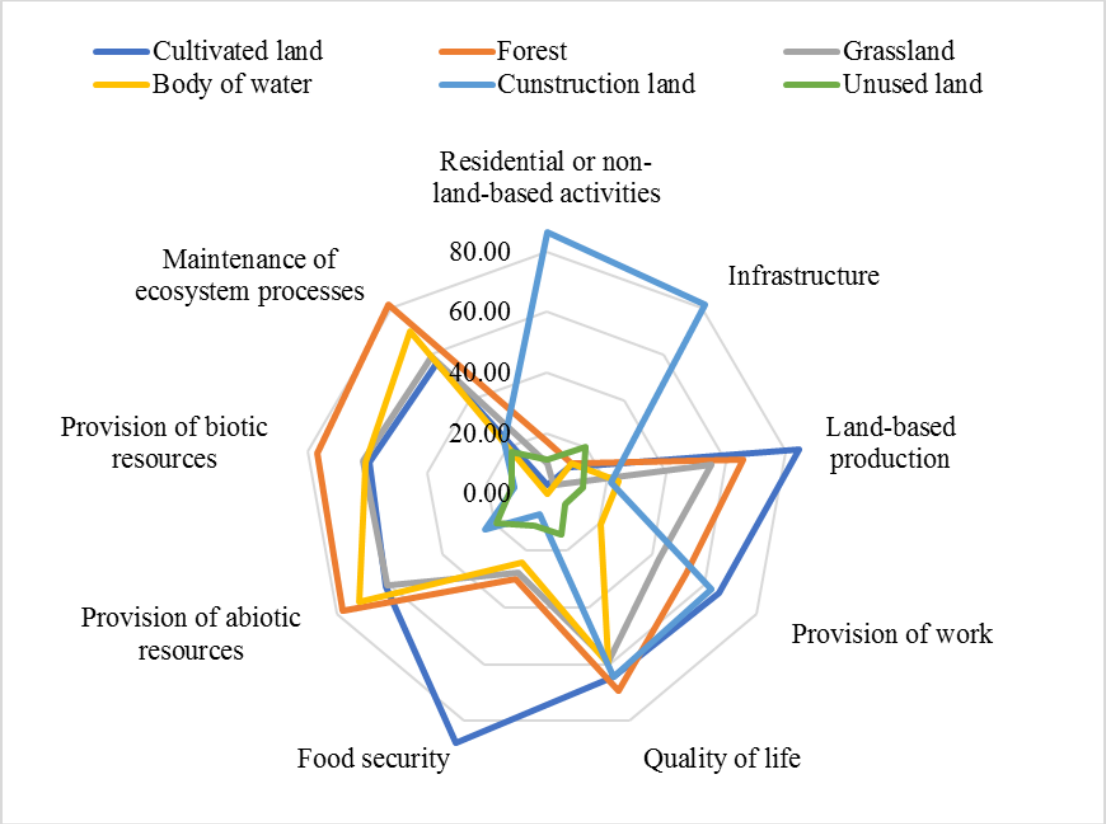


Figure 28. The matrix implemented in the agent-based model for LUFs visualisation in Guyuan, China

From the visualisation results of LUFs in Guyuan (Figure 29), the middle of north part shows the highest integrated LUFs, following with the east part and west part. Combine with the land use simulation results map, this distribution of LUFs seems affected more by the cultivated land, which also revealed the basement role of cultivated land and the agricultural factory in Guyuan. Through the visualisation map for each LUF, we found that the most fundamental or obvious LUFs in Guyuan is ECO3(land-based production) and SOC3(food security). Moreover, the most significant spatial difference is showed in ENV2(provision of biotic resources), which also interpreted the irreplaceable and the importance of contributor, forest, in the middle south part.

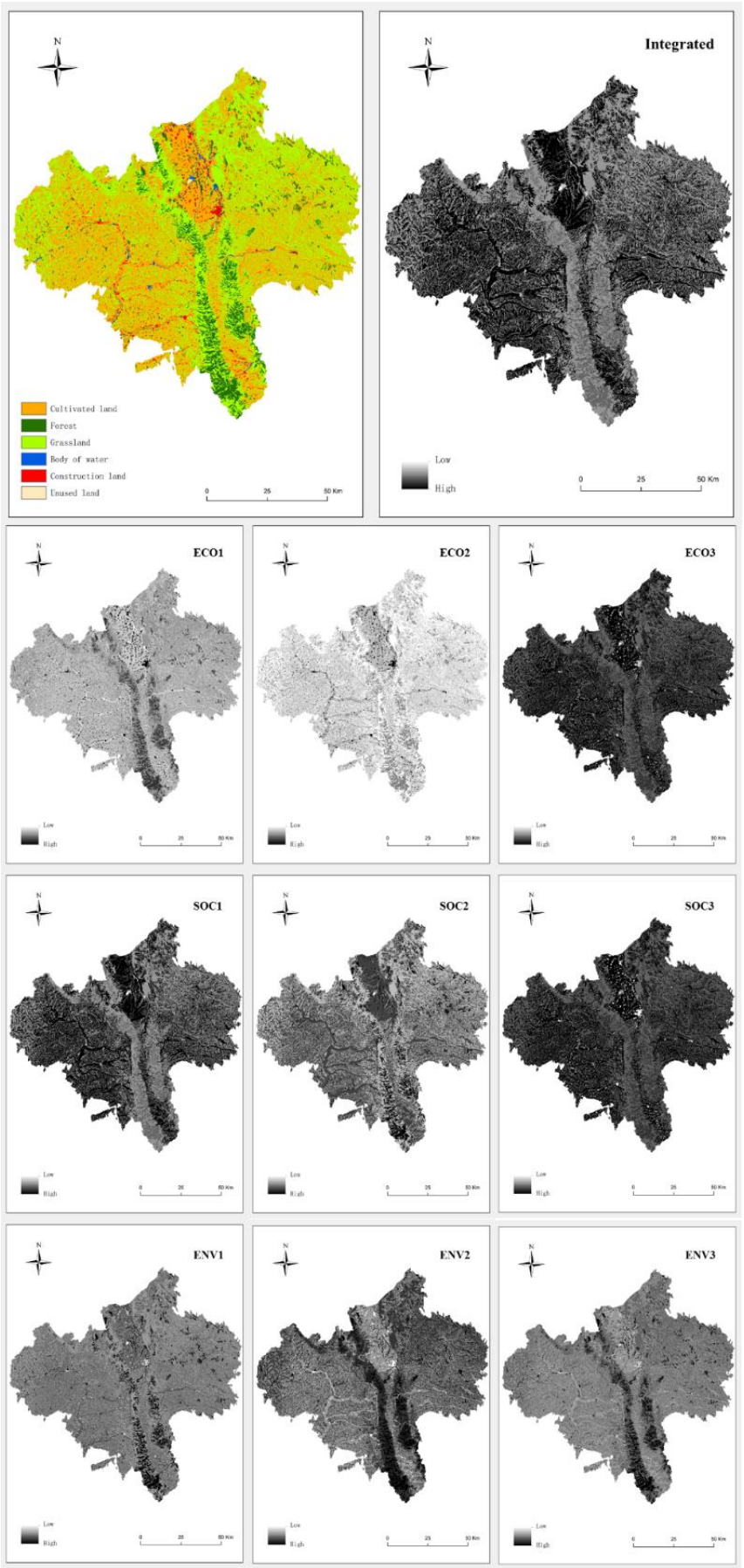


Figure 29. Spatial visualisation of LUFs based on the results of ABM in Guyuan, China

3.5.2 LUFs simulation in Godagari, Bangladesh

The output of ABM in Godagari of Bangladesh including the land use land change map, the LUFs in spatial, the income from cultivated land, land use states (rainfed, irrigated or agroforestry) and the working states for farmers (i.e., which kind of farmers group they belong to). The running and output interface of ABM in Godagari of Bangladesh is shown in Figure 30.

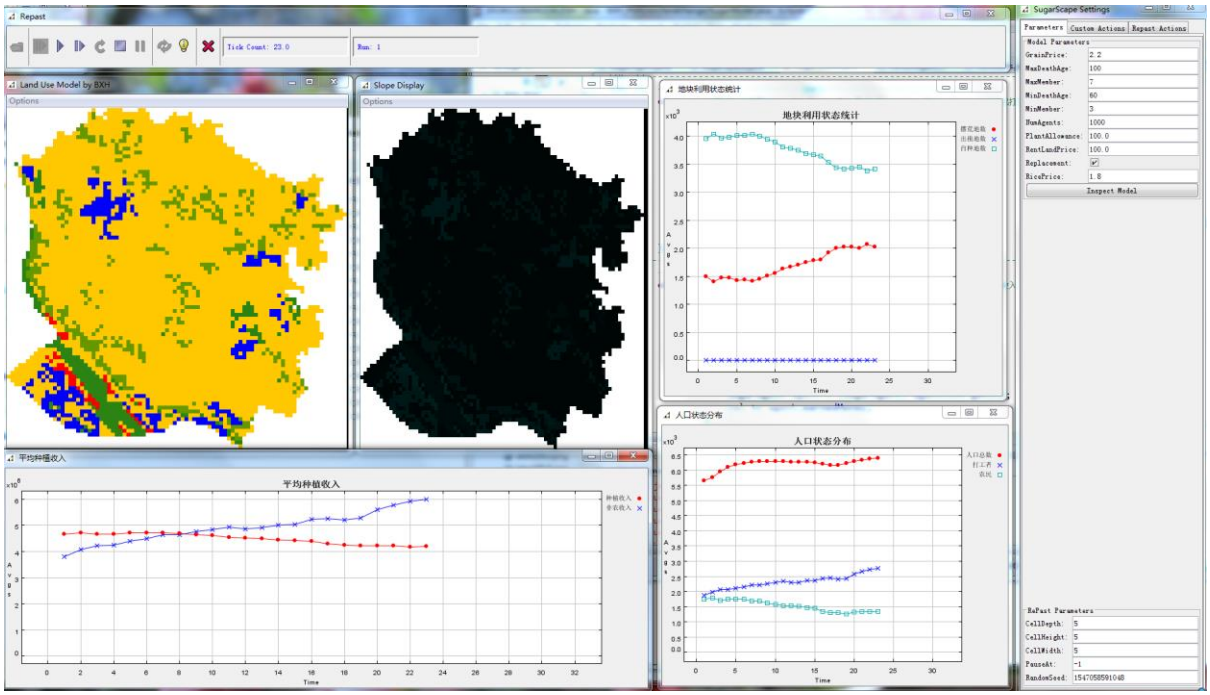


Figure 30. The running and output interface of agent-based model for Godagari, Bangladesh

Figure 31 shows the contribution matrix contained in ABM in Godagari of Bangladesh, which reflected the specific characteristics of each land use types. For the agricultural land, it is mainly contributed to the provision of work, quality of life and human health, food security and land-based production; the water bodies are primary for the maintenance of ecosystem processes and provision of biotic resources; the homestead land use type is the most important for infrastructure or transport and artificial or non-land based production. Moreover, the differences between each kind of land use types are distinct.

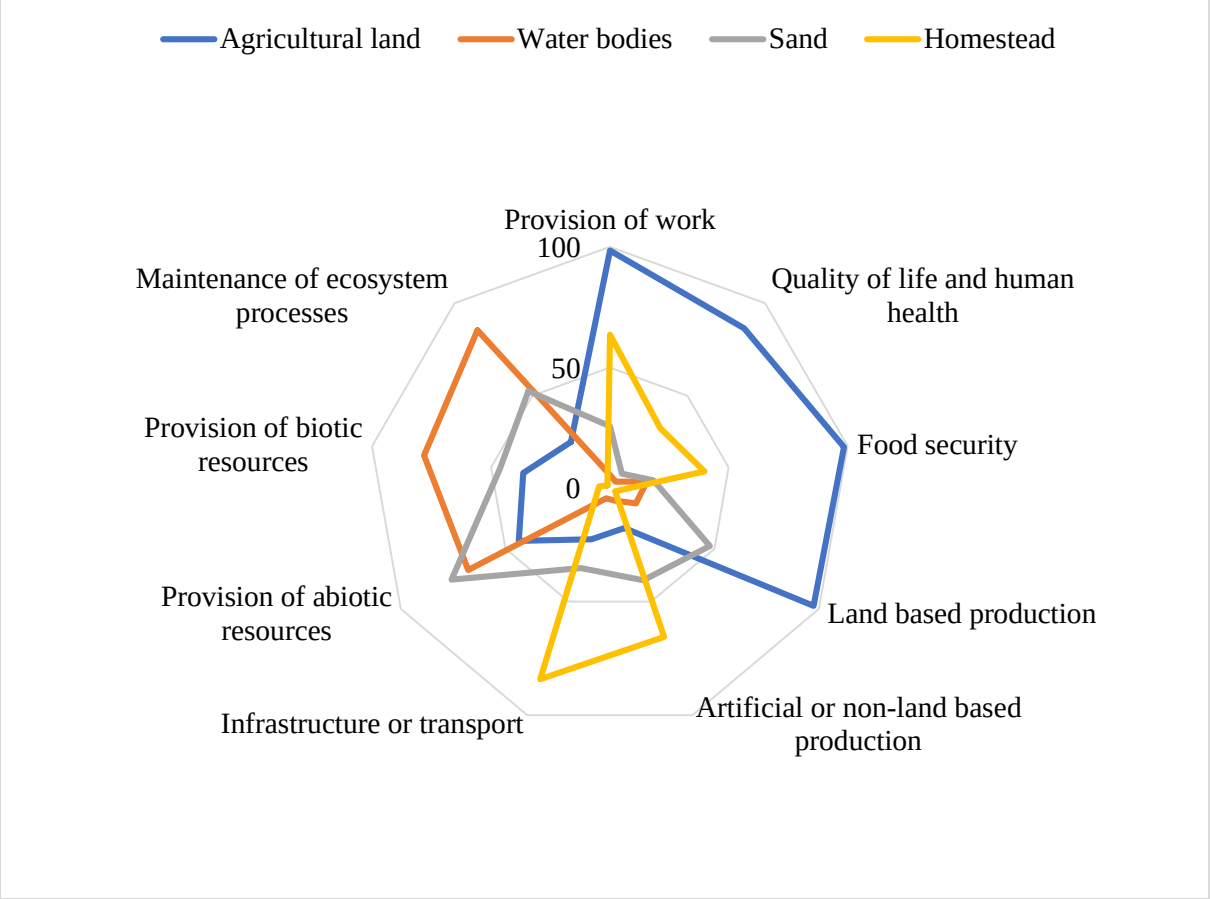


Figure 31. The matrix implemented in the agent-based model for LUFs visualisation in Godagari, Bangladesh

From the visualization results of LUFs in Godagari of Bangladesh (Figure 32), most of the agricultural land has the distinctively high integrated values of LUFs than other kinds of land use types, from the visualization map for each LUFs, they show that the agricultural is outstanding in the SOC1(provision of work), SOC2(quality of life), SOC3(Food security) and ECO1(land-based production). The homestead area, mainly in the northwest part of Godagari, also shows great difference in different LUFs, it has distinct high values in ECO2 (artificial or non-land based production), ECO3 (infrastructure or transport), apparently low value in ECO1, ENV1 (provision of abiotic resources), ENV2 (provision of biotic resources) and ENV3 (maintenance of ecosystem processes), and the middle level of value in SOC1, SOC2 and SOC3.

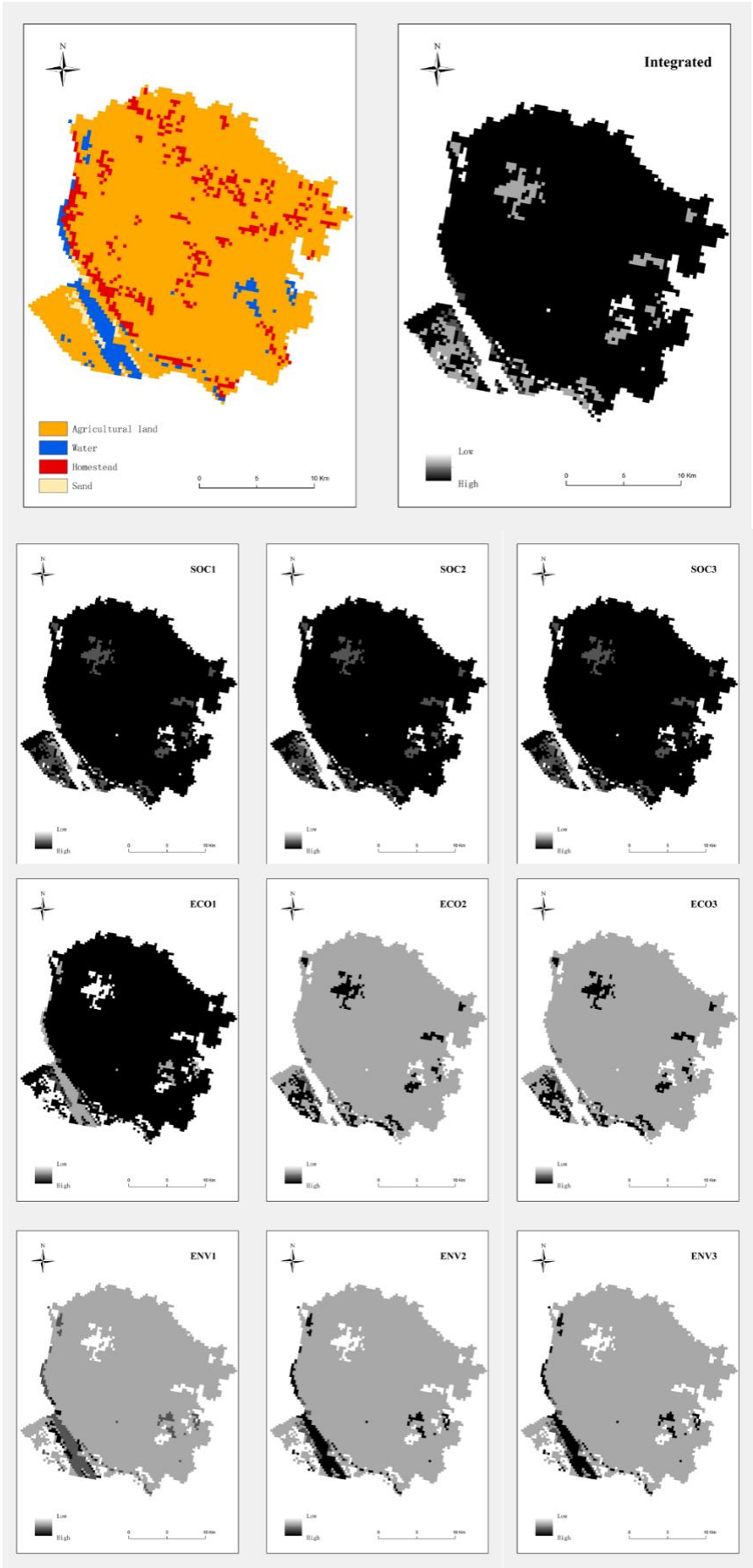


Figure 32. Spatial visualisation of LUFs based on the results of ABM in Godagari, Bangladesh

3.5.3 LUFs simulation in Noto, Japan

Simulated land use from 2020 to 2050 for each scenario are shown in Figure 33. The BaU scenario, which was developed to meet with current national land-use policy, showed a slight decrease of agricultural land corresponding with an increase in bush/grassland area, which indicates an increase of abandoned farmland. NCS scenario, which targets the maintenance of agricultural land and plantation forest with keeping higher populations engaged in agriculture and forestry, showed that the paddy field was maintained while cropland slightly increased. PCS scenarios, which target the intensive use of land, but without any intervention to manage unused land, showed substantial decreases in the paddy field.

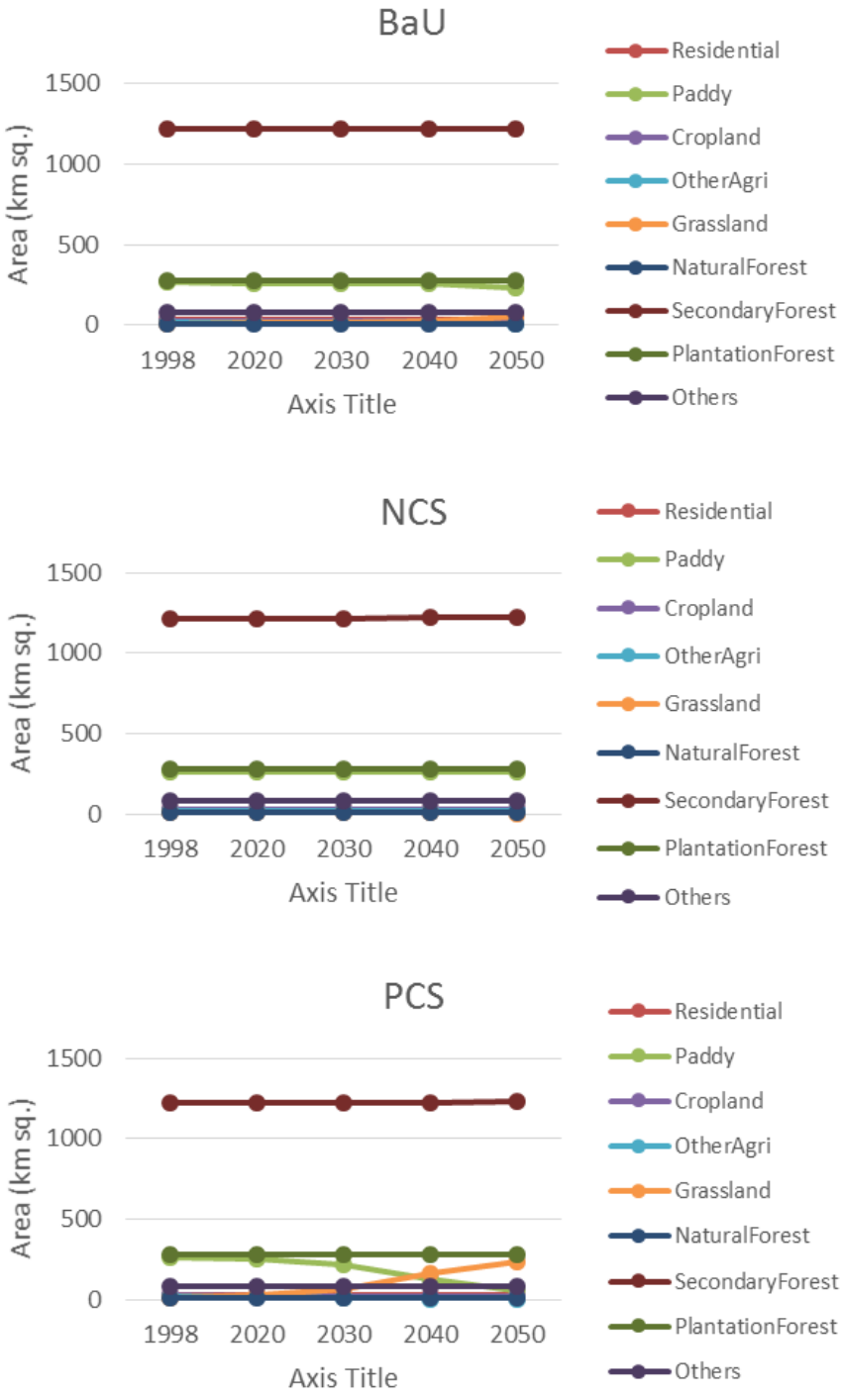


Figure 33. Simulated land use from 2020 to 2050 in Noto, Japan

The category of land use was (1) Residential, (2) Paddy, (3) Crop, (3) Grass/Bush, (4) Natural/Secondary forest, (5) Planted forest and (6) Water. The LUF weighting results are shown in Table 10. The result showed that water had the highest overall capacity (780.7) on LUFs. Participants strongly believed that inland water (rivers, pond and coastal area) had a significant contribution towards economic (fisheries, tourism) and environmental functions (abiotic resources and ecosystem maintenance). Second, the paddy field had the high overall capacity (679.6) on LUFs, followed by crop field (543.9), and especially perceived the value regarding economic function (Land-based production). Notably, the paddy field highly valued as a social function (cultural identity, food security and provision of work), which indicate that the paddy field is recognised as a societal function of the communities because of its long history. Natural/Secondary forest was higher valued (508.6) than planted forest (245.7) on overall functions, especially regarding environmental functions. Considering current situation of less management of planted forest, perceived LUFs provided from planted forest declined except the functions of biotic resources production (timber production). The category of a residential area and grass/bush were relatively lower valued (310.3, 139.8, respectively) because these contribute to only specific functions (residential area contribute to social functions and grass/bush contribute to only environmental functions).

Table 10. Weights assigned to the LUFs for different land use types in Noto, Japan

Dimensions	Land Use Functions	Weight to land use types						
		Residential	Paddy	Crop	Grass/ Bush	Natural/ Secondary forest	Planted forest	Water
Economic	Land based production	5.5	100.0	100.0	0.0	25.3	8.0	6.8
	Non-land based production	3.8	0.0	0.0	0.0	22.0	14.5	100.0
	Services: Tourism	60.5	72.1	42.2	0.0	45.2	21.6	98.0
Social	Provision of work	88.7	85.6	82.1	0.0	2.8	1.4	77.8
	Quality of life	97.3	53.5	22.5	0.0	63.4	12.5	57.8
	Food security	9.9	89.2	76.5	0.0	18.5	15.6	65.7
	Cultural identity	34.0	89.8	83.5	0.0	37.5	29.3	78.5
Environment	Provision of biotic resources	4.1	64.0	68.6	85.7	98.6	86.5	96.1
	Provision of abiotic resources	0.0	58.4	23.0	18.0	95.3	38.5	100.0
	Maintenance of ecosystem processes	6.5	67.0	45.5	36.1	100.0	17.8	100.0
	Total	310.3	679.6	543.9	139.8	508.6	245.7	780.7

3.6 Comparative impact assessment of LUFs on sustainable regional development of three sites

3.6.1 Integrated analysis framework and context of three study sites

3.6.1.1 Study site characteristics

Study sites of Godagari in Bangladesh, Guyuan in China and Noto in Japan (Figure 34) are all located in remote rural areas. This can be defined as being far away from central planning development areas, the major industry is agriculture, and the agricultural lands are mostly present in uplands or sloped lands with slopes greater than 15°, where the farming practices have been strongly affected by regional, national and international land use policies.

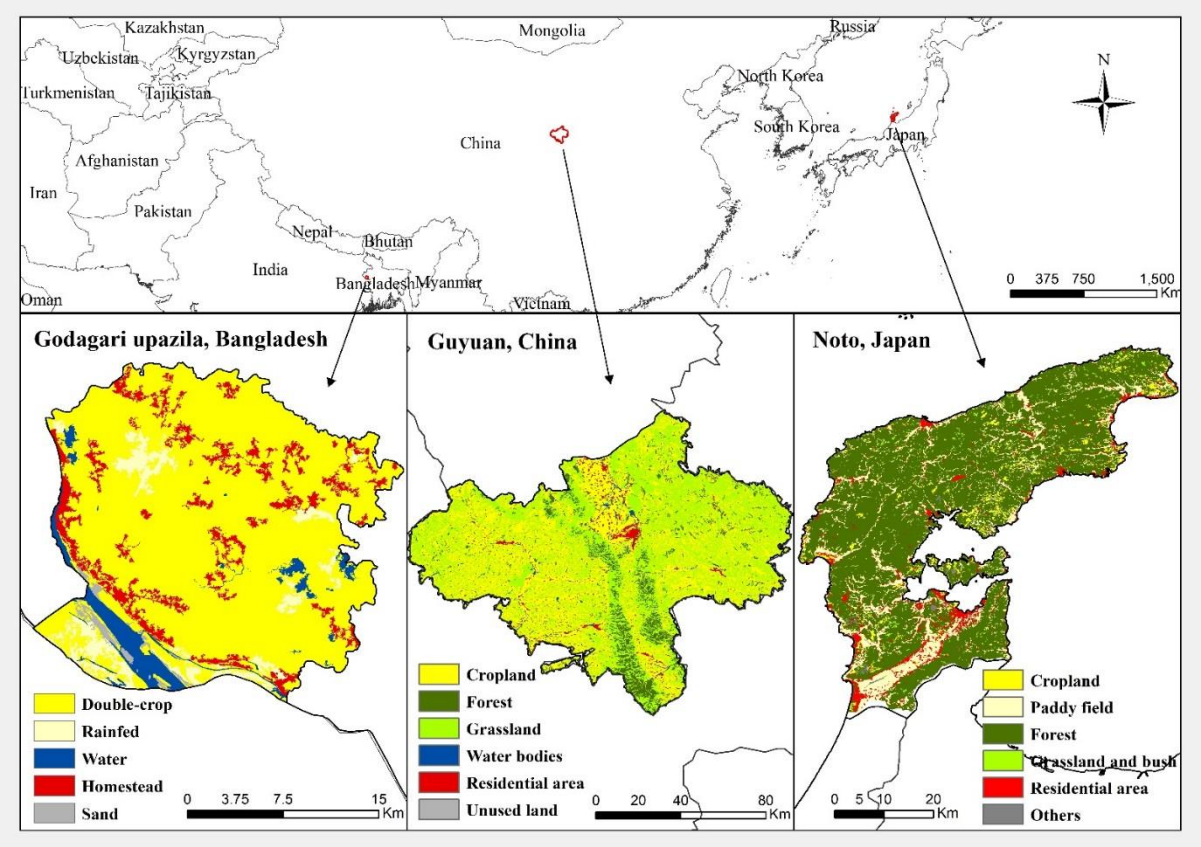


Figure 34. Land use of the three study areas

They show gradient characteristics regarding economic and social dimensions, natural conditions and mainland use problems (Table 11). The lowest amount of arable land per capita is 0.097 ha/person in Noto, and the highest is in Guyuan (0.25 ha/person), which is 2.58 times greater than Noto. The average annual rainfall at the three sites ranges from 492 mm to 2100 mm. The most important land use issue for Barind Tract is improving food security by increasing productivity, while in Guyuan, sufficient and balanced nutritional intake is a key consideration, and agricultural land abandonment caused by reduced labour forces on farmlands has become a challenge. While in Noto, in addition to the high food security requirements of residents and the severe trend of absence of successors in paddy fields, which directly leads to the abandonment of farmlands, Noto has also confronted the loss of cultural inheritance. Young people do not participate in local activities which includes agricultural land practices and cultural events, which is currently the most severe problem.

Table 11. Gradient differences of three study sites

Indicator	Godagari, Bangladesh	Guyuan, China	Noto, Japan	Gradient difference
Landform	70.86% upland	41.64% with slope >15°	49.60% with slope >15°	-
Annual income of household farmer	$4773.69*	$5694.62*	$11,220.12**	↗
Mean annual rainfall	1438 mm***	492 mm**	2100 mm**	↘↗
Arable land per capita	0.10 ha**	0.25 ha**	0.097 ha**	↗↘
Population trends	Increasing	Increasing	Decreasing	↘

Land use problems	- Food security	- Food security - Agricultural land abandonment	- Agricultural land abandonment - Low self-sufficiency rate	-		

* Based on the questionnaire.

** Based on the government agriculture statistics.

***Source: http://climate.barcapps.gov.bd/index.php?p=rainfall

↗increasing trend/ ↘decreasing trend from Godagari, Guyuan to Noto.

Exchange rate (as of 2018): 1 USD=83.6351 BDT; 1 USD=6.9065 CNY; 1 USD=102,227 JPY.

3.6.1.2 Scenarios synthetic arrangement

According to the traditional development disciplines, the three study sites chose their suitable scenario periods independently and set 2030, 2025 and 2050 as the end of their scenario prediction assessment years for Barind, Guyuan and Noto, respectively.

Three types of scenarios were determined. The first one is business as usual (BAU), in which 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 existing at present would still work. The second and third scenarios are both land management or policy scenarios. The second one is increasing agricultural input (IAI). This scenario implies that the government should attempt to improve traditional local agriculture and try to defend the dangers and problems emerging day by day. Generally, these initial and fundamental efforts are mostly based on financial input, e.g., farming subsidies and investments. The third scenario is the reform of rural development mode (RRDM). Experts try to turn the perspective from enhancing current agriculture conditions into finding a new developmental method or building multi-structure agriculture to develop and improve local land management methods. These reforms are not creative or unprecedented and should have successful cases already, and now need to complete evaluations about their impacts on sustainable development (i.e., LUFs) of this specific region, while extensively applying them. Specific hypotheses and definitions of each scenario for each study site have been listed in Table 12.

Table 12. Scenarios defined for the three study sites

Scenario type		Godagari , 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 circulated	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 degrees 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

3.6.2 Comparative results and discussions

3.6.2.1 Land use functions at the study sites

A synthetic analysis of the average weight for the three dimensions of LUFs from each site has shown that the social dimension of LUFs (SOC-LUFs) exhibited the lowest value at all study sites (3.54 in Godagari, 3.39 in Guyuan and 3.33 in Noto) compared with the other two dimensions. In Noto, the economic dimension of LUFs (ECO-LUFs) had the highest value (3.93), while in Godagari and Guyuan, the environmental dimension of 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 (Figure 35).

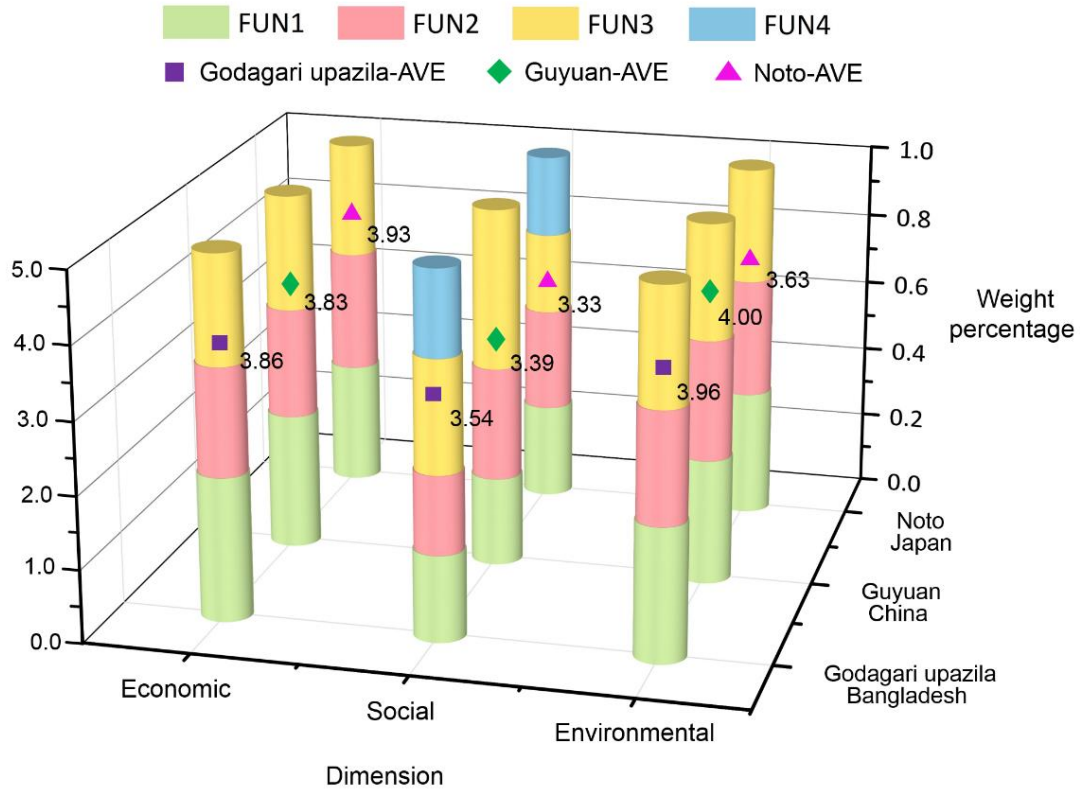


Figure 35. Weights of the LUFs at the three study sites

(FUNn (n=1 to 4) means the nth function at each dimension, specific functions are listed in Table 12. (AVE=average score of LUFs in the dimension of each the study site.)

For ENV-LUFs, experts at both Godagari and Guyuan assigned this dimension with the highest scores (3.96 and 4.00, respectively) compared with the other two dimensions, but with very different reasons behind them: in Godagari, severe land degradation warned people to conserve land in order to improve environmental functioning. As evidenced in the area, water is a necessary 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 levels (Dey et al., 2017), thus a high priority has been given

by stakeholders for the provisions of abiotic resources (4.40). Another aspect is owing to the application of fertilisers and agrochemicals, where approximately 25% of the total applied agrochemicals are being run-off and mixed into soil and water bodies, causing the decline of aquatic biodiversity, including land fertility (Alam, 2016). Thus, with the rising problems, the maintenance of ecosystem processes is much more important at present (3.84). However, in Guyuan, they continuously stress the environmental functions, owing to the fact that they have obtained benefits from landscape protection in past decades through receiving compensations from participation in environmental 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 in Godagari and Guyuan, with an average score of 3.63.

ECO-LUFs were given the highest score in Noto and the middle scores in Godagari and Guyuan. These kinds of differences are all extracted by their traditional backgrounds. First, the three study sites are all rural agricultural regions, and although land management methods are changing over time, land-based production has always been the basic income of local people. According to our survey data, approximately 88.33%, 29.51% and 18.47% of farmers in Godagari, 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. Also, unlike the other two sites, Noto also had nonland-based activities, such as the manufacture of agricultural and fishery products that have been in activity for more than hundreds of years, so they also provide 4.00 to non-land-based production. What's more, since the land was designated as a GIAHS site, nature and culturally-based tourism is a dominant industry, tourism services have become important, with a score of 3.80. Thus, the economic functions of land use in Noto have an extra highest 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 decreasing degree at the three sites are not uniform. According to the statistical data, the population of Bangladesh has increased by 10.7% from 149 million in 2009 to 165 million in 2018. The immense pressure of the growing population has made food security functioning received the highest importance, with a score of 4.38 in SOC-LUFs. Howeveeer, for diversified income sources which include rice mills, handy crafts, cottage industries and bamboo and cane industries is an increasing 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). In Guyuan, with the implementation of national ecological restoration projects and the "rural labour transfer" policy, which has organized 27.7% of the total agricultural workers to move out of their villages to gain employment in the cities in Guyuan in 2015 (Xue and Zhen, 2018), the land provision of work functions received the lowest score (2.50) of all land use functions. In Noto, although having a diverse selection of biocultural activities (e.g., crop variety, traditional craft skills), due to the trend of their 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, and cultural identity has scored 3.00, and even food security is as low as 3.00, exhibiting that the land dependence in Noto is much weaker.

3.6.2.2. Impacts of land use scenarios on LUFs

(1) Scenario impacts on LUFs in three dimensions

Scenario impacts on ENV-LUFs

The IAI scenarios in Godagari and Guyuan received the lowest impaction scores, however, in Noto, it received the highest score (3.70) among the three scenarios (Figure 36). The results reflected different degrees of each country in the appreciation of the local ecosystems and environments. In Godagari, all scenarios have negative impacts on ENV-LUFs. Under the BAU scenario (-11.48), the erratic rainfall patterns (Mondol et al., 2018) always lead to unstable soil moisture, which severely affects the maintenance of ecosystem processes; in the IAI scenario, as pointed out by the experts, irrigated farming would directly threaten the groundwater and its replenishment. According to the questionnaire survey, 100% of the farmers reflected that compared with 20 years ago, they are already observing the decrease of the groundwater table due to the installation of pumps. In the RRDM scenario (-5.91), although meeting the problems of soil moisture and groundwater availability, it has exhibited continuous foliage additions from fruit trees to add organic matter to the soil and thus has higher positive contributions to nutrient cycling (Weinbaum, 1999). In Guyuan, rural land transfer in the IAI scenario has the least positive impact (2.81) on environmental LUFs, causing some of the experts to point out that the uncertainty impact of RLT is due to the homogenization through cultivating a single crop in a large scale, which might bring potential risks to the maintenance of ecosystem processes (Xue and Zhen, 2018). However, with the implementation of SLCP as defined in the RRDM scenario, the trees and grasses planted during this program will gradually mature and enhance the provision of biotic resources and the maintenance of ecosystem processes (Wang et al., 2005). In Noto, 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 the loss of biodiversity caused by decreased land management throughout the country, and furthermore, the intensive land use in the IAI scenario, such as building industry plants or photovoltaic systems, would disturb the local ecosystem processes and further block the provision of abiotic resources of local land, thus experts provided a negative impact assessment result (-3.30).

Scenario impacts on ECO-LUFs

The scores of ECO-LUFs in Godagari and Noto are increasing in BAU, IAI and RRDM, and the impact scores are BAU: 14.23 < IAI: 22.11 < RRDM: 26.88 in Godagari 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 received the highest scores in all of its scenarios (Figure 36). This result reflected that, in agricultural areas of Godagari, more attention is paid to land-based production and their economic effects, furthermore, both irrigation infrastructure and agroforestry land reform could improve the economic functions effectively, with increases of 55.38% and 88.90%, respectively. The statistical results from field survey data showed that the income from per-hectare rainfed land, irrigated land and fruit tree-based farming are 452.0 BDT, 1014.7 BDT and 1324.7 BDT, respectively, which reflected that irrigation systems and agroforestry systems could improve the land income, with increasing income rates of 225% and 293% per acre. In Guyuan, the rural land transfer in the IAI scenario is more effective for improving the economic land use functions (10.80) than SLCP in the RRDM scenario (9.22), and one of the reasons is that 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 impaction 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 compared to BAU. This is mainly due to the development of industry from

outside to develop crops and plant, which are normally benefit-oriented. The statistical data suggests that paddy fields cover 80.4% of the total farmland. However, 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.

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		-1.14		-0.88		-0.86		1.30		1.14		1.22		1.10		-1.60		1.52		-1.64	-11.48	14.23	0.03
	S2	4.40	-0.77	3.65	-2.12	3.84	-0.99	4.62	1.74	3.47	2.20	3.50	1.84	3.38	1.24	3.05	-1.26	4.38	1.76	3.33	-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		0.29		1.14		1.57		-0.43		1.00		1.14		-1.71		1.71		-0.57		-	11.79	6.74	-1.42
	S2	4.17	0.00	4.00	0.29	3.83	0.43	3.67	1.86	4.33	0.57	3.50	0.43	2.50	0.86	3.17	0.86	4.50	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		1.00		-1.00		-1.00		-0.50		-0.50		0.50		0.50		-2.00		1.00		-0.50	-3.30	-2.10	-4.35
	S2	3.80	1.00	3.60	-1.00	3.50	-1.00	4.00	1.50	4.00	1.50	3.80	1.50	3.50	1.50	3.80	-2.00	3.00	1.50	3.00	-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

values for S1
values for S2
values for S3

Figure 36. Scenario impacts on LUFs' dimensions at the three study sites

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 Godagari 's social LUFs, with a score of 9.95. The results reflected that in the BAU scenario in Godagari, SOC-LUFs would not develop much, in which 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 is hard to utilize to ensure a stable and sufficient food provision. This furthers the affect the quality of life for 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, to improve life quality (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 and would, therefore, threaten the food security in these regions (Feng et al., 2005). Thus, it received a lower impact score (7.96) on social LUFs than the IAI scenario (12.57). In Noto, only the mountain agriculture conservation (RRDM) scenario resulted in a positive impact on local social LUFs. This is due to the BAU scenario where rapid depopulation and ageing of the local community gradually breaks down the balance between humans and nature, land use problems including the abandonment of farmland and forests are rising (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 even developed into a GIAHS, land abandonment would turn this paddy land into a natural recovery region and lose the traditional cultural heritage, and all those 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 the negative impact score of -0.85 on local social LUFs.

(2) Synthetic impacts of land use scenarios on LUFs

Impacts of the BAU scenario on LUFs

With the normalized scenario impact results (Figure 37), under the BAU scenario, the impaction order of the three study sites is Guyuan (50.80) > Godagari (7.39) > Noto (-27.08), implying that all of the study sites will have limited and even negative developments if no land management measures are taken. From the balance of the three dimensions' perspective, the order of standard deviations (SDs) is Noto (2.55) < Guyuan (16.17) < Godagari (27.96). The smallest SD in Noto reflected that the environmental, economic and social dimensions all have 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 decreasing rate of 0.7%. Thus, local governments need to cope with this negative trend. Godagari received the most imbalanced results with a standard deviation of 27.96. The main reason 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 agricultural land are still the fundamental and primary issues.

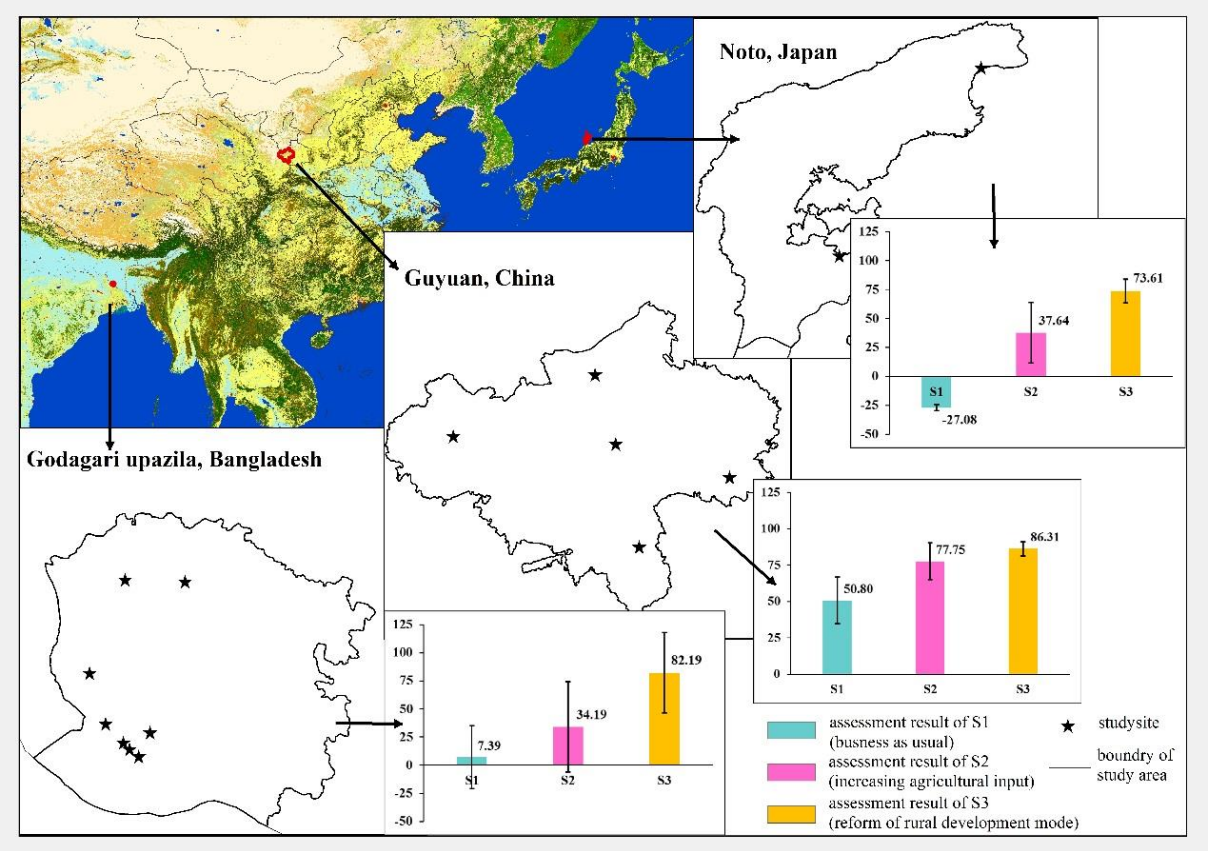


Figure 37. Scenario impacts on LUFs and the standard deviations of the dimensions under each scenario in three study sites

Impacts of the IAI scenario on LUFs

The impact of the IAI on the three study sites are Guyuan (77.75) > Noto (37.64) > Godagari (34.19). The results reflected that the IAI scenario could release the land management problems in all three sites and could improve land use efficiency. From the balanced LUFs in three dimensions, the ranking is Guyuan (12.61) < Noto (26.04) < Godagari (40.26), indicating that all of the sites obtain relatively

imbalanced results among the three dimensions, especially in Godagari, thanks to the higher positive impacts on ECO-LUFs and the lower negative impacts on ENV-LUFs than under BAU, and the polarization is, therefore, more distinct. This possibly implies that although the land management measures in the IAI scenario seem to have a synthetically good impact on local development, the excessive extraction of underground water for irrigation in Godagari could cause severe impacts on environmental conservation, which turns out to also be an unsustainable development pattern. Noto in the IAI scenario also suggests a high SD. The experts pointed out that for intensive land management, an improvement is needed in the local environment and economic development through industrial plants or photovoltaic systems. However, it would 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.

Impacts of the RRDM scenario on LUFs

The synthetic impacts of the RRDM scenario in LUFs at the three study sites by ranking is Guyuan (86.31) > Godagari (82.19) > Noto (73.61), with an SD order of Guyuan (4.86) < Noto (10.12) < Godagari (35.59). In Guyuan, the RRDM scenario has the highest synthetic impact with the minimum SD. Experts of the FoPIA stressed the subsequent effects of SLCP, especially in ENV-LUFs and ECO-LUFs. Since the implementation of the SLCP in 2000, Guyuan has increased the area of forests and grasslands by 3.11 × 105 ha, of which, 1.69 × 105 ha was provided by the conversion of cultivated land, which accounted for 44.9% of the total cropland (3.76 × 105 ha) in 2015 (Guyuan Bureau of Forestry, 2015; Guyuan Bureau of Statistics, 2016a). The trees and grasses planted during this program will gradually mature and enhance the provision of biotic resources and the maintenance of ecosystem processes LUFs (Wang et al., 2005). In addition, villagers currently have developed multiple industries to make full use of the forests, such as raising chicken or bees under the trees, which turns out to provide good economic benefits and could improve the quality of life for residents (Osmaston, 1967). However, with a 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, a combination with RLT to promote balanced local development might be a better choice (Xue and Zhen, 2018). In Noto, with the relevant higher positive synthetic 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 residents to continue mountain farming both from the aspect of land-based production on food security and from the cultural inheritance aspect. However, the most severe problem at present is that even though there are some subsidy policies for farming, farmers are facing difficulties in applying for it. Through the interviews with local farmers, the possible reasons are the complicated application process and multiple livelihood choices.

3.7 Discussions

3.7.1 Importance of the findings, in light of the overall study aims

(1) In Guyuan, China

1) LUF analytical framework: LUFs allow for a balanced classification of regional sustainability issues into economic, social, and environmental dimensions [18,46]. By identifying and defining the key set of LUFs and related assessment indicators, impact assessment would be conducted. With the core of LUFs, we developed a multi-level stakeholder assessment framework. The stakeholders in land use generally include two groups [57]: “decision makers” (e.g., government representatives) and “decision takers” (e.g., local farmers [58]). However, in China, village managers often control the public resources of the village and play a significant role in the life of its farmers. Therefore, we included them as stakeholders in our research and refer to them as “management coordinators”. Since different stakeholder groups had different interests, we used different approaches to survey each group, but with

a shared overall objective: the impact of the RLT program on the LUFs. Our research team comprised both professors and young research fellows with expertise in land use and sustainable development.

2) We used the following methods for the stakeholder groups. First, we used interactive workshops (FoPIA) to survey government employees and local experts. We brought together a multidisciplinary team of experts (see the next section for details) to work with government employees in relevant departments, and organized the workshops to design a policy scenario (the RLT program), a control scenario, and a negative control scenario, and together, we assessed their impacts on LUFs in Guyuan. Second, we used key informant interviews for the "management coordinators" group. In this method, we conducted in-depth interviews to obtain information from community residents who were in a position to know the community as a whole or the particular portion of the community involved in specific land use in their village [59]. Third, we used questionnaires to obtain data from other villagers (the decision-takers). Because it was possible that not all farmers would accept this approach (e.g., some were illiterate) or understand technical concepts such as LUFs, we designed the questionnaire to describe the LUFs in terms they could understand.

3) Changes of LUFs over the past 20 years and consequence of land use policy: the loss of labour force in the rural area and the increasing agricultural land abandonment is tough problems arisen in the past 20 years, and has reflected the negative impact on regional LUFs, especially for social dimension. Effective measures and land policy are urgently needed to release the problems and keep the regional balance development.

4) Land use scenarios impact: compared with the BAU and ALA scenarios, the RLT scenario has the most positive synthetic impact on regional sustainable development. This is especially true for the improvement of the land's economic and social dimensions. Furthermore, the RLT scenario could dramatically benefit the land-based production and food security LUFs, with these two functions showing negative trends under the BAU and ALA scenarios that could be changed to positive trends under the RLT scenario. However, it is also possible that the government should encourage different scenarios in different areas. For example, agricultural intensification may not be an option in the stony mountain areas, particularly if irrigation is not available. In that case, ALA supported by the increased implementation of the SLCP may be the most suitable approach.

(2) In Godagari , Bangladesh

Assessment of land use functions (LUFs) is increasingly recognised as a useful tool for evaluating sustainable land management. In Bangladesh, we investigated the key indicators that act as main stimuli in changing agricultural land use and associated land use functions in Godagari under Barind Tract. A participatory rural appraisal method was used in FoPIA 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 visualisation 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/rainfed with tree-based farming were selected to assess the ten land use functions under three dimensions of social, economic and environmental categories. In the past (20 years ago and more), rainfed was dominant land use system of that locality that severely perturbed by on-going climate-driven changes especially scanty of soil moisture (rainwater), which inspired farmers/experts to seek alternated farming options. Afterwards, irrigation farming system was initiated and expanded tremendously according to peoples huge demands that created opportunities to grow diversified crops. However, overexploitation of groundwater due to the unplanned expansion of irrigated area led to rapid depletion of groundwater level that has already created a number of ecological problems. While gradual introduction of fruit tree based farming system has opened a new hope to overcome this problem with sustainable land management option. Currently, among the three farming systems, fruit tree–based

system provided most of the social, economic and environmental LUFs compared to irrigated and rainfed farming systems. We also validated our information through questionnaire survey as well as key informant interview (KII), where respondent pronounced that they have been receiving a higher economic return from fruit-based farming followed by irrigated and rainfed farming. It was also evident from the FoPIA, questionnaire survey and KII that environmental problem/dimension was more critical than the social and economic problems/dimensions, and those were associated with depletion of soil fertility, installation of the brick kiln, the uncertainty of rainfall, flood, drought, overuse of groundwater. It is worth mentioning that most of the environmental problems could be minimised through adoption of fruit tree based farming. All-inclusive, participatory assessment methods in assessing LUFs helped the different stakeholders, particularly the local officers, researchers as well as policymakers to understand the significant linkages between LUFs and land uses for sustainable land management.

(3) In Noto, Japan

The study revealed the consequences of land-use interventions in plausible future scenarios in a rural area such as land abandonment and underutilization of natural resources, which are now a critical concern due to depopulation and an ageing society in Japan.

3.7.2 Synthesize what has (and has not) been learned about the problem and identify existing gaps

(1) In Guyuan, China

In Guyuan of China, focus was on nine LUFs, land use functions about cultural should be considered for further study. Moreover, the spatial analysis scale should be expended into the whole Loess Hilly and Gully regions to deepen the meaning of this research. Furthermore, the accuracy of agent-based models for simulation of LUFs could be better to some extent.

(2) In Godagari, Bangladesh

In Godagari, currently, the environmental dimension of LUFs is very critical, as overexploitation of groundwater for irrigating crops has led to depletion of groundwater level. Furthermore, the lack of replenishment of groundwater because of increased temperature and decreased precipitation led to a decline in groundwater availability. Therefore, the current situation needs to be overcome through the introduction of sustainable options. In this context, specific priority regarding a further in-depth study on fruit tree based farming system should be given. Furthermore, all high Barind tract land use functions, as well as associated indicators, should be analysed to formulate effective and sustainable land uses. Since this is a new technique in Bangladesh towards sustainable land management, therefore, training is eminent need regarding all the process of FoPIA, data extraction, data analysis, and development of effective and accurate agent-based modelling.

(3) In Noto, Japan

The LUFs approach is effective to combine numerical data with the perspective of the local community via qualitative (FoPIA, KII) and quantitative (indicator assessment and land use simulation) methods. Training on all process will be necessary for researchers, e.g. how to explain the concept of LUFs for other experts to conduct FoPIA session.

4. Conclusions

(1) In Guyuan, China, we get the conclusions as follows:

First, the multi-level stakeholder assessment framework based on LUFs proved to be very useful for comprehensively assessing the impact of land use measures on local sustainable development as well as supporting regional land use decisions. This framework integrates the opinions of all stakeholders to make the results more rational and comprehensive. Using the Guyuan case study, we demonstrated the positive impacts of the RLT program on regional sustainable development while also simultaneously revealing problems with and insights into the implementation of land use measures. Thus, our framework can support the identification of region-specific land use problems and the causal

relationships between land use measures and the selected sustainability indicators. In future research, this method could be improved by consulting all stakeholders, not just the experts, to identify the key LUFs and take in vital indicators. Although the nine LUFs and nine indicators used in the present analysis appeared to be satisfactory and represent a simple and efficient approach to analyze the key issues, it is likely that a broader consultation would reveal more factors that should be accounted for some of the nine LUFs and indicators that are also more important to farmers (e.g., including irrigation into the key infrastructure component, rather than only transportation network).

Second, compared with the BAU and ALA scenarios, the RLT scenario has the most positive synthetic impact on regional sustainable development. This is especially true for the improvement of the land's economic and social dimensions. Furthermore, the RLT scenario could dramatically benefit the land-based production and food security LUFs, with these two functions showing negative trends under the BAU and ALA scenarios that could be changed to positive trends under the RLT scenario. However, it is also possible that the government should encourage different scenarios in different areas. For example, agricultural intensification may not be an option in the stony mountain areas, mainly if irrigation is not available. In that case, ALA supported by the increased implementation of the SLCP may be the most suitable approach.

Third, implementation of the RLT program should be adjusted to account for differences in local conditions to take better advantage of the multiple LUFs provided by the land and to overcome the difficulties imposed by the different landforms and location conditions. For example, for cultivated land in hilly regions, with poor conditions, farmers might be unable to find anyone to rent their land, so the most critical measure might be to promote RLT by improving infrastructure (e.g., roads and irrigation) to improve the land's quality. Thus, for each region, specific measures should be carefully designed to account for that region's needs and constraints.

(2) In Godagari, Bangladesh, we get the conclusions as follows:

FoPIA to assess the land use functions is a holistic approach in maintaining the local land uses sustainably and profitably, as it integrates opinions from different levels of stakeholders, like experts, researchers, policy makers, teachers, agricultural officers, and farmers. The policymakers and/or experts opined that environmental LUFs perceived higher preference at present due to over-exploitation of natural resources for producing more food to meet the demand of the ever-growing population. Nevertheless, impact assessment of three land use systems on LUFs in the study area was in the order of fruit tree based-farming>irrigated farming>rainfed farming, which confers that fruit tree-based farming system has less impact on the environment and it provides diversified year-round income opportunities. Despite the LUFs assessment, FoPIA method is based on qualitative knowledge and information; it can expose the key drivers that are interlinked to the land use and LUFs in economic, social, and environmental dimensions. The results indicated a new era for the improvement of future land use decisions at both local, regional and national levels.

(3) In Noto, Japan, we get the conclusions as follows:

The effects of intervention policies, such as maintaining land-based productive activities to keep populations engaged in agriculture, intensive use of land with only a minor population engaged in agriculture can be examined with LUFs analysis. These intensive/extensive land-use scenarios will be used to assess changes in LUFs and then to communicate with stakeholders.

(4) Comparative studies in three sites of the three countries

By combining the FoPIAs with field surveys to include multilevel stakeholders, and comprehensively assessing the impacts of different land use policy scenarios on remote agricultural areas, we did a comparative study on LUFs in typical remote agricultural areas in Bangladesh, China and Japan, which shows gradient differences on economic, social, and natural conditions as well as mainland use problems. We reached the main conclusions as follows:

1) The three study sites have indifferent attitudes for SOC-LUFs, while they all attached importance to ENV-LUFs, and the rooted reasons are different, and sometimes opposing. Through the lowest weights assigned to the social LUFs at all sites, farmers all reflected a decreasing dependence on their land. The main reasons included increasingly diversified income sources, rural labour transfer and ageing societies in Godagari, Guyuan and Noto, respectively. ENV-LUFs are highly respected, especially in Godagari and Guyuan, respectively, owing to the opposing factors of warning from land degradation and benefits from land restoration.

2) A good synthetic impact result might not stand for a sustainable development pattern when considering the balance of the three dimensions simultaneously. In Godagari Upazila, although the land management measures in the IAI scenario seem to have a synthetically good impact on local development, the great standard deviations for environmental, economic and social dimensions also reflected that with the excessive extraction of groundwater for irrigation, local environmental developments, especially groundwater conservation, might be severely threatened. Thus, combining the integrated impacts and coordination of the three dimensions is necessary when synthetically evaluating the rationality and sustainability of land use management measures.

3) Combining multiland use 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 a good economic development level, the highest per-capita agricultural land and sufficient precipitation, paying subsidies directly and providing consideration for converting extra farmland into forests, which could obtain synthetic and balanced benefits. On the other hand, Guyuan has a medium economic development level, a medium amount of per-capita agricultural land and limited precipitation. Hence, combining the RLT in the IAI scenario with the SLCP in the RRDM scenario could maintain the environmental goodness of SLCP and develop a forestry economy and improve land use efficiency through RLT. On the other hand, Godagari has the lowest economic development level, the least amount of per-capita agricultural land and decreasing precipitation, and therefore agroforestry could significantly improve the soil health, maintain groundwater and have great land-based production. Thus, protecting traditional agricultural and carrying out appropriate agricultural reforms could inject new vitality into agricultural development, thereby, avoiding the loss of traditional culture and promoting regional sustainable developments simultaneously.

5. Future Directions

(1) In Guyuan, China

The specific study site is limited in Guyuan in this study, while implementing the field survey, typical landform of the whole loess hilly and gully region has been collected, to expand our results for the assessment and visualization simulation for whole hilly and gully region is needed to be done in the next step on the basis of currently results. Another issue that is needed to conduct further studies on the comparative of LUFs change under the same land management measures. For instance, we have assessed the impact of rural land transfer(RLT) on LUFs in Loess hilly and gully region focus on the release effect of RLT on local agricultural land abandonment. However, land abandonment is common in other parts of China with different natural conditions, and RLT has also been attending to implemented to improve land use intensity and release land abandonment, the relevant effect should be conducted to obtain a further understanding of impacts from land use policy. The results and data gained from this research will be useful for future comparative studies.

(2) In Godagari, Bangladesh

The current study was confined in one only, therefore, in order to get whole Barind tract land use functions scenario, we need to do repeat similar activities in each. Furthermore, questionnaire survey, as well as land use and land cover change maps of each, will provide us with a comprehensive overview regarding land uses of high Barind tract and its future planning for sustainable management. A similar

study also may be conducted in other ecologically degraded land or disadvantaged areas of Bangladesh such as hilly areas located in the eastern part of the country as well as coastal areas located in the southern part of the country.

(3) In Noto, Japan

In this project, we collected agricultural census data and created a platform to develop an agent-based model. Further research, e.g., to analyse full policy impact on each farmers group, various land use policy impact on the remote area will be necessary.

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7. Appendix (Appendix file also has been attached)

7.1 Agenda and participants list for three project meeting (Conferences/Symposia/Workshops)

(1) Kick-off meeting

Agenda:

Day 1. Nov 3, 2016
Morning
9:30-10:00
Prof. Dr. Lin Zhen
Welcome address
Introduction of land use function concept
Introduction of APN project and implementation plan: "Assessing land use functions for sustainable land management"
10:00-10:30
Prof. Dr. Giashuddin Miah
Land use policy/program and land use practices in Bangladesh/Rajshahi
10:30-11:00
Dr. Kikuko Shoyama
Land use policy/program and land use practices in Japan/Noto region
11:00-11:20
Tea break & Photo taking
11:20-11:50
Dr. Huimin Yan
Agricultural land use in China and multi-agent simulation
11:50-12:20
Ms. Zhichao Xue
Progress on land use function research: a literature review
12:30—13:30
Lunch (box lunch will be provided)
Afternoon:
14:00-14:30
Mr. Chao Wang
Land use policy/program and land use practices in China/Guyuan
14:30-15:30
Prof. Dr. Lin Zhen/Ms. Zhichao Xue
Introduction of research methodology on land use function
15:30-17:00
Participatory group discussion/exercise:
Identification of scenarios and land use functions in each study site
18:00-19:30
Working dinner

Day 2. Nov 4, 2016
Morning:
9:00-11:00
Participatory group discussion/exercise (continued):
Identification of key indicators for assessing land use functions in each study site
11:00—12:00
Problems with the methodology application and solutions
Wrap up
12:30—13:30
Lunch (box lunch will be provided)
Afternoon:
14:00-16:30
Lin Zhen, Giash, Shoyama

Discussions on implementation plan of the project:

- Funds transfer and installation
- Project work plan and timeline
- Communication and networking plan and responsibilities of each site
- Publication plan and responsibilities of each site
- Remaining issues
- Next steps

16:30-17:00

Wrap up

Description of the field survey site and preparations

17:30-18:30

Working dinner

Day 3. Nov 5, 2016

Field excursion:

Surveys on land use change and policy impact around Beijing municipality

Participants:

Table 13. Participants in kick-off meeting in China

Name	Position	Affiliation	Email
Lin Zhen	Professor	Institute of Geographic Sciences and Natural Resources Research	zhenl@igsnrr.ac.cn
Giashuddin Miah	Professor	Bangabandhu Sheikh MujiburRahman Agricultural University	giash1960@gmail.com
Shoyama Kikuko	Dr, Research Associate	United Nations University, Institute for the Advanced Study of Sustainability	shoyama@unu.edu
Huimin Yan	Associate Professor	Institute of Geographic Sciences and Natural Resources Research	yanhm@igsnrr.ac.cn
Bingzhen Du	PhD student	Institute of Geographic Sciences and Natural Resources Research	dubingzhen@hotmail.com
Chao Wang	PhD student	Institute of Geographic Sciences and Natural Resources Research	wangc.12b@igsnrr.ac.cn
Zhichao Xue	PhD candidate	Institute of Geographic Sciences and Natural Resources Research	xuezc.14s@igsnrr.ac.cn
Wanni Yang	PhD candidate	Institute of Geographic Sciences and Natural Resources Research	Yangwn.15b@igsnrr.ac.cn
Hongtao Dou	Master candidate	Renmin University if China	hongtao_dou@ruc.edu.cn

Figure 38. Kick-off meeting in China

(2) Interim meeting

Agenda:

Day 1. Sept. 5, 2017

Morning

Chair: Prof. Dr. Lin Zhen

9:30-9:40

Dr. Kikuko Shoyama

Introduction of UNU-IAS

9:40-10:00

Prof. Dr. Lin Zhen

Overall review of the progress of APN project

10:00-11:00

Prof. Dr. Giashuddin Miah

Progress Report of study site in Bangladesh

11:00-12:00

Dr. Kikuko Shoyama

Progress Report of study site in Japan

12:00-13:30

Photo taking & Lunch

Afternoon

Chair: Dr Shoyama Kikuko

13:30-14:30

Ms. Zhichao Xue

Progress Report of study site in China

14:30-16:00

Discussion on the progress in three sites

16:00-16:10

Coffee/tea break

16:10-16:30

Dr. Takafumi Miyasaka (The University of Tokyo)

Agent-based modeling of complex social–ecological feedback loops to assess multi-dimensional trade-offs in dryland ecosystem services

16:30-16:50

Ms. Zhichao Xue

Introduction of ABM and application in Guyuan, China

16:50-18:00

Discussion about ABM implementation in three sites

18:00-19:30

Working dinner

Day 2. Sept. 6, 2017

Morning
Chair: Prof. Dr. Giashuddin Miah
9:00-11:00
Drafting policy brief based on the progress and results from three sites
11:00-11:20
Coffee/tea break
11:20-12:00
Prof. Dr. Lin Zhen
Introduction of China's relevant research programs and association and potentials for collaboration
- Belt and Road Initiative
- National R & Development Program
- China Society for Natural Resources

Afternoon
Chair: Prof. Dr. Lin Zhen
13:30-14:30
Issues and next steps for Year 2
14:30-15:30
Group discussion
16:00
Closing

Participants:

Table 14. Participants in interim meeting in Japan

Name	Nation	Institution	Major
Lin Zhen	China	Institute of Geographic Science and Natural Resources Research, Chinese Academy of Sciences	Ecosystem services and ecological compensation
Giashuddin Miah	Bangladesh	Bangabandhu Sheikh Mujibur Rahman Agricultural University,	
Kikuko Shoyama	Japan	United Nations University, Institute for the Advanced Study of Sustainability,	Ecosystem services
Zhichao Xue	China	Institute of Geographic Science and Natural Resources Research, Chinese Academy of Sciences	Land use functions
Takafumi Miyasaka	Japan	University of Tokyo	Agent-based modelling and land use change

Figure 39. Interim meeting in Japan

(3) Progress meeting in Bangladesh
Agenda:
23-24 March, 2018, Dhaka, Bangladesh
Overall review of project tasks and outcomes
23 March, 2018
Prof. Dr. Lin Zhen
Institute of Geographic Science and Natural Resoruces Research
Chinese Academy of Sciences
Beijing, China

Progress Report of study site in Bangladesh
23 Mar. 2018
Prof. Dr. Md. Giashuddin Miah
Department of Agroforestry and Environment
and Vice-Chancellor
Bangabandhu Sheikh Mujibur Rahman
Agricultural University (BSMRAU)
Gazipur, Bangladesh

Progress Report of study site in Japan
23 Mar. 2018
Kikuko SHOYAMA
United Nations University, Institute for the Advanced Study of Sustainability, Japan

Progress Report on Assessing Land Use Functions for Sustainable Land Management in Guyuan, China
23 Mar. 2018
Prof. Dr. Lin Zhen
Institute of Geographic Sciences and Natural Resources Research, CAS

Field survey
In rural areas and villages, visit land use patterns, talk with farmers, meeting with village heads, and investigate community organisation and involvement in land management, data gatherings, etc.

Figure 40 Field survey in Bangladesh

Participants:

Table 15. Participants in progress meeting in Bangladesh

Name	Position	Affiliation	Email
Lin Zhen	Professor	Institute of Geographic Sciences and Natural Resources Research	zhenl@igsnrr.ac.cn
Yunfeng Hu	Associate Professor	Institute of Geographic Sciences and Natural Resources Research	huyf@igsnrr.ac.cn
Shoyama Kikuko	Dr, Research Associate	United Nations University, Institute for the Advanced Study of Sustainability	shoyama@unu.edu
Huimin Yan	Associate Professor	Institute of Geographic Sciences and Natural Resources Research	yanhm@igsnrr.ac.cn
Giashuddin Miah	Professor	Bangabandhu Sheikh Mujibur Rahman Agricultural University	giash1960@gmail.com
Shaikh Shamim Hasan	Dr, Associate Professor	Bangabandhu Sheikh Mujibur Rahman Agricultural University	shamim.aer@bsmrau.edu.bd
Abiar Rahman	Professor	Bangabandhu Sheikh Mujibur Rahman Agricultural University	abiar@bsmrau.edu.bd
Md. Mezanur Rahman	Researcher	World Agroforestry Centre of Bangladesh	mrahman@bsmrau.edu.bd

(4) Meeting with UN-World Food Program (WFP) in Dhaka

During the workshop in Dhaka, the project team visited WFP, and held meeting with its director and key staff. The main topics include land use and food security in the world and Bangladesh, the role of WFP, and possible collaborations in terms of result sharing and joint actions on sustainable land use in the region.

Figure 41. Meeting with UN-World Food Program (WFP) in Dhaka, Bangladesh

（5）Workshop on ABM training and practice

Agenda:

26-28 November, 2018, Beijing, China

Day 1. Nov 26, 2018

Morning

Prof. Dr. Lin Zhen

Welcome address

Ms Zhichao Xue
Introduction of agent-based model (ABM)

Dr. Kikuko Shoyama
Progress and problems of ABM in Japan/Noto region

Afternoon
Ms Zhichao Xue & Dr. Kikuko Shoyama
Discussion workshop for ABM in Japan

Day 2. Nov 27, 2018
Morning
Ms Zhichao Xue
Introduction of two specific ABM case

Afternoon
Ms Zhichao Xue & Dr. Kikuko Shoyama
Discussion workshop for ABM in Japan

Day 3. Nov 28, 2018
Discussion workshop on policy brief
Participants:

Table 16. Participants in ABM and policy brief workshop in China

Name	Nation	Institution
Lin Zhen	China	Institute of Geographic Science and Natural Resources Research, Chinese Academy of Sciences
Kikuko Shoyama	Japan	United Nations University, Institute for the Advanced Study of Sustainability,
Zhichao Xue	China	Institute of Geographic Science and Natural Resources Research, Chinese Academy of Sciences

7.2 Funding sources outside the APN

- Institute of Geographic Sciences and Natural Resources Research (IGSNRR) of Chinese Academy of Sciences (CAS) has provided in-kind supports and staff time and salary;
- the National Key Research and Development (R&D) Program of China, "The methodology and indicator system for assessing ecological restoration technology and evaluation of global ecosystem rehabilitation technology" (grant number: 2016YFC0503700), partially provide financial support for field surveys
- Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) has provided in-kind supports and staff time and salary.
- The Environment Research and Technology Development Fund (S-15 ''Predicting and Assessing Natural Capital and Ecosystem Services'' (PANCES), Ministry of the Environment, Japan).
- Japan Society for the Promotion of Science KAKENHI Grant (no. 18K11735).

7.3 List of Young Scientists

1. Ms Zhichao Xue, from Institute of Geographic Sciences & Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS), PR China. Email: xuezc.14s@igsnrr.ac.cn. She is in charge of method training in the project; field survey conduction, data collecting and analysis in Guyuan of China, evaluation and simulation (by ABM) of land use functions change. Draft out progress report and final report under the guidance from Prof. Zhen. Zhichao Xue is a PhD student whose research focuses on land use functions and the policy scenarios sustainable impact assessment. She is also good at using GIS methods, computer science, spatial-temporal data analysis and visualisation. In this project, the above-mentioned background helps her to contribute to this project.

2. Dr Chao Wang, from the Chinese Academy of Environmental Planning. Email: wangc.12b@igsnrr.ac.cn. He was studying for his doctoral degree before 2017 and attend this program during that period. He helps to finish the field study and household questionnaire. His interests field are ecosystem function in developing the region. He has the unique insight of developing in our study area, which is also a developing region. He helped analysis factor impacting on ecosystem services.

3. Ms. Yuehan Dou, from Wageningen University, email: douyuehan@igsnrr.ac.cn. She helped to collect the questionnaire data and second-hand data of this project. Her research field is cultural ecosystem services. She can gain knowledge of the relationship between national culture and ecosystem services and has published one scientific paper ("Assessing the influences of ecological restoration on perceptions of cultural ecosystem services by residents of agricultural landscapes of western China" in Science of the Total Environment in 2018) based on the field survey data.

4. Md. Mezanur Rahman, Researcher, World Agroforestry Centre of Bangladesh Office was involved in FoPIA meeting; records the information from the expert's opinions, and after that, compiled the information for further analysis and draft report writing. His contact address is Department of Agroforestry and Environment, BSMRAU, Bangladesh, e-mail: mrahman@bsmrau.edu.bd

5. Md. Sipon Howlader and Sujan Barua have assisted to Md. Mezanur Rahman in Face to Face questionnaire survey as well as data inputting in excel sheet. Their E-mail ID is: Md. Sipon Howlader. e-mail: siponh@gmail.com; Sujan Barua, sujanag092058@yahoo.com

6. Imranul Islam also helped in preparing land use and land cover change map of Godagari . His contact address is BSMRAU, imran.rajib1971@gmail.com.

7. Mr. Akinobu Kikuchi (Research assistant, Kanazawa University, Japan. notojima.tk@gmail.co.jp): He conducted the face to face interview against local farmers. Through the communication with local farmers and government officers, he became familiar with local knowledge, which is necessary for ecosystem services assessment.

7.4 Glossary of Terms

Asia-Pacific Network for Global Change Research, APN
Framework of Participatory Impact Assessment, FoPIA
Focus Group Discussion, FGD
International Geosphere-Biosphere Program,IGBP
Land use/cover change, LUCC
Global Land Project, GLP

7.5 Actual data or access to data used in the study

Most of the data used in the study are collected from the country collaborators and currently with the country collaborators and the Project Leader, and can be accessed by simply open the Fold "Actual data used in the study" provided as part of the Appendix attached to this final report.

7.6 Abstracts, Power Point Slides of conference/symposia/workshop presentations

(1) Workshop presentations

a. Presentations in kick-off meeting in China

Table 17. Presentations in kick-off meeting in China

Reporter	Topic
Prof. Dr. Lin Zhen	Introduction of land use function concept Introduction of APN project and implementation plan: "Assessing land use functions for sustainable land management"
Prof. Dr. Giashuddin Miah	Land Use Policy and Land Use Practices in Bangladesh
Dr. Kikuko Shoyama	Land use policy/program and land use practices in Japan/Noto region
Dr. Huimin Yan	Agricultural land use in China and multi-agent simulation
Ms. Zhichao Xue	Progress on land use function research: a literature review
Mr. Chao Wang	Land use policy/program and land use practices in China/Guyuan
Lin Zhen & Zhichao Xue	Introduction of research methodology on land use function

b. Presentations in the interim meeting in Japan

Table 18. Presentations in the interim meeting in Japan

Reporter	Topic
Prof. Dr. Lin Zhen	Assessing land use functions for sustainable land management in Asia countries
Dr. Giashuddin Miah	Assessing Land Use Functions for Sustainable Land Management in Asian Countries: Bangladesh
Dr Kikuko SHOYAMA	Progress Report of study site in Japan
Dr Takafumi Miyasaka	IM-LUDAS: an agent-based model for assessing social-ecological impacts of Sloping Land Conversion Program in Inner Mongolia
Xue Zhichao	- Agent Based Model and application plan in Guyuan - Progress Report of Assessing Land Use Functions for Sustainable Land Management in Guyuan, China

c. Presentations in the progress meeting in Bangladesh

Table 19. Presentations in the progress meeting in Bangladesh

Reporter	Topic
Prof. Dr. Lin Zhen	- Overall review of project tasks and outcomes - Progress Report on Assessing Land Use Functions for Sustainable Land Management in Guyuan, China
Prof. Dr. Md. Giashuddin Miah	Assessing Land Use Functions for Sustainable Land Management in Asian Countries: Bangladesh
Dr Kikuko SHOYAMA	Progress Report of study site in Japan

(2) Conference abstract and presentations

a. Global Land Project 3rd Open Science Meeting, oral presentation and abstract

Figure 42. Oral presentation in GLP OSM in China

Ms Xue Zhichao, a PhD candidate in IGSNRR attended the Global Land Project 3rd Open Science Meeting (GLPOSM16), in Beijing from 24 to 27 October 2016. She presented her work by introducing the method of Framework for Participatory Impact Assessment and its application in LUFs assessment and also showed the ABM work in simulating land use changes. By preparing and doing this presentation, Ms Xue has a deeper understanding of FoPIA and LUFs, and communicated much with researchers from other countries, inspirited each other and established a long fellowship.

b. Global Land Programme 2018 Asia Conference, oral presentation and abstract

Shoyama, K., Development of a national land-use/cover dataset and land use scenarios under depopulation in Japan, Global Land Programme 2018 Asia Conference, 3-6 September 2018, Taipei, Oral in Session “Land use drivers and impacts: new trends and experiences from East Asian countries.”

c. 2018 Annual Conference of China Society of Natural Resources, oral presentation and full paper

Ms Zhichao Xue attended the 2018 Annual Conference of China Society of Natural Resources in 1-7 November, in Changsha, China. Oral with Factors Affecting Farmers' Choice of Abandoning Agricultural Land in Loess Hilly and Gully Region: A Case Study in Guyuan, Western China, and also submit the full paper in Chinese with English abstract.

Figure 43. Oral presentation in 2018 Annual Conference of China Society of Natural Resources in Changsha, China

7.7 Conference/symposium/workshop reports

a. The project kick-off meeting has been reported by the website of Institute of Geographic Sciences and Natural Resources Research, CAS and Daily Observer of Dhaka, which aroused a high interest among researchers, especially those major in land use change and land use policy.

综合信息 Information 今天为 2017-7-16 星期日(SUN)

“亚洲土地多功能及在土地可持续管理中的应用研究”国际合作项目启动

发布处室：综合办公室 发布日期：2016-11-16

11月3-5日，由亚太全球变化研究网络（Asia-Pacific Network for Global Change，APN）资助的国际合作项目“亚洲土地多功能性及在土地可持续管理中的应用研究(Assessing Land Use Functions for Sustainable Land Management in Asian Countries)”在京动。项目负责人中国科学院地理科学与资源研究所甄霖研究员、项目成员国孟加拉农大学副校长GiashuddinMiah教授、联合国大学可持续发展研究所（日本）KikukoShoya博士以及项目组成员参加了启动会。启动会着重对项目的实施方案进行了详细讨论，确了各国承担的研究任务、时间节点、预期产出，建立了合作研究机制。

过去几十年，气候变化和人口激增使亚洲地区的土地利用发生了巨大变化，给整亚洲，特别是偏远农村地区的生计维持、粮食安全、生态安全和区域发展带来了挑战。全球土地计划（Global Land Project，GLP）指出土地利用变化对可持续发展的影响是策制定和科学研究目前面临的重大挑战。土地多功能（Land Use Function）研究是评估经济、社会和环境变化对土地利用变化影响的重要手段之一。然而目前的土地多功能研究多集中于欧洲地区的土地多功能性的理论和概念框架研究，土地利用政策如何影响地多功能及如何将土地多功能评估结果用于土地可持续管理的研究相对不足。

本项目聚焦亚洲土地多功能性研究，在中国、孟加拉国和日本分别选择自然条件、社会经济活动类似的农村地区展开案例研究，提出土地多功能变化定量评估体系和方案，回答“土地利用政策如何影响土地多功能及其可持续性”和“如何将科学研究成果应到土地可持续管理决策”两个科学问题。项目将通过联合考察和成果推广等科学交流活动，进一步推动亚太地区在土地可持续利用领域的合作。

资源生态与生物资源研究室 供

Figure 44. Kick-off meeting reported by website of IGSNRR

dailyobserver
We stand for people's rights
Dhaka, 08 November, 2016, Page # 13

Prof Giashuddin presents papers at workshop in China

Eduvista Desk

A regional workshop on 'Assessing land use functions for sustainable land management in Asian Countries' was held at the Institute of Geographic Science and Natural Resources Research (IGSNRR), Chinese Academic of Sciences, Beijing in China during November 3-5, 2016. The workshop was coordinated by Professor Dr. Lin Zhen, IGSNNRR and funded by the Asia Pacific Network for Global Change Research (APN).

Experts from several Asian countries presented country status papers in the workshop. The keynote paper was presented by Prof Lin Zhen of IGSNRR, China. Professor Dr. Md. Giashuddin Miah, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) presented country paper in the workshop highlighting land use and related policies in Bangladesh and future way of action for sustainable land management.

It has been noted that China, Japan and many countries have strong land use planning and actions aside from land use policies while Bangladesh though has land use policy but does not have land use planning or rules to protect its agricultural land from converting to non-agricultural purposes.

A decision was taken at the workshop to conduct case studies in each collaborating countries on the impact of land use policies on the land use functions for sustainable land management, and those would be presented in next workshop which will be held in Japan in the middle of 2017.

Figure 45. Kick-off meeting reported by Daily Observer of Dhaka

b. The interim meeting has been reported by four news media in Dhaka, and achieve a good sharing impaction among researchers on land use change and land use policy.

Main Site Todays Paper Sep 11 2017

THE ASIAN AGE

area leaving him dead.

Meeting on land policy of Asian countries held

Mahabub Alam,
Gazipur

A regional meeting on "Assessing Land Use Functions for Sustainable Land Management in Asian Countries" sponsored by Asia Specific Network for Global Change Research (APN) was held in the Institute for the Advanced Study of Sustainability of United Nations University, Tokyo, Japan during September 5-6, 2017 where experts from Bangladesh, China and Japan attended the meeting.

In this meeting, three important papers based on field works and experts' opinion from three countries were presented. The first day of the meeting was Presided by Prof Dr Lin Zhen, Institute of Geographic Science and Natural Resources Research, Chinese Academy of Sciences, China where discussion was held on the findings of presented papers.

The second day was presided by Prof Dr Md Giashuddin Miah, Vice-Chancellor of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh where route maps for future activities and policy briefs from the outputs of the works were thoroughly discussed. The meeting was coordinated by Dr Kikuko Shoyama, United Nations University, Tokyo Japan.

Figure 46. Interim meeting reported by The Asian Age

dailyobserver Monday, September 11, 2017, Bhadra 27, 1424 BS, Zillhajj 19, 1438 Hijri

BSMRAU VC takes part in land Use Policy meeting in Tokyo

Eduvista Desk

A regional meeting on "Assessing Land Use Functions for Sustainable Land Management in Asian Countries" sponsored by Asia Specific Network for Global Change Research (APN) was held in the Institute for the Advanced Study of Sustainability of United Nations University, Tokyo, Japan during September 5-6, 2017 where experts from Bangladesh, China and Japan attended the meeting.

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Figure 47. Interim meeting reported by Daily Observer

e-Daily INDUSTRY

Daily INDUSTRY
11 September, 2017

Bank & Metro

www.dailyindusty.news

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Meeting on land use policy of Asian countries held in Tokyo

Industry Desk: A regional meeting on "Assessing Land Use Functions for Sustainable Land Management in Asian Countries" sponsored by Asia Specific Network for Global Change Research (APN) was held in the Institute for the Advanced Study of Sustainability.

United Nations University, Tokyo, Japan during September 5-6, 2017 where experts from Bangladesh, China and Japan attended the meeting. In this meeting, three important papers based on field works and experts' opinion from three countries were presented. The first day of the meeting was Presided by Prof Dr. Lin Zhen, Institute of Geographic Science and Natural Resources Research, Chinese Academy of Sciences, China where discussion was held on the findings of presented papers.

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Figure 48. Interim meeting reported by e-Daily Industry

CAMPUS CORNER

DU reopens today after Eid vacation

The academic activities of Dhaka University (DU) will resume on Monday after a 12-day long vacation on the occasion of holy Eid-ul-Azha.

However, the administrative activities started on Sunday, said a press release issued by DU public relations office. The authorities shut down the university on August 30, the release added.

Online registration for KUET admission test begins today

KHULNA: The online registration for honours first year admission test under academic session 2017-18 of Khulna University of Engineering and Technology (KUET) will begin today.

The admission seekers can apply online till September 20 and they could pay registration fees through Rocket (Dutch Bangla mobile banking channel) by 5 pm on September 21, said a KUET press release here on Saturday.

The admission tests will be held from 9.30 am to 12 noon on October 20, the release added. Details of the admission tests, registration procedure, fees, eligibility are available on university website www.admission.kuet.ac.bd. Admission seeker can send mail to admission@kuet.ac.bd, if needed.

Fakrul Alam new pro-VC of East West University

Professor Dr Fakrul Alam has joined as the pro- Vice-chancellor of East West University (EWU) from Sunday for the next four years, says a press release.

He is the 6th pro-Vice-chancellor of this university. Dr Mohammed Farashuddin, Chairperson, Board of Trustees, EWU and Prof. M M Shahidul Hassan, Vice-chancellor, EWU welcomed Dr Alam on Sunday morning.

Before joining EWU, Dr Alam was professor of the Department of English at University of Dhaka (DU). He has completed his B.A. and M. A. Degree from the Department of English at DU. Dr. Fakrul has completed another masters degree from Simon Fraser University, Canada in 1980 and his Ph.D. from the University of British Columbia, Canada in 1984.

Meeting on Land Use Policy of Asian Countries held in Tokyo

A two-day long regional meeting on "Assessing Land Use Functions for Sustainable Land Management in Asian Countries" sponsored by Asia Specific Network for Global Change Research (APN) was held at United Nations University, Tokyo, Japan on September, says a press release.

Experts from Bangladesh, China and Japan attended the meeting.

Three important papers based on field works and experts' opinion from three countries was presented. The first day of the meeting was presided over by Prof Dr Lin Zhen, Institute of Geographic Science and Natural Resources Research, Chinese Academy of Sciences, China where discussion was held on the findings of presented papers.

The second day was presided by Prof Dr Md Giashuddin Miah, Vice-chancellor of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh where route maps for future activities and policy briefs from the outputs of the works were thoroughly discussed.

The meeting was coordinated by Dr. Kikuko Shoyama, United Nations University, Tokyo Japan.

INDEPENDENT NEWS/AGENCY

Figure 49. Interim meeting reported by the independent

c. The Interim Report of the project, based on the outline development from the kick-off meeting of the project.