JOINT COOPERATION PROGRAMME
BANGLADESH – THE NETHERLANDS

Technical Report 10

Land Use Change Knowledge

for adaptive delta management by using land use modelling

JOINT COOPERATION PROGRAMME
Bangladesh Netherlands
Knowledge development for a prosperous delta

JCP Technical Report 10

Land Use Change Knowledge

for adaptive delta management by using land use modelling

November 2022

Developing the partnership for applied research by

Deltares CEGIS Center for Environmental and Geographic Information Services WAGENINGEN UNIVERSITY & RESEARCH IWM Water Environment & Climate Kingdom of the Netherlands

Document information

Document Title	Land Use Change Knowledge (LUCK) for adaptive delta management by using land use modelling
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Reference	

Dissemination level

- ☑ Technical Report
- ☐ Technical Note
- ☐ Planning and Progress Report
- ☐ Others

Dissemination level

- ☑ Public
- ☐ Other Programme Partners
- ☐ Restricted to a specific group
- ☐ Confidential

Document Version and Review Management

Version No.	*Status*	*Date*	*Author(s)*	*Review*	*Approval*
1			Dr Farhana Ahmed	Md. Mostafizur Rahman	WO
2				Dr. Shaikh Shamim Hasan	
3					

Key Project Information

This document is an output of the Joint Cooperation Programme (JCP) Bangladesh – the Netherlands

Grant agreement No.	DHA/OS/2018/4000001952
Grant organization	Embassy of the Kingdom of the Netherlands (EKN)
Project manager	William Oliemans
Project start date	December 2018
Project duration	4 years
Coordinating organization	Stichting Deltares
Partner organization	Center for Environmental and Geographic Information Services (CEGIS), Institute of Water Modeling (IWM), Wageningen University and Research (WUR).

EXECUTIVE SUMMARY

BDP2100, Perspective Plan, SDG and similar other plan define short, medium and long-term goals, targets and strategies to reach the long-term vision 'achieving safe, climate resilient and prosperous delta' step by step which includes spatial planning and land use management focusing on coastal protection, controlled flooding, water security for consumption and agriculture, food security, infrastructure, environment, ecology and institutions and governance. All these plans have set strategies for development in broader terms, which need to be translated into actions at regional and local level which will influence the landscape level the land use pattern, and for which informed decision making and monitoring is still lacking. Land Use change is at the base of any planning either local, regional or national approach. Assessing baseline status of land use pattern and probable future conditions sets a platform for taking informed decisions for setting robust development pathway(s). Analysing future land use change is the aim of this study which enables informed decision making and aid the overall planning process.

The South-West region of Bangladesh has been chosen for this study, considering the vulnerability to hazards (e.g., sea level rise, salinity intrusion, flooding, drought) and huge potential for blue economic activities (e.g., shrimp culture, seaports etc.). Experts from CEGIS, WUR, CAS and BSMRAU have tried to amalgamate local information and expertise with satellite image, GIS methods, and international tools in this study, which can be a key pilot study under the JCP umbrella for implementation of BDP2100.

This study focuses on the broad research question – "How to get insight of the spatial distribution of future land use, given certain government policies". The outputs of this study can be used in preparing concept notes for developing projects under the implementation portfolio of BDP2100. At first, the outputs can be used in exploring potential areas for development. Then the study can be upscaled at more detailed level for other hydrological regions (considering the basin-wise planning approach in adaptive delta management for implementation of BDP2100).

I-Clue model enables land use change analysis for the future in best and worse scenarios with respective climatic and socio-economic parameters. Standard simulation procedures including literature review, driver selection, model parameterization, expert validation – have been followed in this study. Key stakeholders have been consulted in person (after defining their roles and scope using stakeholder diagramming technique), over virtual meeting platforms and in the Delta Knowledge Days 2022, to ensure their involvement in assessing the land use change, selecting typology, and validating the procedure and driver selection.

Land Use change and relevant underlying variables Population, GDP, Climatic variables (temperature and precipitation) comprise the baseline analysis for the study area. The population analysis revealed the districts with most population influx and decrease in the last two decades. Contribution of districts within the study area to national GDP was also analysed to explore the economic potential of this region. The change in climatic variables was analysed to represent the climate change in the recent decades. The land use classes were defined to reflect the land use patterns and trends in this area.

As mentioned, i-Clue modelling environment was used for this purpose. Land use change is likely to be governed by the hazards (influenced by climate change) and socio-economic potential. That is why the relevant hazards (storm surge, salinity, and drought), climatic and socio-economic variables were selected as drivers. Productive 2050 and Active 2050 scenarios were developed to replicate the best and worst conditions, respectively, in line with BDP2100. The real-world conditions were replicated in the i-Clue environment in terms of Land Use demands, Ease of Change and Neighbourhood parameters.

After the set of simulation runs, the outputs revealed some key insights. The settlement and partially cropped areas are likely to increase in future. Agricultural lands are likely to be converted into these land use classes to cope up with the demand. The spatial allocation of land use classes, the prime reason of using i-Clue platform over others, illustrated the pattern of land use change. In Active 2050 scenario, the settlement is likely to be developed in clusters

around the existing areas, which represents concentrated development. In Productive 2050 scenario, the expansion is more dispersed. In Active 2050 scenario, the settlements get developed around the primary road network, especially in the Jessore- Khulna region. In Productive 2050 scenario, the Upazila road network also plays a key role in decentralized settlement expansion. In both scenarios, the Partially Cropped Areas get expanded in the vicinity of current areas. The increase in Partially Cropped Areas is considerably more in Productive 2050 scenario, depicting better socio-economic conditions and diversifying economic practices.

This is a pilot study, so the outputs can be linked to other existing and proposed research and implementation projects. For example, the outputs can be part of the knowledge base of the proposed knowledge facility funded by the EKN to Bangladesh. The outputs can be linked to Bangladesh Metamodel, which is a decision support tool developed under the JCP umbrella for implementation of BDP2100. The outputs can be directly used for developing concept notes for the implementation portfolio of BDP2100 as well. Existing govt. projects dealing with land use change such as My Village My Town (LGED) and Sustainable Land Management (DoE) can be also benefited by insights from this study. Other govt. ministries and agencies such as MoP, MoL, MoI, MoS, SRDI, BADC, DAE etc., can be benefited by this study with due upscaling.

This was an incubator project under the JCP umbrella. So, the time and budget allocation restraint were defining parameters in scope and extent of this research project. Other than upscaling of this project, some activities in further research studies may be conducted including land use conversion analysis, to find prominent conversion mode and zonal statistics (district/upazila level), to find out the land use change at more micro-level.

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1 INTRODUCTION

1.1 Rationale of the study

The formulation of the Bangladesh Delta Plan 2100 was initiated in 2014 and approved in 2018. The BDP2100 has a holistic approach to planning, and works towards a sustainable future incorporating national and hotspot wise strategies and comprehensive measures for 2030 (short term), 2050 (mid-term) and a long-term view till 2100 (GED, 2018). This is a comprehensive strategy to define short, medium and long-term goals, targets and strategies to reach the long-term vision 'achieving safe, climate resilient and prosperous delta' step by step which includes spatial planning and land use management focusing on coastal protection, controlled flooding, water security for consumption and agriculture, food security, infrastructure, environment, ecology and institutions and governance (GED, 2018). Moreover, BDP 2100 is linked with resources that would contribute to the short-term five-year plans as well as contribute to achieving Sustainable Development Goals (SDG)s and other policy goals. Also, Bangladesh Perspective Plan 2021-2041, another long-term plan formulated by the government has set a target of transforming the nation to a developed country by 2041 through coherent strategies in consideration of climate change and future demands (GED, 2020). All these plans have entitled vision and set strategies for development in broader terms, which need to be translated into actions at regional and local level which will influence the landscape level the land use pattern, and for which informed decision making and monitoring is still lacking, thus resulting in progress being the only agenda.

For instance, at present, during the implementation stage of the Bangladesh Delta Plan, a couple of activities such as dredging of small rivers and canals, development of a cross dam to facilitate coastal land reclamation etc. are being conducted and many more implementation activities will follow on in near future which will definitely influence the local biophysical and socio-economic environment through the changes in land use pattern over the years. Until the impacts on ecosystem services, or sustainability indicators are measured and assessed, the net development from the formulated plan cannot be ensured. A clear understanding of current land use pattern and research on the future land use under different climate, economic and population scenarios are crucial to help enlighten the impacts and make adaptive plans for the given future scenarios. So far, Bangladesh has no insight into future trends of land use changes. In Bangladesh, mostly research activities have focused on spatio-temporal land use change analysis, and classification of land uses but have not included modelling land use to foresee the future land use pattern, which would allow assessment of preferred pathways.

A couple of research activities such as (Waddell, 2002), (van Asselen & Verburg, 2012), (Verburg, et al., 2002) , (Brown, Robert, Seto, & Manson, 2004), (Ahmed, Moors, Khan, Warner, & van Scheltinga, 2018) and others were conducted on land use modelling in different areas from different perspectives and provide useful stepping stones. Inspired by the research activities conducted by (Verweij, et al., 2018), (Huber Garcia, Meyer, Kok, Verweij, & Ludwig, 2018), (Hasan, Deng, Li, & Chen, 2017), (Verburg, et al., 2002) , and some others, the LUCK project also aims at using an internationally recognized land use model called iCLUE to develop land use scenarios in the context of Bangladesh.

1.2 Aims and objectives

The aim of this study is to provide insight in land use and land use changes using an internationally established model in the context of Bangladesh. The specific objectives of this project are to:

- prepare land use information for base year i.e., 2020
- project land use scenarios based on socio-economic and climate projections for i.e., 2050
- interpret the land use projections and inform the decision-making process

- formulate appropriate follow up

1.3 Study area

The project needs to focus on an area, preferably linking to existing policy priorities, like the earlier mentioned My Village, My Town, and Bangladesh Delta Plan 2100. Under the LUCK project, the development of the land use model of Bangladesh wa be setup for the coastal region as well as some selected urban areas. It is foreseen that follow up activities work towards coverage of the entire country under the model

The areas considered are-

a) Regional level at a broader scale: Coastal Region especially South West (SW) region (including six districts i.e., Khulna, Satkhira, Bagerhat, Jessore, Faridpur and Kushtia)

b) Local level at a more detail scale: Urban areas (e.g., Khulna City Corporation, Barishal City Corporation)

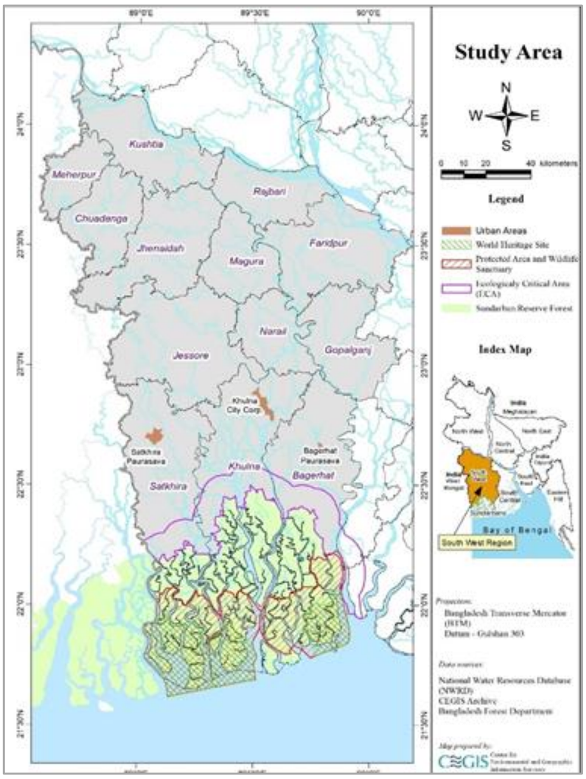


Figure 1.1: Study Area

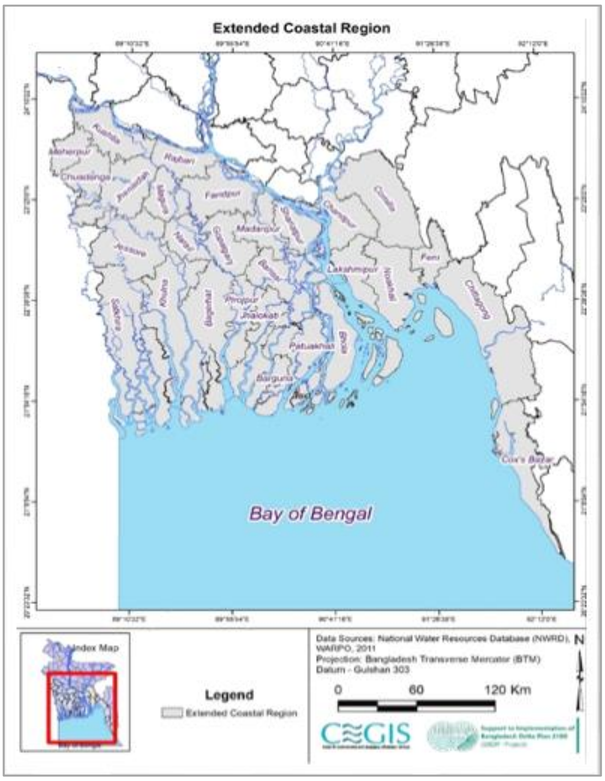


Figure 1.2: Extended Coastal Zone (ECZ), identified for the ADM programme in SIBDP

The SW region is one of the hydrological regions of Bangladesh. Influenced by tidal waterflow from the sea and freshwater flow from upstream, many parts having a unique brackish water ecosystem. The region has vast low-lying areas enclosed by man-made polders and is considered to be highly vulnerable to climate change induced hazards. With a projected population of 22 million, the region comprises the six districts of Khulna Division and Faridpur District of Dhaka Division. There are 50 municipalities, including Khulna City Corporation and six major cities: Faridpur, Chuandanga, Jessore, Jhenaidah, Kuhstia and Satkhira. The Sundarbans covering 10,000 km2 is located in this region. It contains the world's largest area of natural mangrove forests. The area has both local and global significance due to its diversity, uniqueness, biological productivity and rich ecosystems

1.4 Background

Bangladesh is one of the most dynamic and fertile deltaic countries in the world which has a population of about 160 million crammed into 1,47,570 km2 including rivers resulting in one square kilometer area being allotted to approx. 1200 people. Bangladesh is highly vulnerable to climate change and water related threats and impacts which is even more challenging in making the achieved growth sustainable in the face of extreme climate variability, storms and tidal surges, flooding and droughts. Owing to the deltaic formation of the country, the configuration of the rivers and climate change, Bangladesh has been ranked as the 6th most vulnerable country in the world in terms of risks from natural hazards. During the annual monsoon rains, the river discharge increases, consequently the land floods, and fertile sediment is left behind. Due to industrialization, pollution, urbanisation, population growth and climate change, the natural system is increasingly put off balance. The fertile agricultural lands are being replaced due to urbanisation and industrialization. Bangladesh is progressing toward becoming a developed country and under the slogan "My Village, my Town", the government aims to provide all the villages with urban facilities to reduce rural-urban migration and at the same time improve their quality of life[1]. The subsequent urbanisation will then enhance related problems such as urban flooding, waterlogging, heat island effects etc. Land and soil are impacted by salinization and a changing water regime; especially in the south west i.e. the coastal region. Rising sea-level is another threat for the coastal districts in Bangladesh. Land scarcity and also displacement due to river erosion forces the poor to build their houses on unprotected floodplains and wetlands for livelihood security. All the occurrences are continuing with changes in the land use patterns that have high cumulative impacts on the environment. It is important to develop scenarios of possible developments based on most suitable location selection, so informed decision making and monitoring takes place.

This is why, this Land Use Change Knowledge (LUCK) project was initiated for developing a modelling framework which provides an insight to present and future land use, based on a set of indicators formulated with expert judgement. The Land Use Change Knowledge (LUCK) is an incubator project under Joint Cooperation Programme Bangladesh – the Netherlands (JCP) with a duration of one year starting from August 2021 through July 2022. This project is funded by Incubator fund of JCP that has been intended for the development of additional research ideas into feasible projects, bringing new partners on board and welcoming new knowledge and fresh perspectives. Led by CEGIS, originally the proposal was submitted by Wageningen University & Research (WUR) whereas, Department of Agriculture Extension (DAE) and General Economics Divisions (GED) are the knowledge clients.

External partnerships with Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), and Climate Adaptation Services (CAS), and private sector parties are established for the further development of the incubator. This project fulfils the incubator criteria having more than two JCP partners, being achievable by JCP period and clearly addressing the needs of knowledge clients and having high potential for upscaling. The JCP Review Committee approved this project assessing its criterion based on: i) quality; ii) implementation readiness; and iii) impact in relation to the goals of the Bangladesh Delta Plan 2100 (BDP2100).

[1] https://bangladeshpost.net/posts/my-village-my-town-equips-rural-folk-with-urban-amenities-11736

2 RESEARCH QUESTION AND METHODOLOGY

2.1 Research question

The ever-changing land use patterns in Bangladesh, especially in coastal region being so dynamic and having climate change effects and in urban areas being influenced by population expansion is so typical that collection of information on land use change scenarios is the time demanding study for public to private sectors, throughout the nation to align with the strategies and goals set for the future Bangladesh.

A couple of reasons are there behind the project initiative that has driven the necessity of the study to take place. The governmental sectors are in quest of information to help prepare for the organizational activities. DAE can be exemplified that has placed specific request for information on land use change scenarios since DAE is concerned with organizing advises from national to individual level farmers throughout the country and providing them with knowledge of agronomic techniques and skills to improve their productivity, food security and livelihoods. Further, at national level, DAE is involved in planning for future agricultural developments, in line with BDP2100 implementation, for which information on future land use and land use changes is important. Moreover, during a recent Bangladesh Metamodel consultation session with the Planning Commission/GED, they expressed the need to be able to visualize the future changes in land use so that projects can be planned and the impacts of investment plan can be assessed. LGED plays a key role in developing the cities and towns with facilities and services in the period of rapid population growth while the associated hazards will generate a great difficulty in planning process. Land use modelling can assist the urban planners to get an insight in the city's growth in future (based on scenarios) and to prepare the development plans accordingly. Indeed, this project is expected to play a vital role in providing future patterns of land use changes, a modelling set-up that has the potential to scale up to the whole country and more importantly, thus supporting informed decision making.

In summary LUCK addresses the broader question 'How to get insight of the spatial distribution of future land use, given certain government policies' – for the specific case of Southwest Bangladesh (link to BDP2100) and Khulna and Barisal city corporations by developing a modelling framework using iClue for these area/cities and exploring how this can be scaled up towards whole Bangladesh.

2.2 Methodology

2.2.1 *iCLUE*

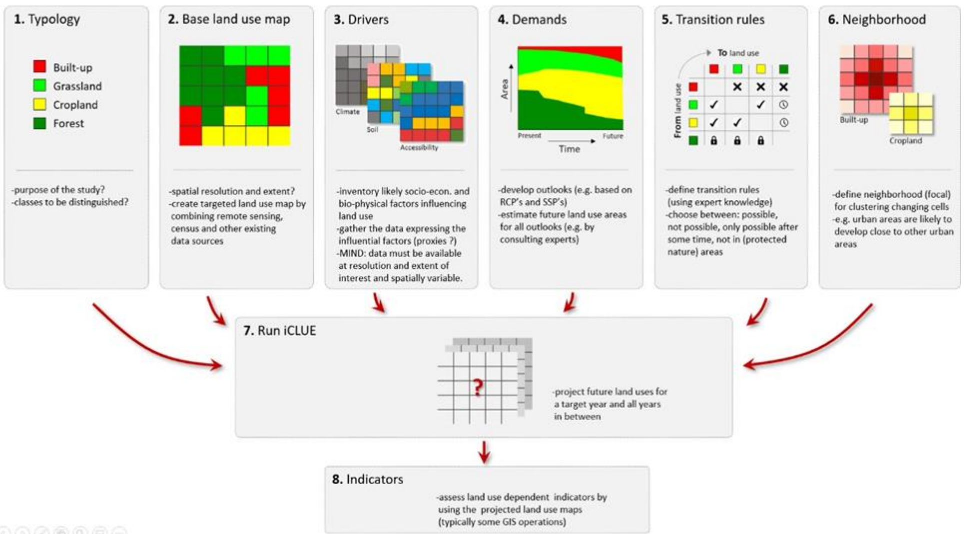


Figure 2.1: The iCLUE model and the pre-modelling (1 to 6), model execution (7) and post-modelling (8) steps.

The most recent member of the Change Land Use and its Effects (CLUE) model family (Veldkamp, et al., 2001); (Veldkamp & Fresco, 1996); (Verburg & Overmars, 2009); (Verburg, et al., 2002);, iCLUE, applies areal land use demands to assign land use (Verweij, et al., 2018). This land use allocation process is driven by: (i) land use suitability, (ii) specific area demand for all land use classes, (iii) conversion rules and (iv)land use types of adjacent cells.

i. *Land use suitability:* determined through socio-economic and biophysical features, e.g. climate, soil, accessibility and terrain. The suitability for every land use cell is calculated through a stepwise regression analysis performed by the iCLUE model.

ii. *Area demands for all land use classes:* aggregated land use demands for every land use class for the final projected year of modelling. These demands are calculated through trend extrapolation or by other models.

iii. *Conversion rules:* impact the possibility to change from one land use type to another. There are two types of conversion rules: (a) conversion elasticity and (b) land use shift order.

  a. *Conversion elasticity:* expresses the chance of land use change through a cell value of 1 when conversion is allowed and cell value 0 when conversion is not allowed. For example, built-up areas have a low probability of change since the development costs were high (Verburg & Overmars, 2009) .

  b. *Land use shift order:* through a conversion matrix it is indicated whether the conversion is possible, conversion impossible, conversion possible after specified time and conversion (im)possible in specific area. The conversion is determined from every land use class to another land use class.

iv. *Land use types of adjacent cells:* the transformation of a land use cell is affected based on the land use type of the adjacent cells. For instance, forest area will expand around existing forest area.

Since the LUCK project aims to develop land use model suitable in the context of Bangladesh, the internationally recognized iCLUE model has been chosen to apply in this project. The model is customized to a set of parameters for land uses in urban and coastal areas in Bangladesh, jointly agreed upon with the team. The model is then applied to the case, and based upon the results, discussion with the key clients took place, to assess the functionality. In parallel, considerations for further upscaling were determined and worked out into possible follow up projects. Considering the required technical approach to reach the objectives, the methodology has been designed as described below in 9 steps.

1. Define modelling objective and possible scenarios through literature review, trend analysis

To conduct any research activity, literature view and conceptualization are the first and foremost tasks to be done with an aim to earn knowledge, find research gaps and brainstorm the methodology. The articles, journals, peer reviewed papers, books etc. relevant to land use modelling was studied and conceptualized to support methodology for tool development and gain knowledge about land use pattern, land use changes and modelling techniques and define modelling objective.

Trend analysis included a concise overview of major socio-economic and climate trends. This was then be the basis of a joint formulation of possible scenarios, which is further elaborated in step 5.

2. Development of land use typology and baseline data including land use map

After the completion of literature review and conceptualization, data on land use patterns and classifications have be developed. For this project, 2020 has been considered as the base year. A recently developed land use map (100x100m) is used as basis. It has been further adapted towards the objective of this study.

3. Stakeholder and expert consultations

Stakeholder and expert consultations are a continuous process and key in generating outputs through an interactive manner. Land use modelling experts and knowledge experts from both government and public sectors are consulted to exchange knowledge, information, techniques to support data processing and tool development. Private sector involvement is required to enhance the knowledge base through public-private partnership and also to explore funding for upscaling.

4. Bio-physical and socio-economic data collection and preparation

Bio-physical and socio-economic data for study areas were collected, processed and prepared so that they can be used in the model as drivers for land use change analysis. These datasets are very important since they influence the generation of future scenario following the trend of land use changes.

5. Development of future scenario and land use demand

Land use future scenarios and demand were projected based on the analysis of existing demand to achieve knowledge about the changing patterns and the active drivers behind accelerating the changing processes. The analysis turns put as the key to the tool development which incorporates the trends or land use patterns in the model.

6. Model parameterization/calibration

Model parameterization is a crucial step before it is run. The iCLUE model will be set up with the bio-physical and socio-economic drivers and land use demands from scenarios and conversion.

7. Model Simulation and validation

After all the parameters are set in the model, model will be run and validated. Careful documentation of the modelling is essential, in order to be able to translate the results to knowledge clients and reflect on possible upscaling options.

8. Dissemination of results

Finally, the model results have been translated to the knowledge client, and reflections are discussed. Further, for further upscaling, a proposal will be formulated.

9. Report Preparation

Reporting is the important step to document all the tools, methods and techniques that will be used during the tool development process and prepare documents to share with team. Three reports at three different stages- inception, intermediate and final will contain the progress and methodological improvement in its way. At the initial stage an inception report was prepared summarizing the joint approach. The final report includes an overview of the modelling results and reflections from users, as well as a proposal for follow up projects.

2.2.2 Stakeholder involvement

Planning for land use change and subsequent development is a macro-scale and interdisciplinary task in nature. Considering this, the stakeholders were first listed. Then their involvement was conceptualized at different levels.

Figure 2.2 illustrates the stakeholder involvement at different levels and their level of involvement. The stakeholders are classified into 4 categories as per their role in planning phase. Decision Maker authorities would be involved in formulating policy, plan, rules and acts which can drive land use change. Experts provide technical and analytical support, which includes the regulating authorities. Implementation authorities include agencies which are likely to implement programmes and projects associated with land use change. The end users, who are likely to be impacted by land use change have been termed as User.

3 different levels of involvement depict the scope of stakeholders' involvement at this stage. Co-Knowing stakeholders would be involved in the shell-level with decision making, providing technical and analytical support, disseminating the information to people at core-level. The Co-thinking stakeholders are involved in the intermediate level. Co-operating stakeholders are at the core. Their involvement includes helping in ground-truthing the results of GIS-based analysis, supporting in preparation of Land Acquisition Plans and Resettlement Action Plans (for the people who are likely to be re-habilitated due to projects) and disseminating the measures to the public.

The stakeholders were consulted using different methods. In some cases, the expert consultations were done over telephonic conversations or using virtual platform. Delta Knowledge Days 2022 proved to be a great platform for stakeholder consultation session. The stakeholders were invited for discussion during a plenary session. A knowledge sharing session (including basic training on land use modelling) was also organized to consult the stakeholders.

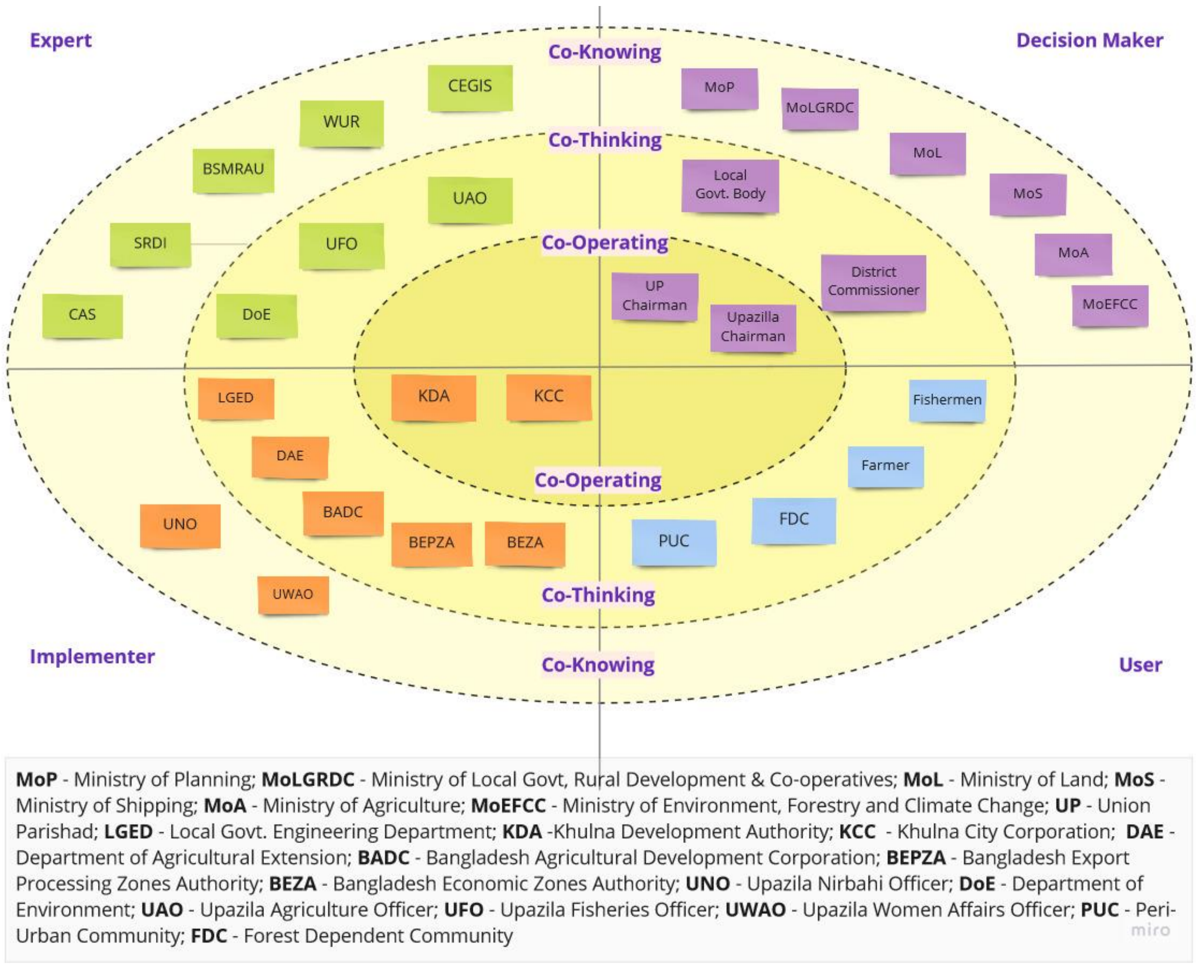


Figure 2.2: Stakeholder map - Planning Phase for Land Use Zoning

3 BASELINE ANALYSIS

Land Use change is a gradual phenomenon. The change is usually governed by recent trends, while policy directives or recent interventions can induce abrupt change. Scoping of selected climatic and socio-economic parameters has been conducted to represent the environmental, socio-economic parameters which are likely to influence land use change in this area.

Considering the spatial variability in land use, the categories in this region have been classified with due expert judgement. Relevant stakeholders have been consulted to make this analysis representative. This chapter explains attributes of existing land use classes, trend of relevant parameters and role played by key stakeholders.

3.1 Scoping (trends)

Land use is intertwined with human activities at all scale and levels. The geographical and environmental settings of a region drive the establishment and expansion of human settlement in an area. The socio-economic activities induce land use change. Changed land use creates new socio-economic activities. Extent of this cycle in the South-West region has been analyzed by exploring the following trends –

1. Population trends
2. GDP trends
3. Land Use Trends
4. Climate Trends

The scoping analysis is described in detail below –

3.1.1 Population Trends

The population density (district-level) in the study area has been analysed for the years 2001, 2011 and 2022. These are the years when Population and Housing Census has been carried out by Bangladesh Bureau of Statistics.

From the Figure 3.1, it is observed that the trend of population density is on the rise in most districts from 2001 to 2011. Kushtia is the most densely populated district in both 2001 and 2011. In Khulna, Satkhira, Bagerhat, Gopalganj, Pirojpur, Madaripur and Barisal districts, the population density has declined from 2001 to 2011. Bagerhat, and Satkhira are the districts with most decline in population density.

Population density exhibits increasing trend in all the districts from 2011 to 2022. Rajbari, Kushtia and Faridpur are the districts with most increase, whereas Bagerhat and Satkhira are the districts with least increase in population density. According to the recently performed population and housing census, Kushtia, Jessore, Madaripur are the most densely populated districts while Bagerhat and Satkhira are the least densely populated districts in the South-West region of Bangladesh.

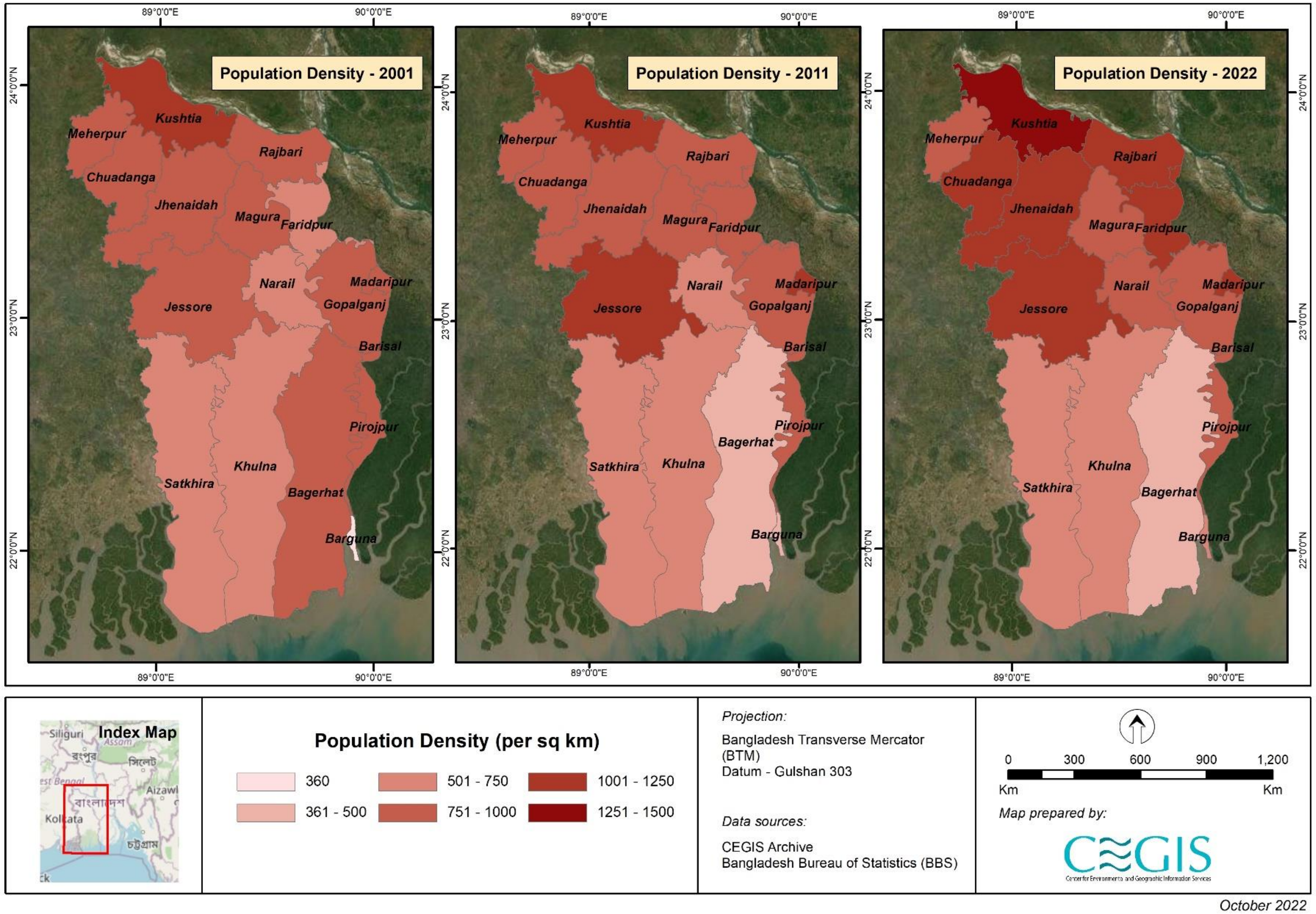


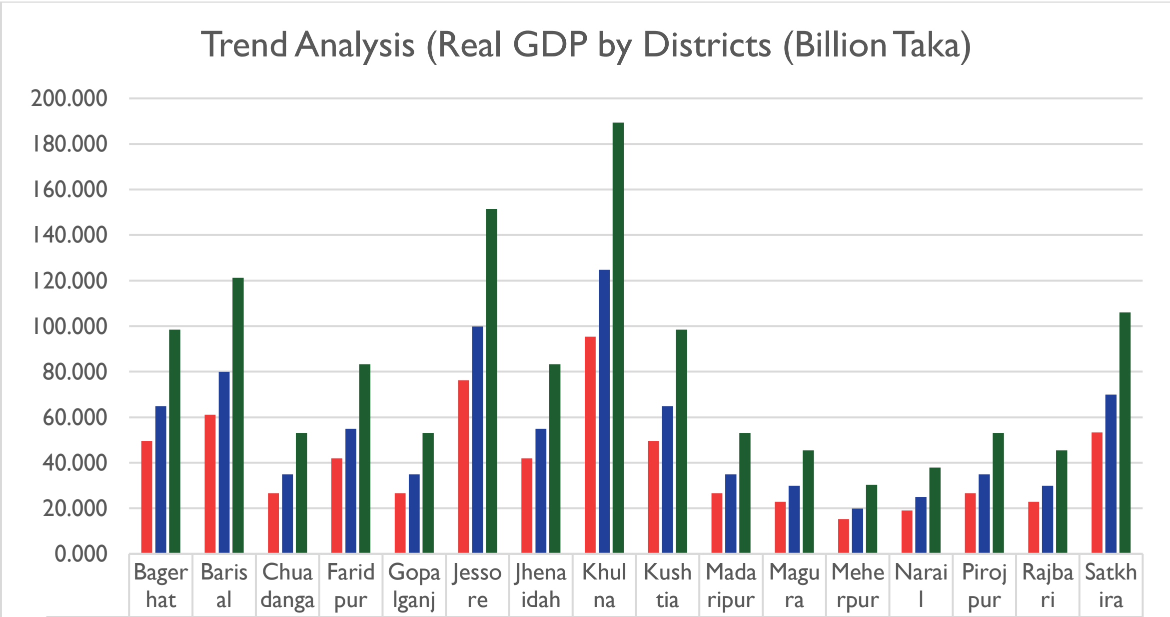
Figure 3.1: Population Density (District-level) in the study area in 2001, 2011 and 2022

3.1.2 GDP Trends

GDP is very important socio-economic driver. Because of this socio-economic driver the land-use change is trigged and the changes in land-use also effect the socio-economic flow and GDP trends. Bangladesh's economy has seen significant change since attaining independence in 1971, and future changes may be more significant by 2050 than those already experienced. Along with the expansion brought on by the great developing nations, the global economy is also set to experience considerable changes. Especially, the geopolitical situation may have significant impact over GDP growth in present and future. As according to the Perspective Plan, Bangladesh is in pursuit of becoming a developed country by the year of 2040, many development projects are taken to fulfil the targets. These development projects and plans are influencing the land-use changes which will directly and indirectly effect the GDP growth rate pattern.

<u>GDP Growth Category of South West Region</u>

Here, the real GDP value and growth rate value, which are accessible from BBS, have been used to estimate the Southwest region's (16 districts) GDP (Islam, Mujeri, Alam, & Islam, 2014) over a ten-year period (FY 2011 through 2020). Figure 3.2 displays the findings of 16 districts' trend analyses for the years 2011, 2015, and 2020. The main economic development initiatives are more advanced in Khulna than in other districts in the south-west region because it is the divisional district. In the year of 2011, 2015 and 2020 GDP of Khulna districts are 95.3 billion TK, 124.7 billion TK and 189.3 billion TK. Figure 3.2 clearly displays the GDP values for different districts of SW region. Apart from Khulna, the GDP value of Jessore, Barisal, and Bagerhat are also improving in terms of GDP value.



	Bagerhat	Barisal	Chuadanga	Faridpur	Gopalganj	Jessore	Jhenaidah	Khulna	Kushtia	Madaripur	Magura	Meherpur	Narail	Pirojpur	Rajbari	Satkhira
FY11	49.59	61.03	26.70	41.96	26.70	76.29	41.96	95.36	49.59	26.70	22.88	15.25	19.07	26.70	22.88	53.40
FY15	64.88	79.85	34.93	54.90	34.93	99.81	54.90	124.7	64.88	34.93	29.94	19.96	24.95	34.93	29.94	69.87
FY20	98.46	121.1	53.01	83.31	53.01	151.4	83.31	189.3	98.46	53.01	45.44	30.29	37.87	53.01	45.44	106.0

Figure 3.2: Sectoral contribution of SW to National GDP

DATA SOURCE:(ISLAM, MUJERI, ALAM, & ISLAM, 2014)

The GDP value of 16 districts has been categorized into five classes: very low, low, moderate, high and very high. The category is shown below:

Table 3.1: GDP district value categorization

Category	**GDP (Billion Taka)**
Very Low	Less than 50
Low	50 - 150
Moderate	150-500
High	500-1000
Very High	1000-2000

Meherpur, Rajbari, Jhenaidah, Magura, and Faridpur all have very low GDPs in the year 2020. Other districts with low GDP values include Kushtia, Chuadanga, Jhenaidah, Faridpur, Madaripur, Gopalganj, Satkhira, Bagerhat, Pirojpur, and Barisal. However, it is predicted that by 2040, these very low GDP and low-categorized districts will rise to a moderate level with a GDP of at least 150 billion Tk. It will still fall under the moderate category in 2050.

By the year 2020, only Jessore and Khulna out of 16 districts fall into the moderate category. Compared to other SW regions, Khulna and Jessore have a more advanced economic development. Since Khulna is a divisional district, the other 15 districts' economies are equally reliant on it. By 2030, the GDP of these two districts will be in the high range, and by 2050, it will be in the very high range.

In comparison to their moderate and low GDP levels in 2020, Khulna, Jessore, and Satkhira are expected to contribute very high GDP levels by the year 2050. Meherpur, Rajbari, Jhinaidah, Magura, Faridpur, and Narail districts are currently in a very low category but will move up to a moderate to high category by the year 2050.

In the year of 2020, all of the districts of SW regions are in very low to moderate category. The GDP value of these districts are under 500 billion Tk. However, these districts will advance into moderate to very high level if the economic force remains stable and is not affected by other disputes.

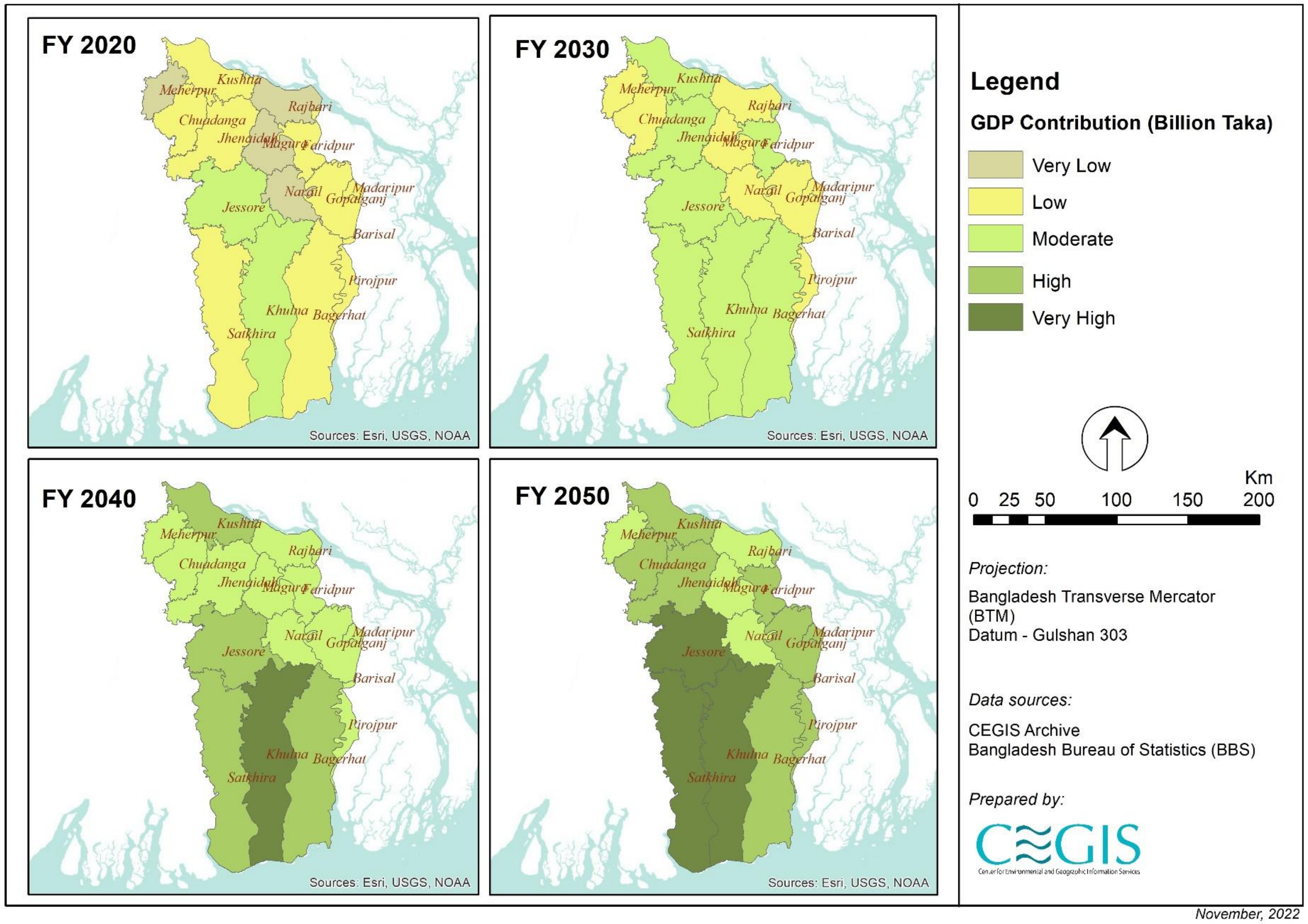


Figure 3.3: GDP Contribution of Districts in the SW region

3.1.3 Land Use Trends

Trend analysis of past events is the first step for any sort of future simulation or projection approach. Considering the key objective and scope of this study, the Land Use change has been analysed for 2010-2020. The key policies, plans and programmes by Govt. of Bangladesh which have considerable impact over future land use change, including Bangladesh Climate Change Strategy and Action Plan (2009), National Adaptation Programme for Combating Desertification (2005), SDGs (2015-2030), Bangladesh Delta Plan 2100 (2018), National Water Act (2018) etc. have been either taken up or initialized for implementation in this period.

For this study, the broad categories recommended in the IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (IPCC, 2003) have been used. The categories are provided below:

5. Aquaculture
6. Cropland
7. Forest Land
8. Grasslands
9. Other Lands
10. Settlements
11. Wetlands

Land Use Change in the study area has been presented in Figure 3.4 and Figure 3.5. From the figures, it is observed that all the LU categories show increasing trend, except Cropland. The climatic conditions, hazards, and conversion of croplands to housing and industrial areas are the prime factors behind this decline. It is very positive to note the increase in Forest Land. The slight increase in Wetlands depict the implementation of policies, plan and programs for conservation of river and waterbodies. The net erosion-accretion process also plays significant role in decrease of the croplands and increase of wetlands, considering the accreted chars and areas adjacent to rivers are used for agricultural purposes.

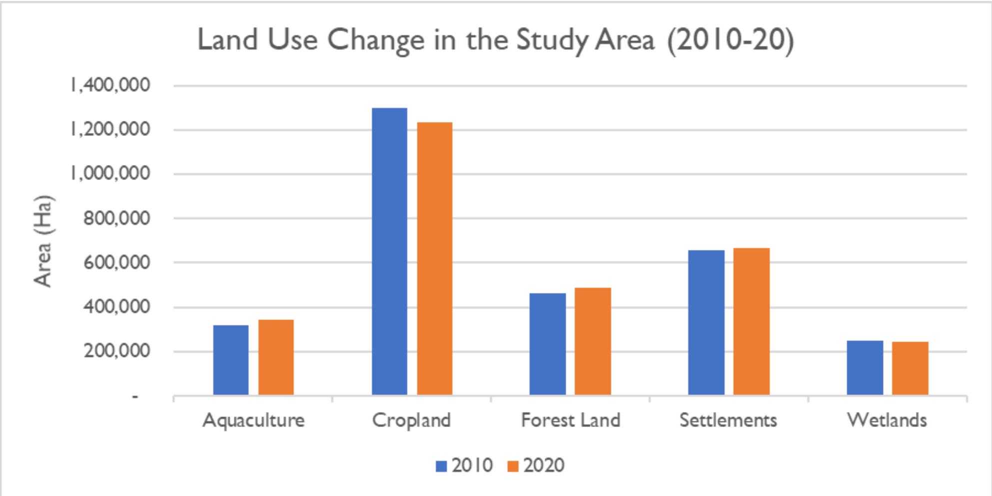


Figure 3.4: Land Use Change in the Study Area (for categories with area > 100,000 Ha)

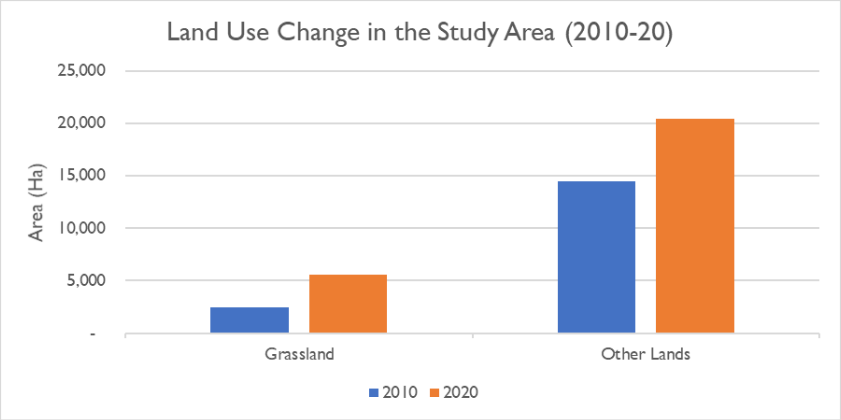


Figure 3.5: Land Use Change in the Study Area (for categories with area < 100,000 Ha)

3.1.4 Climate Trends

The climatic variables are key factors in development of natural resources and topography, human settlement and other associated anthropogenic activities. All of these are key factors in Land Use change. That is why the climatic variables temperature and precipitation were analysed. Data was attained from 12 stations maintained by Bangladesh Meteorological Department (BMD) which are in the vicinity of South-West Region and are likely to have impact over regional climate (Figure 3.6).

Figure 3.6: BMD Stations in the Study Area

Temperature

The temperature data was attained from 1948-2017 for the aforementioned stations in the vicinity of study area. The annual maximum temperature and annual maximum temperature for the study area was computed to get a representative picture of the prevalent conditions.

It is observed from Figure 3.7 that annual maximum temperature has varied within 34-40°C during the observation period. The trend shows that recorded maximum temperatures used to be higher in the past. From the 2000's the maximum temperature has been recorded in the region of 35-37°C.

Time-series analysis of the annual minimum temperature has been presented in Figure 3.8. The annual minimum temperature has varied between 8-12°C from 1948-2017.

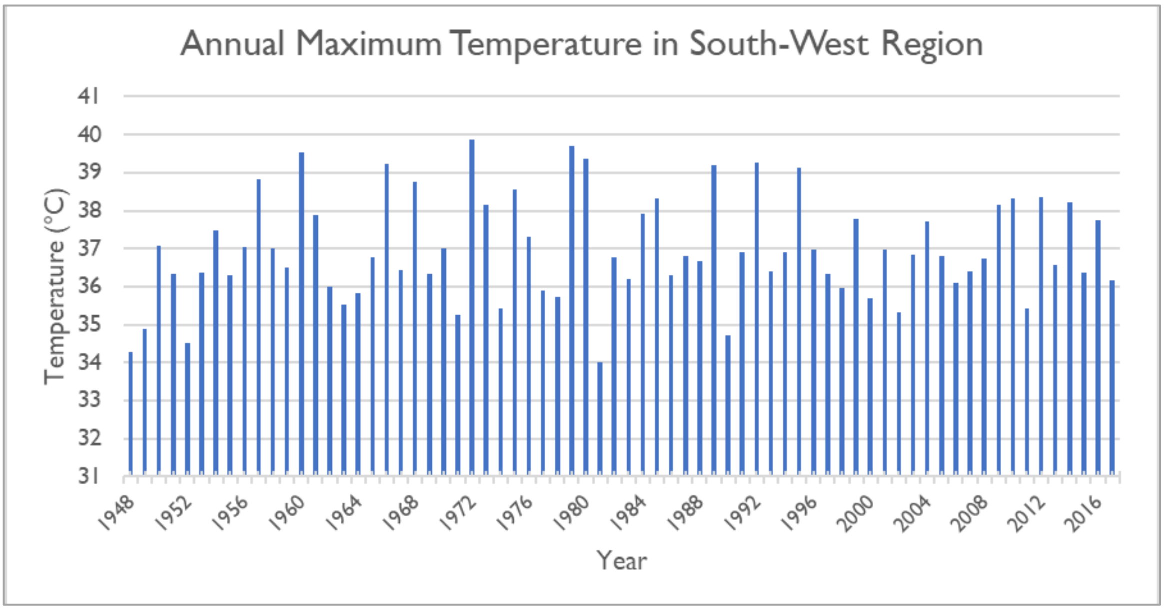


Figure 3.7: Annual Maximum Temperature in the South-West Region

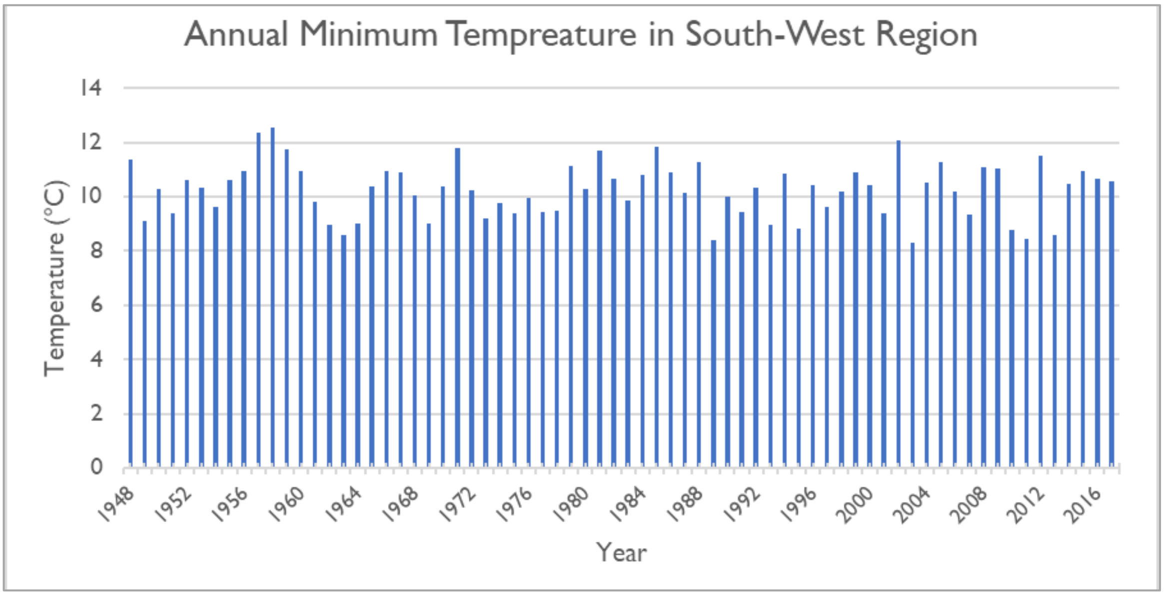


Figure 3.8: Annual Minimum Temperature in the South-West Region

Precipitation

The precipitation data, attained for 1948-2013 from the aforementioned BMD stations have been analysed as a Time-Series graph to portray the historic trend of precipitation in the study area. From Figure 4.1, it is observed that the average annual precipitation has varied between 1500-2200 mm over the years. The maximum annual rainfall was recorded in 1960 while the lowest annual rainfall was experienced in 1972.

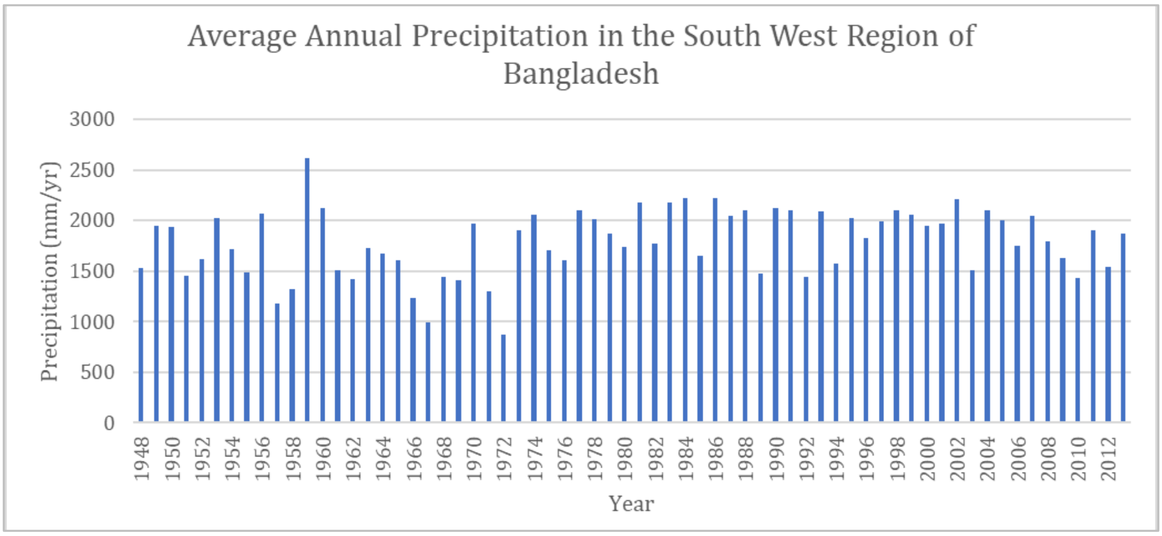


Figure 3.9: Average Annual Precipitation in the South West Region of Bangladesh

3.2 Typology (legend) and baseline map

The land use typology for this study has been developed as per IPCC guidelines (see section 3.1.3). However, some adjustments have been made to the IPCC classes as per previous studies and expert judgement. The IPCC classes with respective modifications are shown in Table 3.2.

Table 3.2: Land Use Typology used in the Study

Land Use Class NAMES (IPCC)	Adjusted Land Use Class NAMES
Aquaculture	Partially Cropped Areas
Cropland	Agriculture
Forest Land	Forest Land
Grasslands	Grasslands
Other Lands	Other Lands
Settlements	Settlements
Wetlands	Rivers and Canals

The Land Use practices in South-West region of Bangladesh have some indigenous attributes. Main form of aquaculture in this region is Shrimp cultivation (recently, Crab hatcheries are also getting popular). Shrimp cultivation requires the land to be submerged in brackish water for the project duration. Eventually, salt gets deposited on the top soil and the saline water percolates and infiltrates into the root zone. This phenomenon renders the land in the vicinity useless for agricultural and other purposes. That is why, the shrimp farmers leave the land as fallow land for 1-2 year after the shrimp project. The salt deposition gets washed away by runoff from precipitation (usually monsoon rainfall) and the farmers can use the land parcel for agricultural purposes. In case of some low depression areas, (locally known as beels, baors etc.) fisheries culture is practiced in wet season and crop cultivation is done in dry season (Boro rice being the main crop). That is why, the class name was modified as **'**Partially **Cropped Areas'** from **'Aquaculture'**.

'Cropland' and **'Agriculture'** is often used interchangeably. The term **'Rivers and Canals'** was preferred to **'Wetlands'** as common practice and for avoiding confusion.

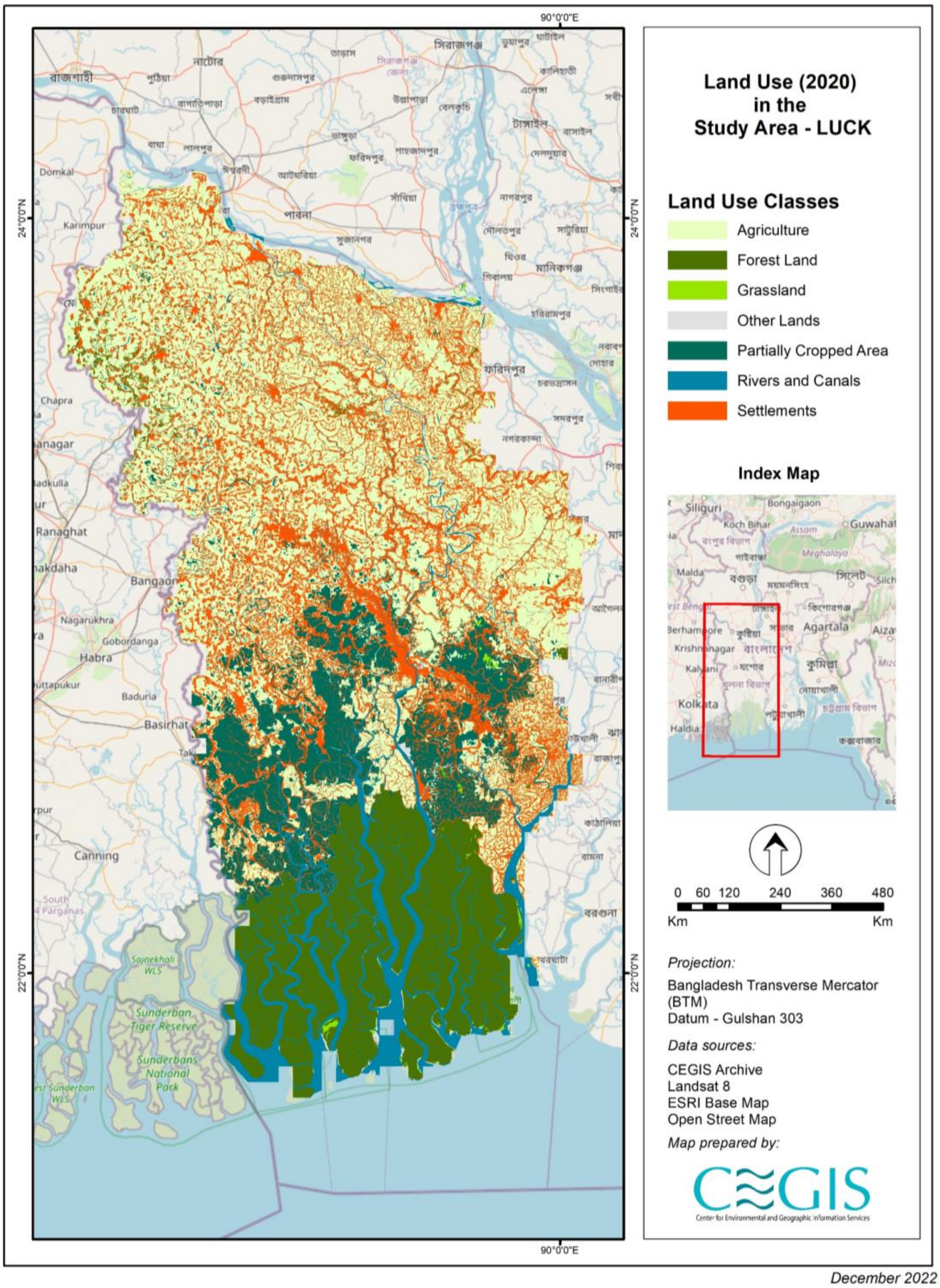


Figure 3.10: Land Use (2020) in the Study Area

4 LAND USE CHANGE ANALYSIS FOR THE FUTURE

Regional planning for an area is influenced by a number of driving factors such as socio- economic development, climate change and natural hazards, population dynamics etc. All of these factors govern the demand for land use in future. This makes land use the key driving factor in devising strategic measures for devising development pathways. For this purpose, land use modelling has been used in this study to provide an indication to future possible changes in the land use pattern of the South-West region. Analysis of land use change analysis for the future and interpretation of the outputs are presented in the following sections.

4.1 Scenarios

The potential of using the iClue model for two land use policy alternatives has been demonstrated in this study. These alternatives are based on the scenarios that were identified in the BDP2100 project. Under BDP2100, four scenarios were developed. Within the scope of the LUCK project, it is not feasible to generate land use maps for all four scenarios.

Here, we take the two most extreme scenarios: productive and active. In the PRODUCTIVE scenario, there is a deliberate strategy to develop economic zones to prevent unplanned urban sprawl. In this scenario, the district cities and the key economic zones are being developed. This will lead to a concentration of urbanisation in selected parts of the study area.

In the ACTIVE scenario, there will be a more uncontrolled urban sprawl-like urbanisation pattern emerging. This means the urbanisation is scattered more randomly across the study area, following a business-as-usual pattern where existing settlements will expand and new settlements occur along the road infrastructures.

The iClue model is used to analyse the spatial patterns of both land use policy alternatives against the background of a changing climate. The NAP for Bangladesh is currently in the phase of completion and this document contains the most recent overview of the projected climate change impacts and projections for Bangladesh. The NAP report contains a multi-hazard map of the country indicating where the different types of hazards occur.

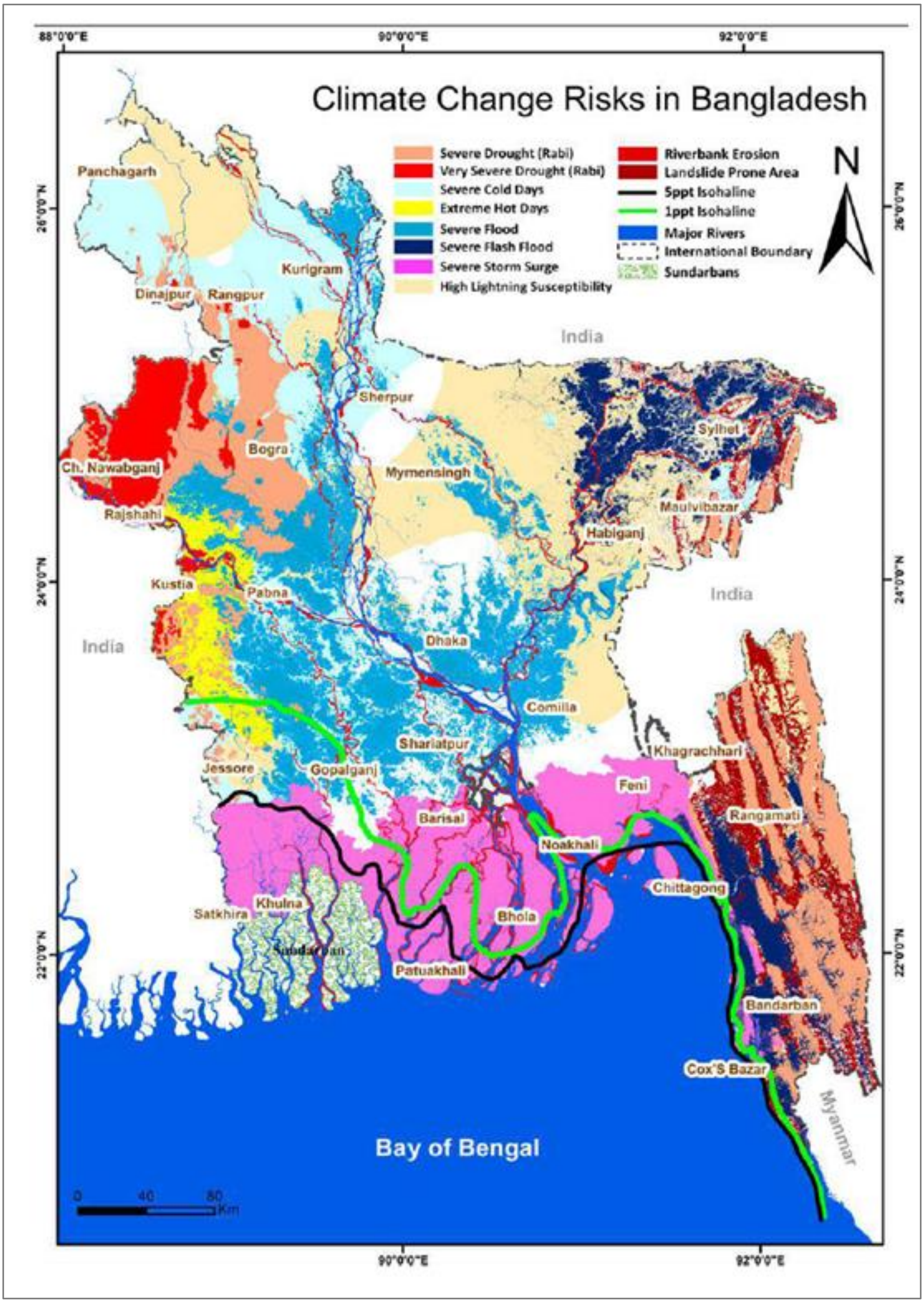


Figure 4.1: Multi-Hazards Risk Map of Bangladesh due to Climate Change

SOURCE: (CEGIS, 2021)

This map shows that in the study area a range of hazards occur: storm surges, salinity, severe flooding, extreme heat days and severe droughts in the rabi season.

For the LUCK project we selected a moderate climate change scenario, consistent with the Paris Agreement (1.5-degree target) in 2050 and a high climate change scenario consistent with RCP 8.5 in 2050. For the climate projections, the NAP report contains the following map:

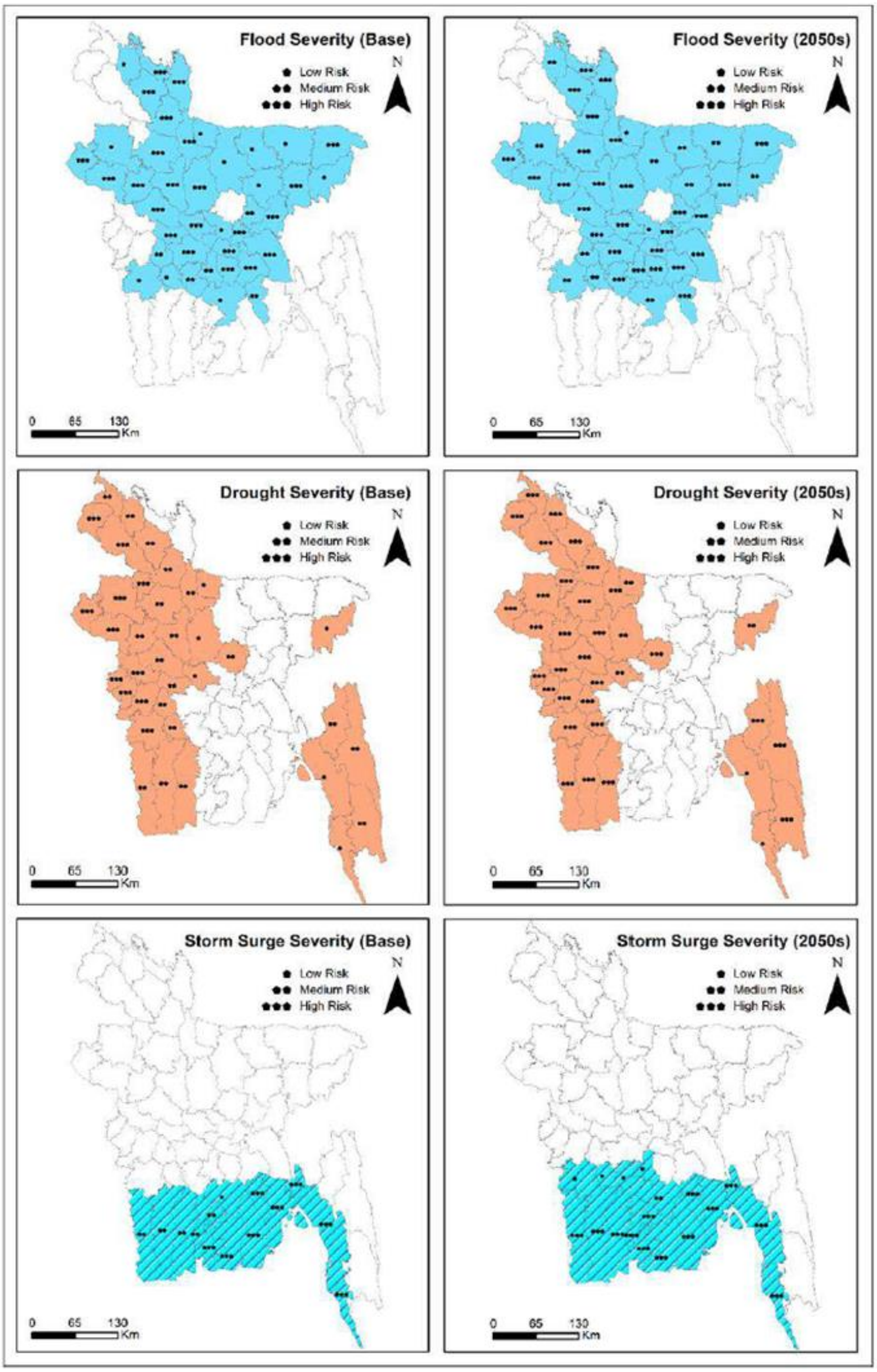


Figure 4.2: Flood, Drought and Storm Surge Severity in Bangladesh due to Climate Change

SOURCE: (CEGIS, 2021)

For the land use modelling it is important to use underlying spatially explicit data layers for the various hazards. The above map aggregated the hazard data to administrative boundaries. Using this map would cause unwanted boundary effects in the land use model outputs.

We have used the following maps (Figure 4.3 and 4.4) for the flood prone and drought prone areas:

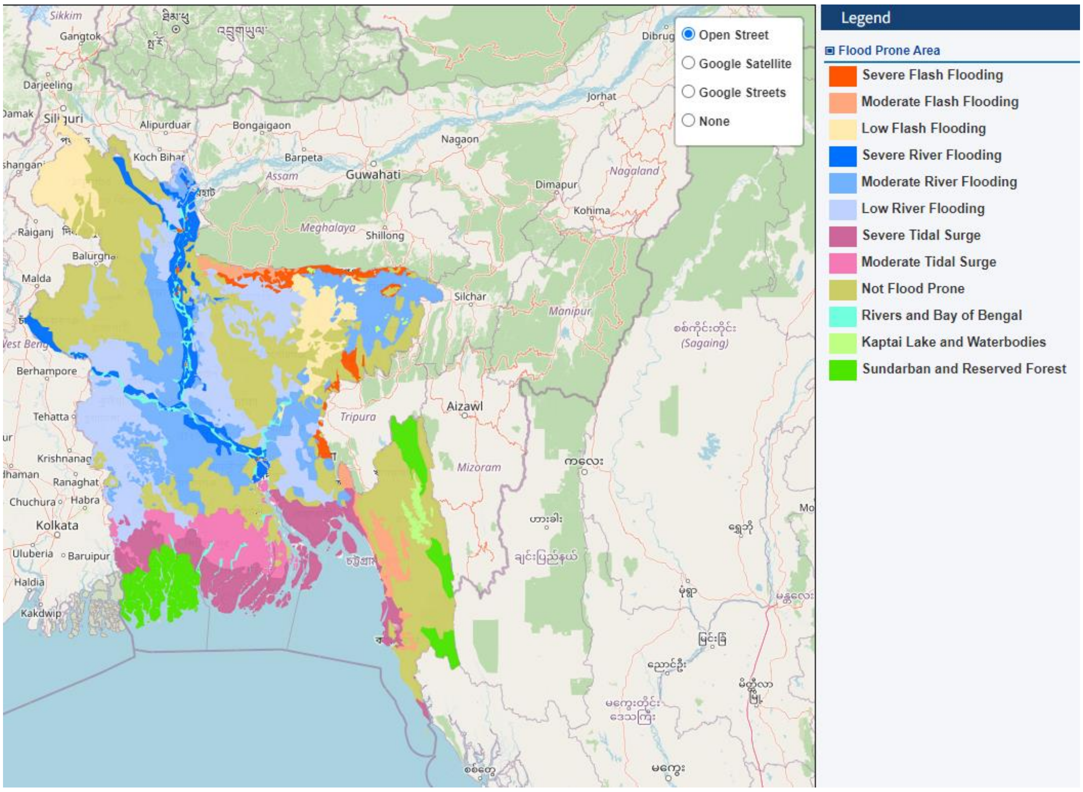


Figure 4.3: Flood Prone Areas in Bangladesh

SOURCE: (GED, 2022)

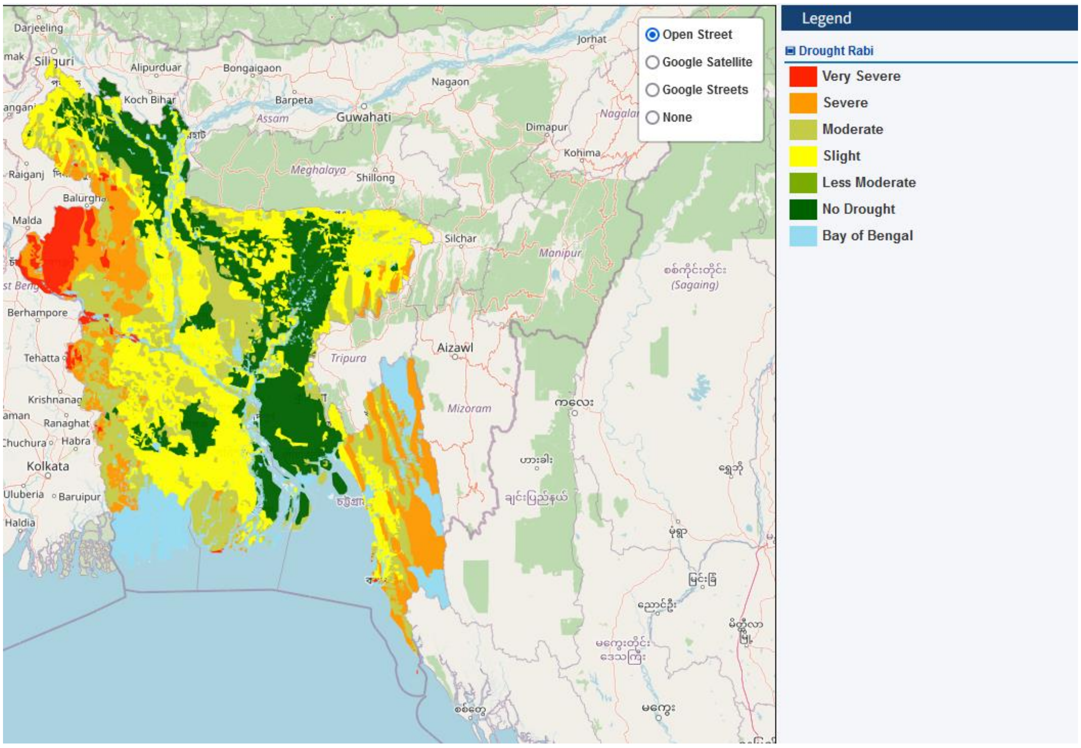


Figure 4.4: Drought Prone Areas in Bangladesh

SOURCE: (GED, 2022)

For the climate projections, there is no complete data set covering all hazards for all scenarios. Proxy data sets have been used to indicate the climate change impacts.

The following data layers have been for the climate change scenario:

- Flood extent map for a 1: 25-year return period (to indicate low climate change)
- Flood extent map for a 1: 100-year flood event (to indicate high climate change, RCP 8.5)
- Salinity lines (current and the shifting lines under RCP 4.5 & 8.5

4.2 Driver Selection

The land use in South- West is driven by climatic and socio-economic factors. Due to the land ports in Jessore & Satkhira and sea port in Mongla, this region has huge potential for economic development. Proximity to the coast line works as a conducive environmental and geographical setting for blue economic activities. On the other hand, this is one of the most hazard-prone regions in Bangladesh with vulnerability to Cyclone and storm surge events, floods, salinity etc. These hazards create a lot of challenges in realizing the potential of this region. Considering these factors and their influence on land use, following drivers have been used in this analysis –

12. Climatic Drivers
13. Precipitation (SSP 1-2.6 for Productive, SSP 5-8.5 for Active)
14. Maximum Temperature (SSP 1-2.6 for Productive, SSP 5-8.5 for Active)
15. Hazards
16. Cyclone and storm surge affected areas
17. Salinity (RCP 4.5 for Productive. RCP 8.5 for Active)
18. Rabi Drought
19. Socio-Economic Drivers
20. Distance to Urban Areas (for Active scenario) and Distance to Urban Areas and Economic Zones (for Productive scenario)
21. Distance to Primary Roads
22. Distance to Secondary Roads
23. District-wise GDP contribution
24. Topographical Drivers
25. Elevation
26. Slope

4.3 Model parameterization

Setting up the model is very essential in any simulation-based analysis. The parameterization involves replicating real-world phenomena in mathematical terms for the simulation in a modelling-ready format. A brief outline of parameterization for this model is illustrated here.

4.3.1 Land use demands

i-Clue model tries to spatially allocate the land use demand based on statistical correlation among the drivers. This makes predicting the demand for each land use class a key step in the simulation process. Demand for each land use class was computed on the basis of past trends, policy directives and scenario parameters. A qualitative representation of the demand for each land use class is provided in

Table 4.1.

Table 4.1: Land Use Demands used in Model Parameterization

Land Use Classes	Active 2050	Productive 2050
Partially Cropped Area	Increase	Rapid Increase
Settlements	Increase	Rapid Increase
Other Lands	Rapid Decrease	Decrease
Agriculture	Decrease	Rapid Decrease
Forest Land	Decrease	Unchanged
Grassland	Decrease	Rapid Decrease
Rivers and Canals	Unchanged	Unchanged

4.3.2 Ease of change

The parameter 'Ease of Change' determines whether a land use of a particular pixel is likely to be converted into other classes e.g., agricultural lands can be converted into human settlement. In some cases, policy directives are imposed to drive land use change in a certain direction. Considering qualitative likelihood of land use conversion and policy directives, the 'Ease of Change' parameters were included in the model.

4.3.3 Neighbourhood function

Neighbourhood functions are included to indicate adjacent and co-dependent land use change. One of the Active 2050 scenario assumptions was that expansion of urban areas is likely to take place in clusters around existing developed areas indicating concentrated development. That is why neighbourhood function was applied to settlements in Active scenario.

4.4 Simulation

The methodological framework is presented in Figure 4.5. The process starts with literature review for setting up the baseline condition. Then the Land Use Typology was defined. Baseline conditions were parameterized. The i-Clue modelling environment was used for the model simulation. The outputs are analysed to observe the projected Land Use.

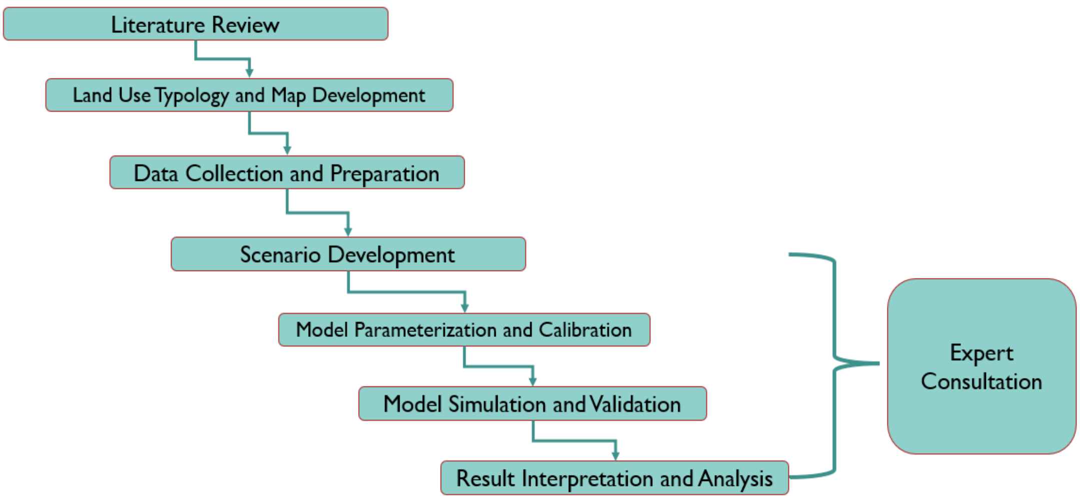


Figure 4.5 Methodological framework of Model Simulation for LUCK

4.5 Result interpretation

The i-Clue model is designed to indicate where the land use change is likely to happen in future. The Figure 4.6 shows Baseline conditions along with the model outputs according to Productive 2050 and Active 2050 scenario. From the figure, the increase in settlement is observed. Though settlement is expected to increase in both Active 2050 and Productive 2050 scenario, the nature of expansion in settlement is inherently different. In Active 2050 scenario, the expansion is noted to be more clustered. The expansion is likely to be more dispersed and in case of Productive 2050 scenario. This indicates current developed-area-oriented growth in Active scenario and more balanced, planned and decentralized development in Productive scenario. The increase in Partially Cropped Area is more prominent in Productive scenario, which indicates a shift towards blue-economic activities, mixed agricultural methods in forms of aquaculture and rice-fish cultivation methods rather than traditional agricultural practices. The Partially Cropped Areas are likely to be expanded around Khulna, Jessore and Satkhira districts as the topographical and environmental conditions in these areas favour the aquaculture practices. Reduction in Agricultural land is anticipated in both scenarios, which indicates conversion of croplands into other land use classes (predominantly Settlements) to cope up with increasing demand for development.

Table 4.2 shows the quantitative input for model simulation. The noticeable difference in increase of Settlements in Active 2050 scenario and Productive 2050 scenario is congruent with qualitative interpretation of Figure 4.6 the table reflects assumptions that agricultural land is likely to be converted into other land use classes for accommodating the increasing demand. The expedited decrease in Agricultural lands Productive 2050 is driven by favourable climatic and socio-economic conditions, depicting dependency on industrialized economy. This attribute is also reflected by difference in increase in Partially Cropped Areas in the 2 scenarios. The reduction in Rivers and Canals (in both scenarios) and Forestlands (Productive scenario) are a bit deviant from model assumptions (areas under these land use classes be unchanged). The small amount of deviation can be credited to modelling uncertainties and are within standard acceptable range of error.

It is also visible from Figure 4.6 that the road network plays a vital role in development and expansion of settlements. The settlement areas are often established in the neighbourhood of roads. In case of Active 2050, it is anticipated that development of primary roads (i.e., National, Regional highways and District roads) would be prioritized considering stymied economic conditions. Hence, clustered expansion of settlements also follows the primary road networks. In case of Productive scenario, the Upazilla roads are also likely to be well-developed, which plays a vital role in distributed settlement expansion.

Table 4.2 Projected Land Use in Study Area

Land Use Classes	Baseline 2020 (km^2)	Change in Active 2050		Change in Productive 2050	
		Area (km^2)	**Percentage**	**Area (km^2)**	**Percentage**
Partially Cropped Area	3421	329	10%	494	14%
Settlements	6689	609	9%	1461	22%
Other Lands	213	-72	-34%	-23	-11%
Agriculture	12329	-605	-5%	-1857	-15%
Forest Land	4869	-228	-5%	-33	-1%
Grassland	48	-3	-6%	-12	-25%
Rivers and Canals	2466	-30	-1%	-30	-1%

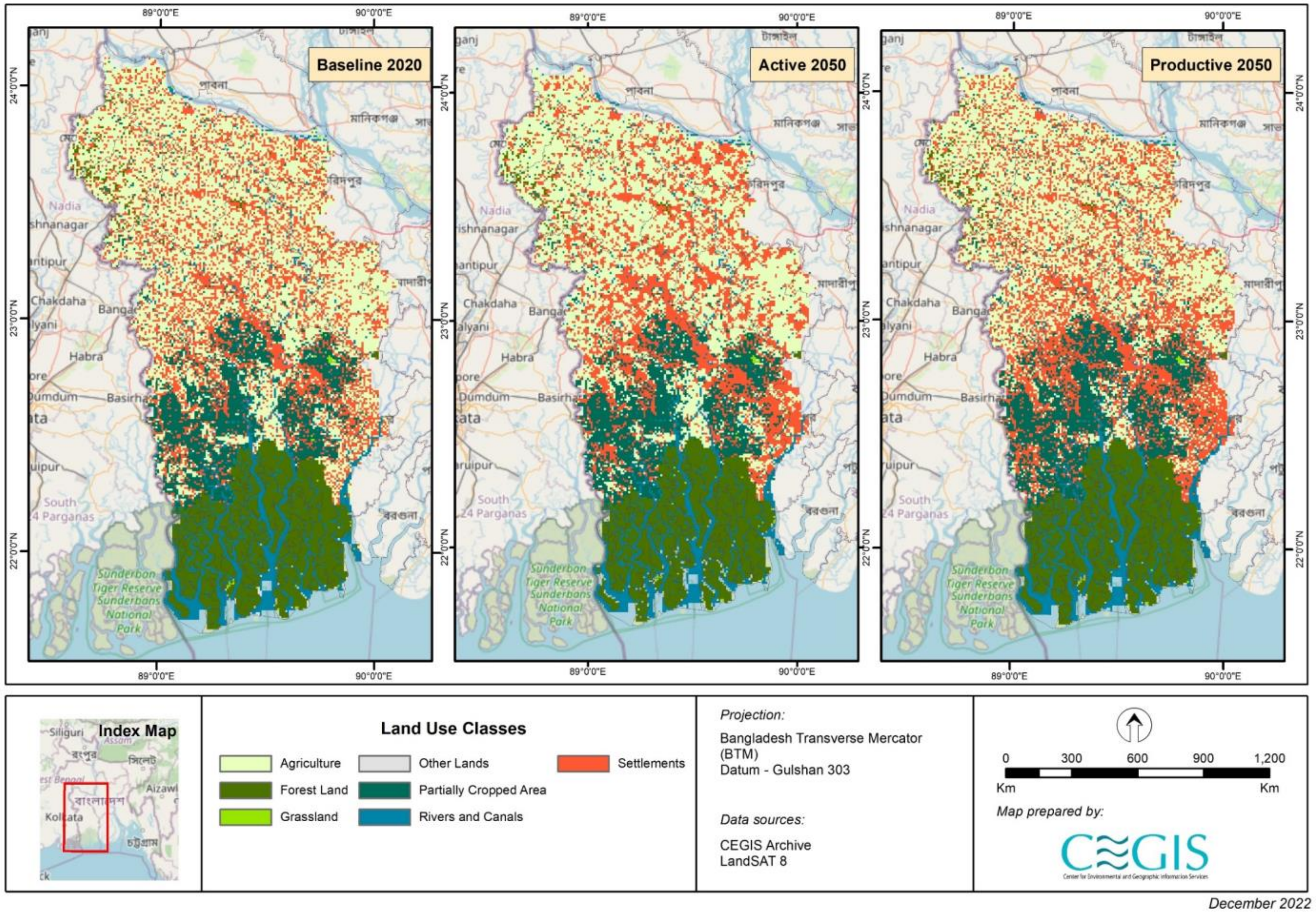


Figure 4.6 Projected Land Use in SW Region

5 APPLICATION AND FOLLOW-UP

5.1 Application

The objective of scenario studies lies in catalysing systemic thinking and support of dialogue on how the future could develop and their socio-cultural, environmental and economic implications. The land use projections described in this report serve that same purpose: to engage actors and society in exploring how the future might evolve by taking off blindfolds to avoid moving unconsciously into future situations that would be harmful and undesirable. Scenarios are typically based on divergent narratives to be able understand broad implications of potential future developments in which part of the developments cannot be influenced directly (e.g., climate change), while others can be (e.g. through policy decisions) (O'Neil, et al., 2020); (Kok, 2009).

Model projections should not be mistaken for predictions. The uncertainty in projections is much larger than with predictions (like weather predictions). Projections typically concern a further future than predictions and are influenced by many more unknown factors. The reliability of model projections can be estimated by using historical datasets in combination with a dataset of the present. The historical dataset, in combination with the scenario that led to the present, is then used to 'project' to the present. For iClue a comparison of the deviation in size and spatial patterns of the 'projected present' and actual present is a measure for the model's fit (Verweij, et al., 2018).

(Adnan, Abdullah, Dewan A., & Hall, 2020) studied the historical effects of land use change after (Abdullah, Masrur, Adnan, Baky, & Dewan, 2019) and flood hazards in south west of Bangladesh, just north of The Sundarbans mangrove forest at a 30 m^2 resolution. Their study area is smaller than the area described in this study and focuses on effects on poverty over the last 15 years. (Adnan, Abdullah, Dewan A., & Hall, 2020) use similar drivers (including elevation, climate, soil and GDP) with historic trend that reduces agricultural land and increases aquaculture and urban; a comparable trend that is extrapolated into the future in the 'PRODUCTIVE' scenario of this study. (Hasan, Deng, Li, & Chen, 2017) projected land use at a resolution of 1 km^2 for all of Bangladesh for 2030. In both their future scenarios urban area expands uncontrolled. One of their scenarios ('ecological protection') prevents land conversion in forested areas. This study adds to the literature by doing a more detailed futures study a growth region of Bangladesh to provide insight on expected land use changes under controlled ('PRODUCTIVE') and uncontrolled ('ACTIVE') urbanisation scenarios. As can be seen from (Figure 4.6) urban sprawl is projected to have a large impact on almost all landscapes of the study area in the ACTIVE scenario. Urban sprawl leads to loss of open space and environmental quality and higher emissions from road transport. Because of the need for more infrastructure to connect all the spread-out urbanised areas, it also increases the cost of providing key public services, exerting pressure on local public finance (*see also* (OECD, 2018)). The PRODUCTIVE scenario shows where land use changes are projected to take place under controlled urbanisation through the assignment of economic zones and encouragement of development therein. In the PRODUCTIVE scenario, hotspots of development are projected. These hotspots indicate locations for developing key public services, like water, waste management, energy infrastructure and transport to facilitate the encouraged rapid economic development through the increase and diversification of industry, employment, production and export (BEZA, 2022).

5.2 Follow-up

The follow-up activities that may emanate from the outputs of LUCK project are:

- In future it will be good to link the knowledge of this project to other projects e.g., SIBDP, JCP (Metamodel, 'Make it Real', Clean and Safe Water, CHAR, MAR), Land Zoning Project etc. to bring in new knowledge and insights. Possibly, this can be done through the "Knowledge Facility" currently being setup by the Netherlands embassy
- The land use can also be used as input for the regional model which is being setup for the Bangladesh Metamodel. The land-use information can feed into the 'Bangladesh Meta Model' which is to extended for the development of the regional models for the remaining hydrological regions apart from the already setup models for the NW and the Coastal region.
- This project can have direct linkage with SIBDP2100. For instance, LUCK may assist providing information about land use distribution based on assumed future scenarios for the SW region which is one of the critical parts of the Extended Coastal Region, for which an adaptive delta management programme is being developed under the SIBDP.
- Other land-use management related projects are My Village My Town, of LGED and projects of DAE, and possibly also Department of Environment (DoE) may also be benefitted.
- Further collaboration with GED, DAE, LGED, DoE and Soil Resource Development Institute (SRDI) will be explored in future.

6 CONCLUSION

The study aimed to provide an insight into dynamics of land use pattern in the South-West region of Bangladesh. Trends in the recent past and the relevant underlying parameters were analysed for the insight on baseline conditions. This trend was projected in the future in two scenarios to identify probable variations in land use due to uncertain climatic and socio-economic conditions.

Considering the scope and limitations of a pilot research study, this research has significant scope for further upscaling (national or regional), detailing and improvement. The most noticeable mode of land use conversion might be analysed in further studies. Generating land use change analysis statistics and insight at more micro level (e.g., district or upazila level) would provide a sound basis for developing local development plans and adaptation measures against the hazards. The hazards data layers need to be updated according to model outputs considering the scenario parameters developed in the IPCC 6th Assessment report for better, perhaps more realistic, insight into the uncertain future.

Land use change itself is an intertwined topic in nature. So, the outputs of this study need to be applied in other studies, research and implementation projects for realizing the potential of the study outputs in true sense. This land use change analysis would be a very effective stepping stone in implementation of BDP2100, Perspective Plan 2041, 8th (and further) Five Year Plan etc. Integrated decision support systems (e.g., Bangladesh Metamodel), hazard vulnerability analysis, ecosystem services assessment, biodiversity hotspot analysis, economic potential exploration may be such potential research topics for propagating the outputs of this research study which will also enable informed decision making.

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