ASSESSING LAND USE CHANGE AND ITS IMPACT ON ECOSYSTEM SERVICES IN KHULNA CONURBATION

A Thesis
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The thesis titled '**ASSESSING LAND USE CHANGE AND ITS IMPACT ON ECOSYSTEM SERVICES IN KHULNA CONURBATION**' submitted by Md Salman Ferdous, Roll No. 0417282020, Session: April 2017 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Water Resources Development on 28 February, 2022

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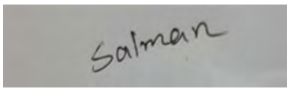

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Session: April 2017

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Abstract

Bangladesh is one of the most densely populated countries in the world with a population of 165 million which is 2.11% of the world population. The population increased from 14.1 million to 165 million from 1981 to 2020. To fulfill the extra need, each year 82,900 ha of cropland and 221 ha of arable land are changed over into other land employments. Land-use changes are intense in southwest seaside areas of Bangladesh. 56% of the rural place where there is southwest waterfront Bangladesh was changed over to other land use classifications (water bodies, desolate land, and vegetation). Khulna Conurbation is the economical hub of the Khulna district which is also affected by the land-use changes. Generally, Conurbation is defined as the extended urban area through which sub-urban areas are merged with the center of the city. In this research, the land-use change of Khulna Conurbation has been dissected utilizing Landsat images from 1987 to 2018 through GIS analysis and its effect on the ecosystem has been decided with the assistance of auxiliary information. The major types of land use in Khulna Conurbation are settlements followed by vegetation, agricultural, wetland, and river. The present study showed that in Khulna Conurbation, build-up territory expanded from 1343 ha to 4332 ha (223%) from 1987 to 2018 because of a quick improvement in the city, particularly in the north-western and centerpiece of the city. On the contrary, vegetation area decreased from 5716 ha to 3597 ha (37%); Water Bodies are decreased from 940 ha to 172 ha (82%); River areas are also decreased from 1987 to 2018 from 784 ha to 692 ha (12%) during this period. Because of the reduction of vegetation area and water bodies, the provisioning services like the production of rice, fish, and livestock is decreased. People living in agriculture and fisheries have chosen other professions like auto-rickshaw & easy bike driving, grocery shop, saw miller, and other small businesses. These land-use changes put a critical effect on the different ecosystems. From 1987 to 2018, the ecosystem service values for all land use categories were negative except for urban build-up which is 2485 million BDT. The largest amount of declination was observed in the case of vegetation which was about 1014 million BDT. Land-use change had an impact on the regulating services like the natural drainage system of Khulna Conurbation which resulted in severe waterlogging problems. Due to the rapid urbanization and high population growth rate, the few wards of the city faced serious groundwater depletion. Proper district and Upazilla level land use plans should be implemented to maintain the sustainable growth of the city and enhancement natural ecosystem services. Besides steps should be taken to make awareness among the local people.

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Ecosystems are the life for the environmental systems which reframe the relationship between humans and the rest of nature (Millennium Ecosystem Assessment, 2005& Costanza et al. 2014). Human beings and other living organisms derive goods and benefits directly or indirectly from ecosystems. Ecosystems consist of provisioning services like food and water, regulating services such as flood and erosion control, cultural services for example recreational experiences, intellectual and spiritual inspiration, and supporting services like nutrient cycling, and scientific discovery (Costanza et al. 1997& Mooney et al. 1996). Increasing evidence revealed that the impact of anthropogenic activities on ecosystems has been expeditious in the recent past. Human domination of nature has led to the alteration of ecosystem composition and functions at all scales (Adgar et al. 2018). This degradation or alteration of ecosystem services have an impact on human and pose a great threat to nature. Land use and land cover change are among the most influential factor that overwhelms or erodes the capability of ecosystem process and function (Li et al, 2007 & Islam et al. 2015).

Land use and land cover change is a dynamic process driven by natural phenomena and anthropogenic activities. Land use defines the way of using the land for different purposes such as recreational, agricultural, commercial, residential, industrial, etc. On the other hand, land cover is the physical characteristics of the earth's surface such as forests, water bodies, shrubs, pasture, wetland, etc. (Rawat & Kumar, 2015). With the pace of development initiatives and interventions land, different parts of the world are changing. Conversion of land from natural ecosystem to urban area (residential area, industrial area, commercial area), agricultural land has increased over time. Population growth and urbanization are the widespread anthropogenic causes of changing the use of land (Dewan and Yamaguchi, 2009). The stats show that in 1950, the world's urban population was 746 million with an urbanization rate of 30 percent and the urbanization rate increased to 54 percent in 2014 with a population of 3.9 billion. By 2050, 66 percent of the world population is projected to be urban (United Nations, 2014). This type of high growth rate and rapid urbanization has forced a change in the use of land for different purposes.

Many studies have been done so far related to land use and land cover changes around the world. From 1990 to 2010, 135 Mha (3.3 percent) in the forested areas has reduced the expansion of agricultural land (FAO, 2010). Africa has lost 16% of its forests and 5% of its woodlands and grasslands over the 1975 to 2000 period, equating to over 50,000 km2 per year of natural vegetation (Eva et al. 2006). The conversion of agricultural land to urban land has been most pronounced in India. From 1955 to 1985, Indian urban land expanded by about 1.5 million ha, primarily through encroaching on agricultural land, and its urban growth is continuing. In China, from 1990 to 2005, human-dominated land uses (i.e., urban and agriculture) have expanded rapidly at the cost of natural lands (wetlands, forests, and grassland). The area of urban land uses increased from 417,000 hectares in 1990 to 629,000 hectares in 2005, with a total increment of 51% (2.78% annually) (Zang et al. 2010). In southern Chile, it was observed that urbanization reduced recreational and ecotourism opportunities for the entire landscape from 65,050 persons in 1976 to 21,608 persons in 2007 (Nahuelhual et al. 2014). Land-use change from nature (forest, wetland) into human-dominated land uses (urban area and agricultural land) is detrimental to several ecosystem services such as food and water availability, nutrient cycle, climate regulation, erosion control, recreational activities, etc. (Gonzalez et al. 2012). Different studies have been done to appreciate the importance of balanced ecosystem services around the world. Some of the studies quantify the ecosystem value in monetary terms and some are described qualitatively. The total value of ecosystem services declined by 62% from $ 316.77 to 120.40 million per year between 1990 and 2000 in Chongming Island, China. This massive decrease is largely attributable to the 71% loss of wetlands/tidal flats (Zhao et al. 2004). From 1996 to 2004, 231.3 million Yuan decreased because of decreasing areas of woodland, wetland, and water body in Shenzhen, a coastal city in China (Tianhong et al. 2008). The total ESV of the watershed has declined from US$26.83*$10^6$ in 1985 to US$22.58*$10^6$ in 2000 and US$21.00 *$10^6$ in 2015 in Andassa Watershed in the Upper Nile Basin of Ethiopia due to the continuous expansions of cultivated land and built-up area, and withdrawing of the forest, shrubland, and grassland (Gashaw et al. 2018). Due to the land-use changes, a significant portion of grassland is lost in Uruguay which affects provisioning services (Vihevara et al. 2012).

Bangladesh has also been experiencing massive land use changes over the last few decades due to rapid urbanization and population stress (Mukhopadhay, 2018). The population numbered 14.1 million in 1981, 22.5 million in 1991, 31.1 million in 2001 (BBS, 2001) and 160 million in 2011 (BBS, 2011). To meet the additional demand, every year 82,900 ha of cropland and

221 ha of arable land are converted into other land uses (Islam & Hasan, 2011). The per capita land area in Bangladesh has shrunk to 0.09 ha, one of the lowest ratios in the world, making land one of the crucial and diminishing resources in Bangladesh (Rai et al. 2017). Land-use changes are acute in southwest coastal regions of Bangladesh. According to Khan et al. (2014), almost 56% of the agricultural land of southwest coastal Bangladesh was converted to other land use categories (water bodies, barren land, and vegetation). The area of land lost through riverbank erosion from the period 1996–to 2000 led to financial losses totaling 540 million USD (Hossain et al, 2015). Rapid urbanization has led rural areas to urban and it has been estimated that 199, 908 hectares of agricultural land is urbanized (Sayed & Haruyama, 2015). For example, urban growth has been found in Dhaka from 11 to 344% between the period 1960 to 2005 (Rai et al. 2017) and at that time build-up area increased by 15,924 ha and agricultural land decreased by 7,614 ha (Dewan et al. 2010). As a divisional city and the third-largest city in Bangladesh, Khulna conurbation has witnessed substantial changes in its land cover over the past several decades. From 2001 to 2011, Khulna conurbation is facing rapid urbanization with an urbanization level of 28.49% and during that period the population of Khulna increased by 37% (Rouf & Jahan, 2014). Land-use change in the urban areas is responsible for slimming down agricultural land and wetland. The continuous encroachment of wetland is reducing the production of captured fisheries, limiting the flow of freshwater, and destroying the natural drainage system of the city. Due to the reduction of agricultural land and freshwater flow, the production of agriculture decreasing. Therefore, the land turning into urban areas have detrimental effects on several ecosystem services of this city such as provisioning services (rice, fisheries production, and livestock), regulating services (natural drainage system), and cultural services (aesthetic view). In this study, the nature of land-use changes and the impact on ecosystem services are explored.

1.2 Objective of Study

The objectives of this study are given as follows:

1. To explore the past and present land use scenarios of Khulna conurbation.
2. To assess the past and the present value of ecosystem services.
3. To assess the impact of land use change on the ecosystem services in the study area.

1.3 Research Question

While covering the above-mentioned objectives the following questions had arisen. In this study they have been met with plausible explanations:

1. What is the extent and nature of land use changes in Khulna Conurbation in the years 1987, 1996, 2007, and 2018?
2. How do the values of ecosystem services change with the changes in land use in the study area?
3. What are the impacts of land use changes on ecosystem services in Khulna?

1.4 Scope of Study

Khulna city is the headquarters of the Khulna district. Previously it was known as Khulna Pourashava. It was declared as Khulna City Corporation in 1982. Although the history of Khulna City extends over more than a century, its growth and development took place in recent decades. The increasing population pressure makes adverse impacts on Khulna city. In the process of urbanization, the physical characteristics of the city are changing day by day and natural land is turning into a build-up area. The changing land use put significant impacts on the ecosystem services of the city. In this study, analyzing Landsat images from 1987 to 2018 with 11 years intervals would help to quantify the decadal changes in land use. Costanza's valuation method is applied to determine the changes in ecosystem service value with the change in land use. Secondary data is collected from the respective organizations to analyze the impact of land-use changes on ecosystem services (Ecosystem services data such as the production of rice, fisheries, and livestock, groundwater depletion, etc.) in the study area.

1.5 Structure of the Thesis

This research is divided into seven chapters which are described below:

The first chapter (Introduction) describes the issue for which the research work has been preceded. The chapter also describes the objectives of the research, the research question linked to the objectives, and the scope of the study.

The second chapter (Literature Review) describes terminology such as land-use change, ecosystem services, types of ecosystem services, land use changes on a global scale, land-use change in Bangladesh, the impact of land-use change on ecosystem services, and values in Bangladesh.

The third chapter (Study Area) provides brief descriptions of the study area such as geographic location, population density, administrative structure, meteorological information, agricultural production, geological formation, etc.

The fourth chapter (Methodology) describes the materials and methods employed to carry out the research.

The fifth chapter (Land Use Analysis) provides an assessment of land-use change and its accuracy using a confusion matrix and ground-truthing.

The sixth chapter (Impact of Land Use Change on Ecosystem Services) discusses the impact of land-use changes on the environment and livelihood.

The seventh chapter (Conclusions and Recommendations) has made remarks on the research findings. The chapter has also given an understanding of the scope for further study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Land Use and Land Cover

The land is the most important natural resource in the world. The land is defined as the place where all human activities are conducted (Parveen et al, 2018). The use of land by the people for different purposes gives rise to the term land use. Land use is termed as the management strategy on the land covered by human agents and exploitation of land by human activities such as residential zones, commercial zones, agriculture, grazing, etc. (Chrysoulakis et al, 2004). On the other hand, land cover is defined by the attributes of the earth's land surface for example vegetation, water, desert, and ice, and the immediate subsurface, including biota, soil, topography, surface, and groundwater, and it also includes those structures created solely by human activities such as mine exposures and settlement (Lambin et al, 2003). Land-use change is the changes of physical, biological, and chemical change which may include the conversion of grazing to cropping, drainage improvements, the building of farm dams, deforestation, and conversion to non-agricultural uses (Quentin et al, 2006). Land use and land cover changes may be grouped into two broad categories as conversion and modification. Conversion refers to changes from one cover or use type to another, while modification involves maintenance of the broad cover or use type in the face of changes in its attributes (Baulies and Szejwach, 1998). Land cover classification has recently been a hot research topic for a variety of applications. A great deal of research has been conducted throughout the world in an attempt to understand major shifts in land use and land cover and to relate them to changing environmental conditions.

2.2 Land Use Classification

Land use classification may be defined as the classification of land use patterns based on equal features; generally, to recognize their vital services in full filing the requirements of human society (Mandal, 1990). In 1950, FAO divided the land use pattern into four categories including-

(i) Arable land (cropland)
(ii) Grassland (permanent pasture)
(iii) Forest land (forest and woodland)
(iv) Other lands

The United States Government Geological Survey (USGS) devised a land use and land cover classification system for use with remote sensor data which is given below:

i. Urban or Built-up Land is composed of cities, towns, villages, highways, transportation, power and communication facilities, mills, shopping centers, and industrial and commercial complexes.
ii. Agricultural land includes croplands, pasture, orchards, groves and vineyards, nurseries, ornamental horticultural areas, etc.
iii. Rangeland land is defined as the land of vegetation, grasses, and grass-like plants, forbs, or shrubs.
iv. Forest Land represents areas that have a free-crown aerial density of ten percent or more stocked with trees capable of producing timber or other wood products and erect an influence on the climate or water regime.
v. The Water category includes streams, canals, lakes, reservoirs, bays, and estuaries.
vi. The Wetland category designates those areas where the water table is at, near, or above the land surface for a significant part of most years. Examples of wetlands include marshes, mudflats, and swamps situated on the shallow margins of bays, lakes, ponds, streams, and artificial impoundments such as reservoirs.
vii. Barren Land is land of limited ability to support life and in which less than one-third of the area has vegetation or another cover such as dry salt flats, beaches, bare exposed rock, etc.
viii. Tundra is the term applied to the treeless regions beyond the geographic limit of the boreal forest and above the altitudinal limit of trees in high mountains ranges
ix. Perennial snow on ice areas occurs because of a combination of environmental factors that cause features to survive the summer melting season.

Table 2.1 USGS Land Classification (Source: Anderson et al. 1976)

Level-I	Level-II
Urban or Built-up Land	1.1 Residential 1.2 Commercial and Services 1.3 Industrial 1.4 Transportation, Communications, 1.5 Industrial and Commercial Complexes 1.6 Mixed Urban or Built-up Land 1.7 Other Urban or Built-up Land
Agricultural Land	2.1 Cropland and Pasture 2.2 Orchards, Groves, Vineyards, Nurseries 2.3 Confined Feeding Operations 2.4 Other Agricultural Land
Rangeland	3.1 Herbaceous Rangeland 3.2 Shrub and Brush Rangeland 3.3 Mixed Rangeland
Forest Land	4.1 Deciduous Forest Land 4.2 Evergreen Forest Land 4.3 Mixed Forest Land
Water	5.1 Streams and Canals 5.2 Lakes 5.3 Reservoirs 5.4 Bays and Estuaries
Wetland	6.1 Forested Wetland 6.2 Nonforested Wetland
Barren Land	7.1 Dry Salt Flats. 7.2 Beaches 7.3 Sandy Areas other than Beaches 7.4 Bare Exposed Rock 7.5 Strip Mines Quarries and Gravel Pits 7.6 Transitional Areas 7.7 Mixed Barren Land

Level-I	Level-II
Tundra	8.1 Shrub and Brush Tundra 8.2 Herbaceous Tundra 8.3 Bare Ground Tundra 8.4 Wet Tundra 8.5 Mixed Tundra
Perennial Snow	9.1 Perennial Snowfields 9.2 Glaciers

2.3 Ecosystem Services

Ecosystem services are the benefits people obtain from ecosystems and are co-produced by the interactions between ecosystems and societies (MA, 2005). In other words, ecosystem services result from the interactions between ecosystems and societies, which together form a social-ecological system.

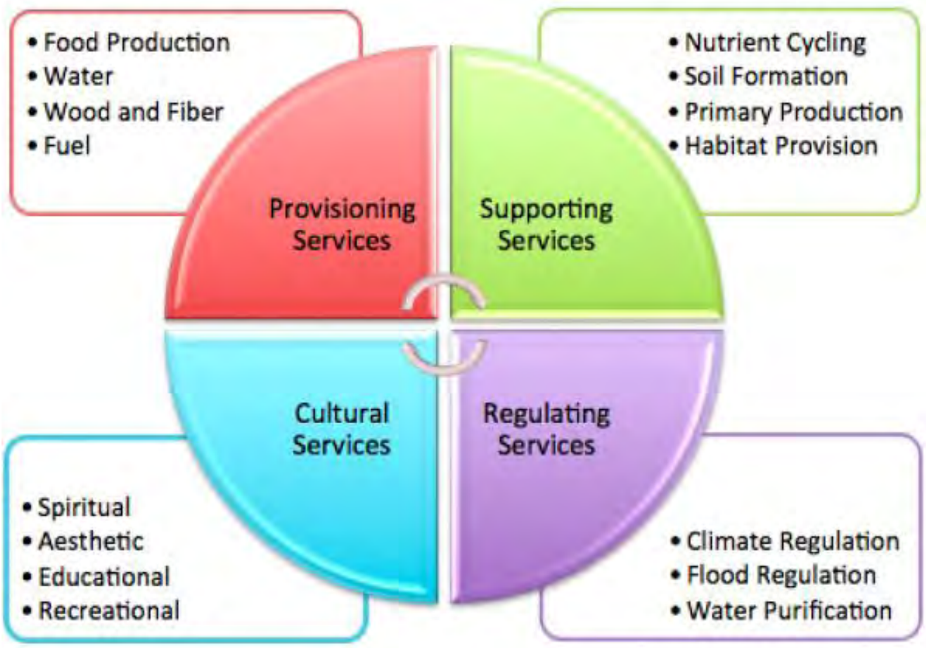


Figure 2.1 Types of Ecosystem Services

(Source: Millennium Ecosystem Assessment, 2005)

Four types of ecosystem services can be distinguished which are given as follows:

Table 2.2 Provisioning Services (Source: Balvanera et al. 2016)

Services	Description
Provisioning Services are the goods gained from ecosystems directly.	
Crops	All cultivated edible plant products (e.g. maize, wheat, olive, apple
Fodder	All vegetable tissue and grains are grown in rangelands and pastures as well as in agricultural fields to feed livestock
Livestock	Includes beef, pork, goat, and other species grown to obtain meat, milk, and skin.
Aquaculture	All fish and invertebrate species are cultivated in continental, coastal, or marine water bodies.

Table 2.3 Regulating Services (Source: Balvanera et al. 2016)

Regulating Services are obtained from the regulation of ecosystem processes.	
Climate Regulation	Mediated by carbon stored over the long-term in vegetation that is not released and carbon taken from the atmosphere via photosynthesis
Water Regulation	Can be impaired by nutrients (phosphorus and nitrogen), sediment dissolved organic carbon content, temperature, pH, and concentrations of pathogens or toxic compounds. The abiotic and biotic components of ecosystems can contribute to mitigating such contaminants

Regulation of Soil Fertility	Refers to the physical, chemical, and biological characteristics of soils that underpin the number of nutrients available for agriculture, fodder, forestry, and biofuel production

Table 2.4 Cultural Services (Source: Balvanera et al. 2016)

Cultural Services are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.	
All Non-Tangible Benefits	Includes a large array of non-tangible benefits from ecosystems that include heritage(cultural or religious), inspiration (spiritual or artistic), sense of place, identity, social relations, and education, among others
Aesthetic Views	Refers to various landscape features that are appreciated and enjoyed.
Nature-Based Tourism	Multiple characteristics of landscapes, water bodies, and biodiversity determine whether areas are attractive to tourists.
Recreation	Includes hiking, angling, cycling, birding, swimming, diving, and others

Table 2.5 Supporting Services (Source: Balvanera et al. 2016)

Supporting Services are those that are necessary for the production of all other ecosystem services. For example, erosion control can be categorized as both a supporting and a regulating service depending on the time scale and the impact on humans. For example nutrient cycling, primary production, soil formation,

2.4 Studies on Land Use Changes

The understanding of land-use/land cover change has moved from simplicity to realism over the last few decades. In the mid-1970s, it was recognized that human intervention on land surfaces for survival which has an impact on regional climate and in a broader sense impact on ecosystem goods, services, and values (Parveen et al, 2018). To predict future development and its impact on ecosystem services; it is very important to study the present land use changing pattern and the availability of land for different purposes like Forest area, Agricultural area, Built-up area, and Waterbodies. Conventional ground methods of land use mapping are labor-intensive and time-consuming for land-use change monitoring. With the invention of remote sensing and Geographical Information System (GIS) techniques, land use mapping has given useful and detailed information for the selected area. The advent of high spatial resolution satellite imagery and more advanced image processing and GIS technologies has resulted in a switch to more consistent monitoring and modeling of land use/land cover patterns. Different studies have been conducted to monitor the land-use changes using GIS and Remote Sensing approaches.

Yuan et al. (2004) developed a study to monitor the land cover change using multi-temporal Landsat Thematic Mapper (TM) data for Seven County Twin Cities Metropolitan Area of Minnesota for 1986, 1991, 1998, and 2002. The maps showed that between 1986 and 2002 the amount of urban or developed land increased from 23.7% to 32.8% of the total area, while rural cover types of agriculture, forest, and wetland decreased from 69.6% to 60.5%.

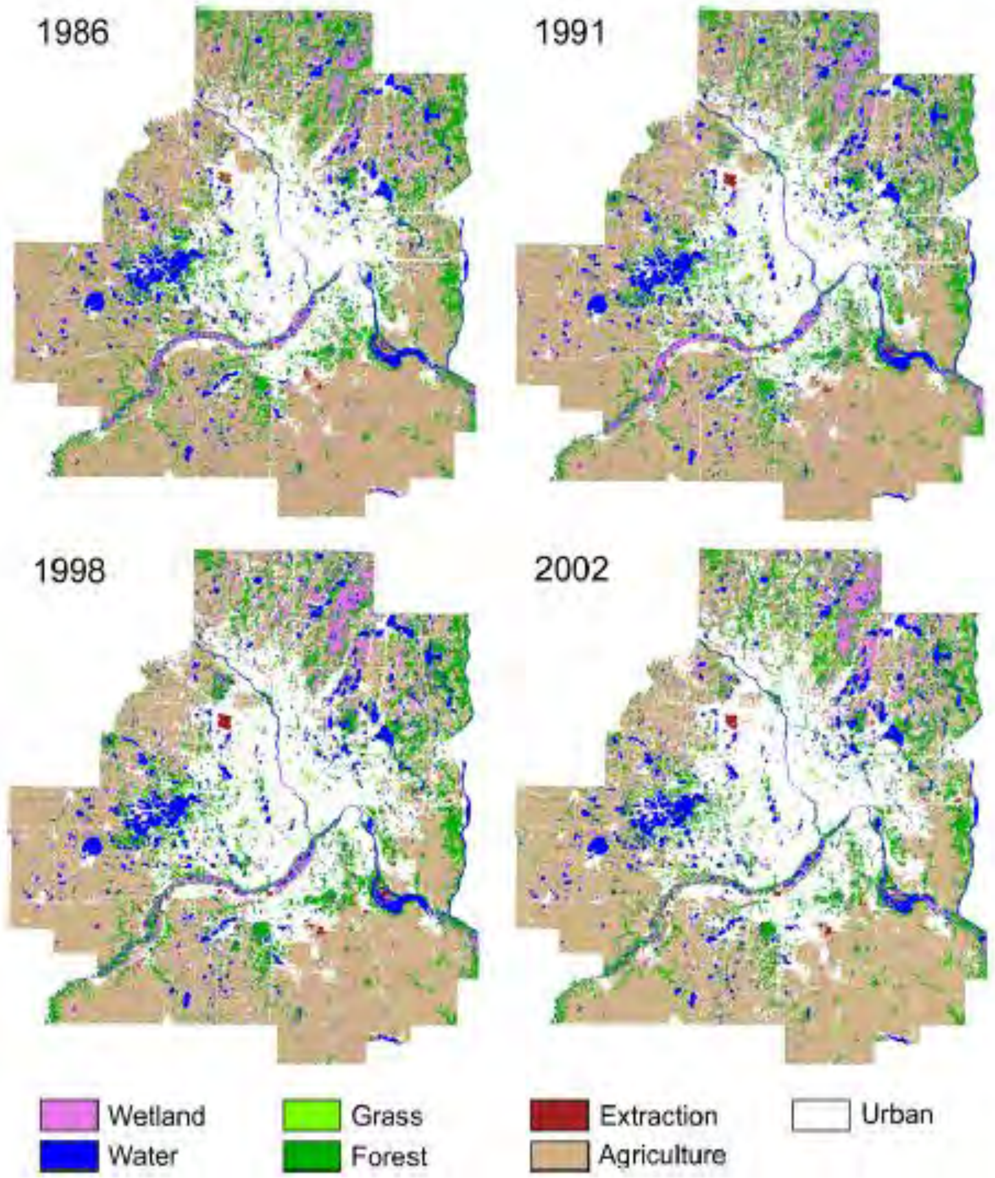


Figure 2.2 Land Use Change from 1982-2002

(Source: Yuan et al. 2004)

Xiao and Weng (2005) used satellite imagery to study temporal changes in Guizhou Province in China. They used Landsat thematic images to examine the changes in land use and land cover. The results showed that agricultural land decreased, while urban areas expanded dramatically, and forest land increased slightly from 1991 to 2004.

Sonis et al. (2007) used matrix-based land use analysis and Geographical Information System (GIS) for analyzing multi-date satellite images to study landscape changes in the Israeli Carmel area. The Matrix Land Use Analysis is utilizing the matrices of the land use redistributions within a given set of regions in a given period.

Mark and Kudakwashe (2010) have carried out a study in the Shurugwi district in the Midlands Province of Zimbabwe. They observed the increase of cropland because of land reform and resettlement programs. Forestlands were cleared for different farm-related activities like opening new farming plots, wood for fuel, poles for building both homes, and cattle pens, among other activities.

Li et al. 2014 assessed the changes in land-use and ecosystem services in Changzhou municipality, Peoples' Republic of China, 1991–2006. They studied before 2001, farmland was the main type of land use, accounting for more than 53.3% of the total area. But In 2006, farmland and built-up areas were the main land-use types. The built-up area increased by 122% from 1991 to 2006. On the other hand, farmland, forests, grasslands, and water-covered areas decreased by 24.1%.

Hegazy and Kaloop (2015) used GIS techniques to detect the land-use change due to urban growth in Daqahlia Governorate, Egypt. They found that Mansoura and Talkha in Daqahlia governorate cities experienced land cover changes driven by unorganized expansion, increased immigration, and rapidly increasing population. Change detection analysis of this study showed that built-up area increased from 28 to 255 km^2 by more than 30% and agricultural land reduced by 33% from 1985 to 2010.

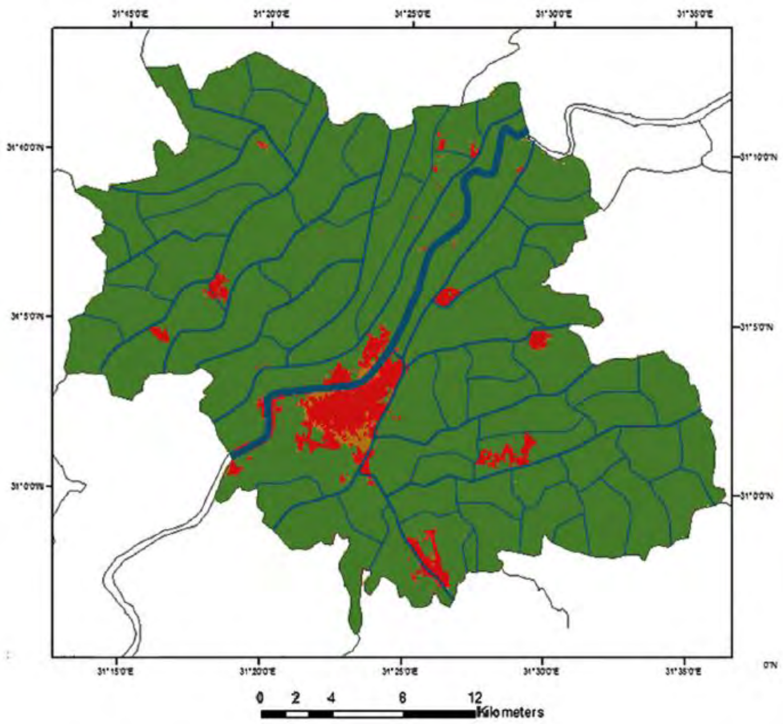


Figure 2.3 Mansoura and Talkha Land Use Maps in 1985

(Source: Hegazy & Kaloop, 2015)

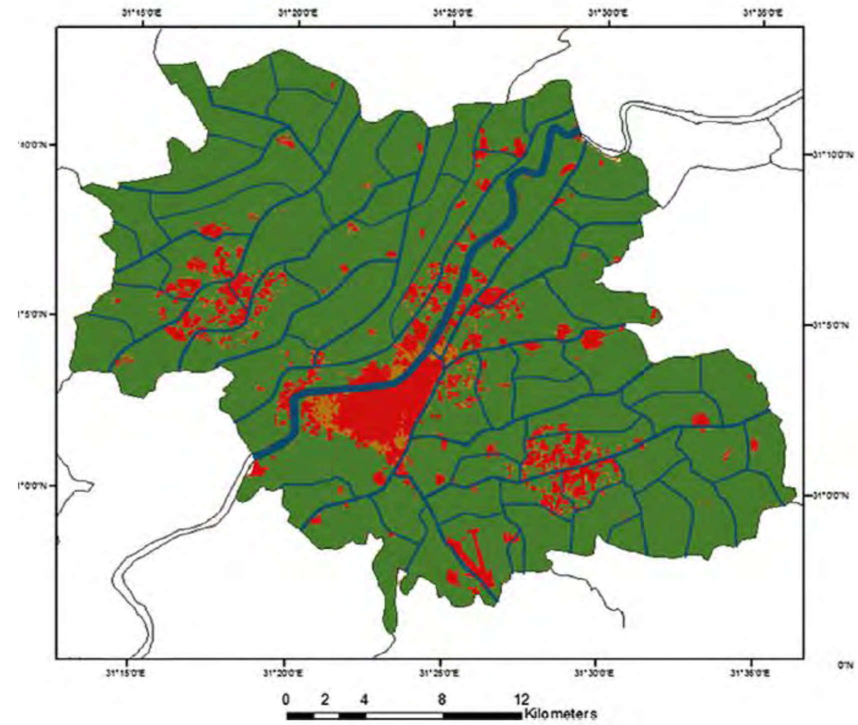


Figure 2.4 Mansoura and Talkha land use maps in 2000

(Source: Hegazy & Kaloop, 2015)

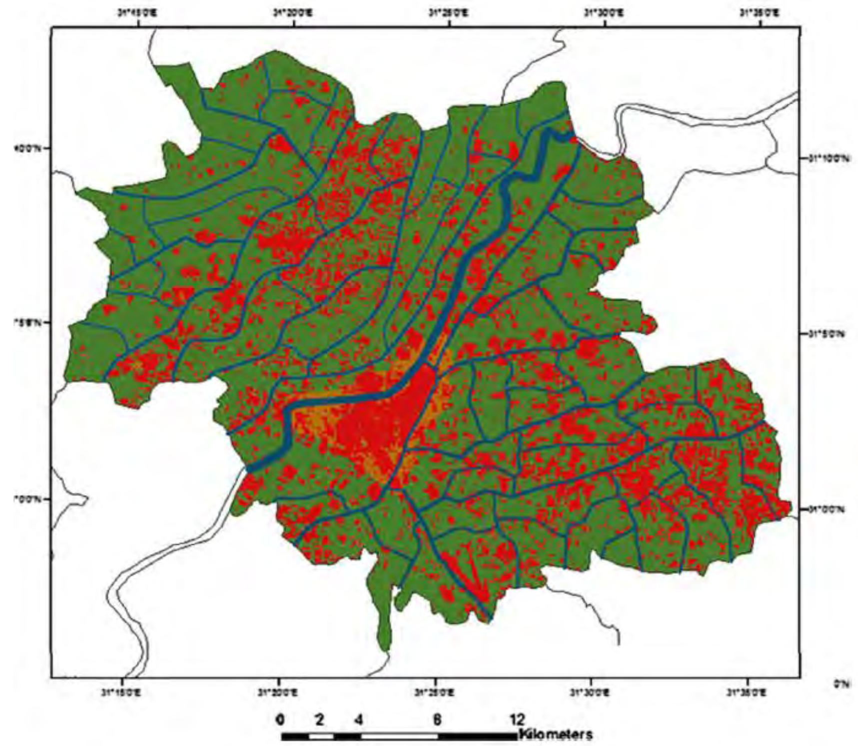


Figure 2.5 Mansoura and Talkha land use maps in 2010

(Source: Hegazy & Kaloop, 2015)

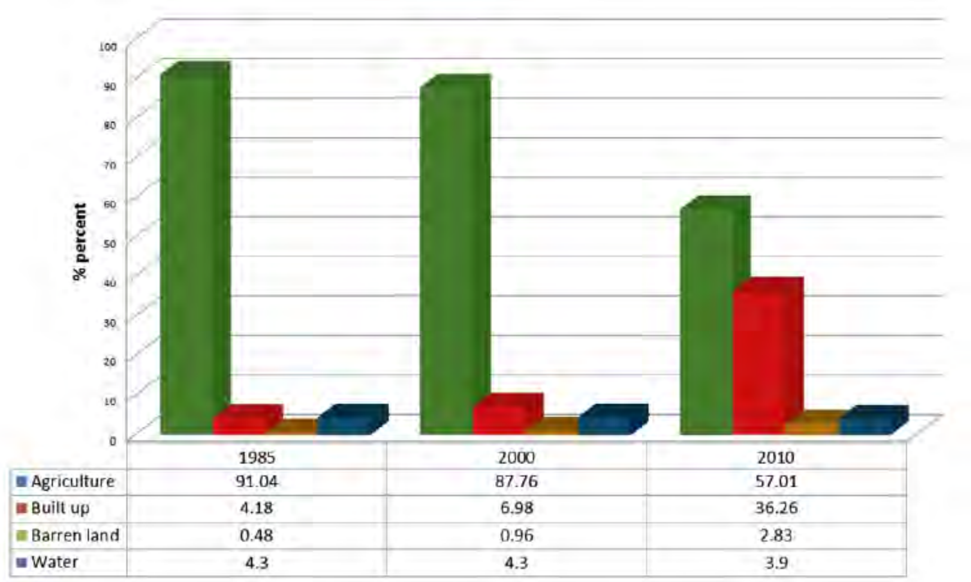


Figure 2.6 Land cover for Mansoura and Talkha in 1985, 2000 and 2010

(Source: Hegazy & Kaloop, 2015)

Rawat and Kumar (2015) illustrated the land-use dynamics of the Hawalbagh block of district Almora, Uttarakhand, India by using multi-temporal satellite imagery. The results indicate that during the last two decades, vegetation and built-up land have been increased by 3.51% (9.39 km2) and 3.55% (9.48 km2) while agriculture, barren land, and water body have decreased by 1.52% (4.06 km2), 5.46% (14.59 km2) and 0.08% (0.22 km2), respectively.

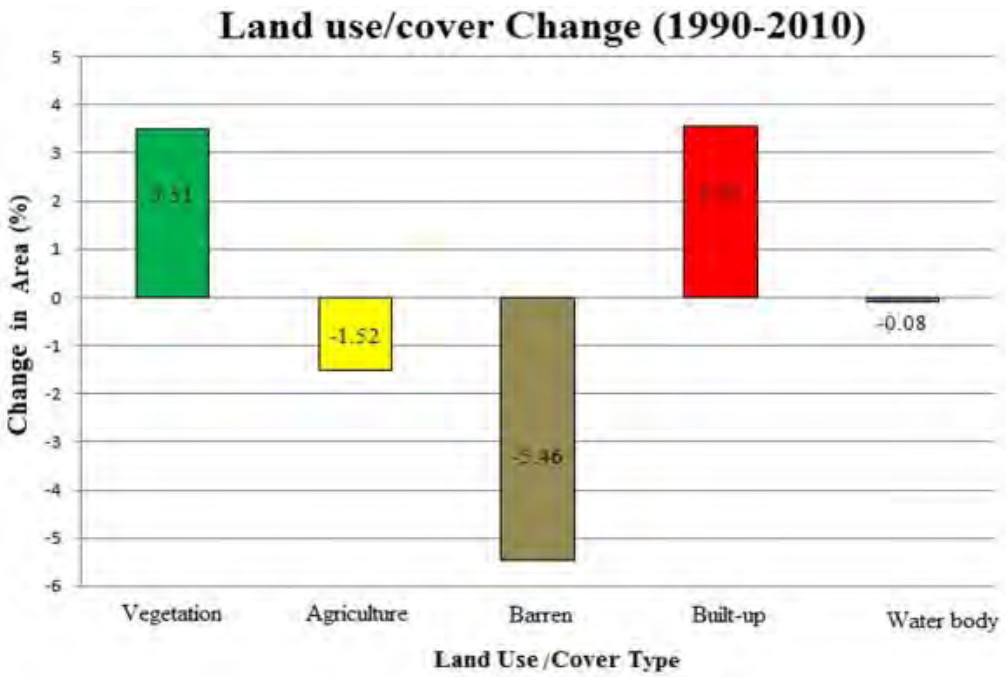


Figure 2.7 Land Use Change 1990 to 2010

(Source: Rawat & Kumar, 2015)

Cegielska et al. (2018) analyzed changes in land use and land cover in northern Hungary (the Pest County) and southern Poland (the Małopolska Province) using GIS. The results indicated a downward trend for agricultural land in Hungary and Poland as well as for uncultivated land in Hungary. An upward trend was found for uncultivated land in Poland and forest land in both countries. Changes in land cover in the Pest County and the Małopolska Province (in 2000 and 2012) show a decrease in agricultural areas and an increase in artificial surfaces, forests, and semi-natural areas with the change in Poland being more intensive than that in Hungary.

Sumari et al. 2020 analyzed the influence of population growth on spatial changes in the Morogoro urban municipality (MUM) in Tanzania between 2000 and 2016. Shannon's Entropy was used to interrogate the land-use and land cover change. From the period 2000 to 2016 the increment of entropy value indicated the urban spatial expansion. Also, it is noted that the entropy values continuously increased outward from the city center during the study period.

The spatial distribution of land use increases in the urban built-up area while the natural (non-built up) areas of the city such as forest, agriculture, woodland, and waterbodies kept declining.

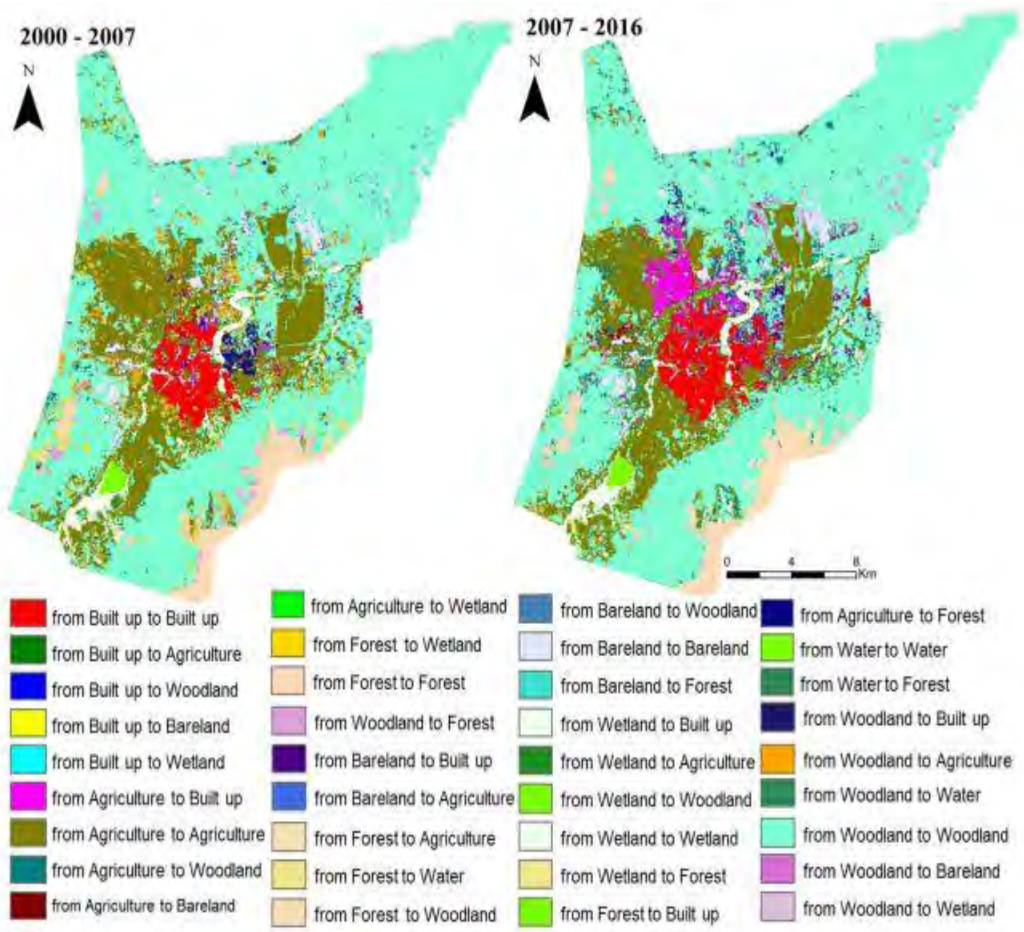


Figure 2.8 Land Use Changes of Morogoro Urban Municipality, Tanzania

(Source: Sumari et al. 2020)

Chtterjee and Majumder (2021) made an effort to find out the urbanization induce land-use changes in Kolkata city. In this study, they have shown how the vegetation cover is affected by urban growth and how the built-up area grew over time. To find out the vegetation cover and built-up area of Kolkata city, Normalized Difference Vegetation Index and Normalized Difference Built-up Area Index and Landsat satellite images between the years 2005 and 2019 have been used. This study revealed that vegetation area decreased towards the city core areas and percentages of built-up areas increased in the urban area. In 2019, only 16.73 percent of the area is under good vegetation cover and nearly 70 percent of the area experiences a low density of vegetation which creates an adverse impact on vegetation.

2.5 Studies on the Impact of Land Use Changes on Ecosystem Services

Ecosystems are life-support systems for the earth's environment. But ecosystem services are highly vulnerable to several impacts due to the increasing anthropogenic activities and subsequent land-use change (Arunyawat & Shrestha, 2016). Understanding the importance of ecosystem services, scholars studied the impact of land-use changes on ecosystem services and values.

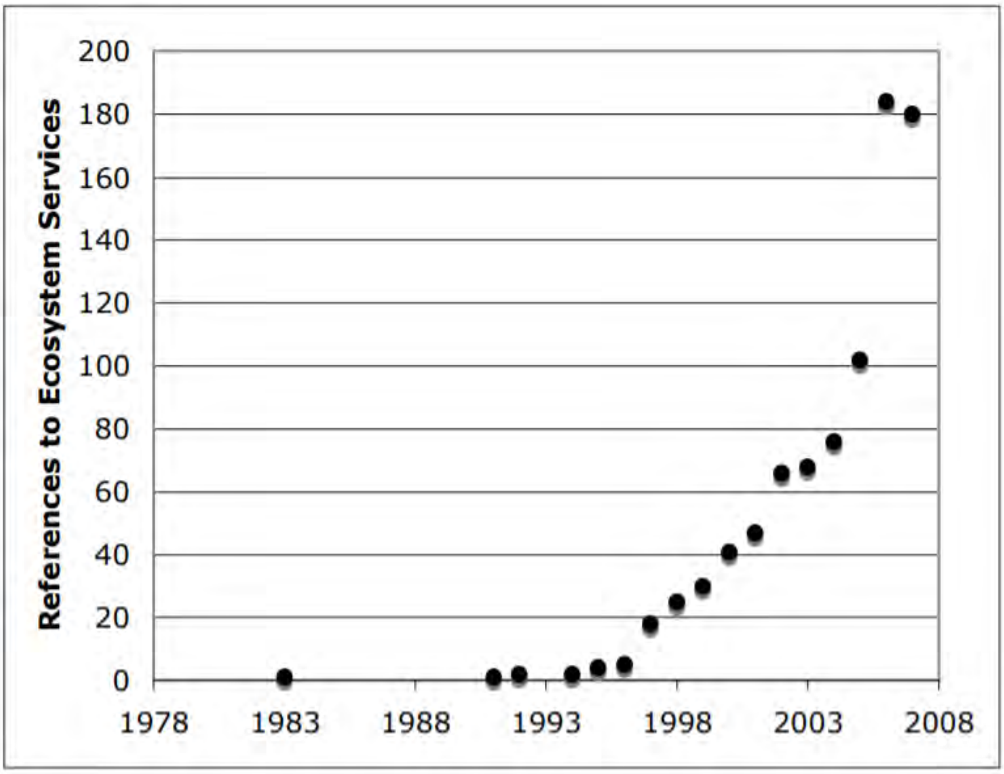


Figure 2.9 Studies on Ecosystem

(Fisher et al. 2009)

Mamat et al. 2018 analyzed time-series Landsat data to determine the influences of oasis land-use changes on the ecosystem services in the Kashgar region in Northwest China. Over the past 30 years indicate that grassland, sandy land, and unused land remain the dominant cover types in the study area. Among all the land-use types, the highest change in cover occurred in grasslands, which decreased from 27% of the total area in 1986 to 16.8% in 2015. They analyzed that from 1986 to 2015, cultivated land, forest land, construction land, and sandy land all increased, whereas grassland, water, salinized land, wetland, and unused land decreased. The considerable decreases in grassland and wetland, are a result of the rapid development of commercial agriculture and inadequate regulations for the protection of wetlands and curbing irrational water use.

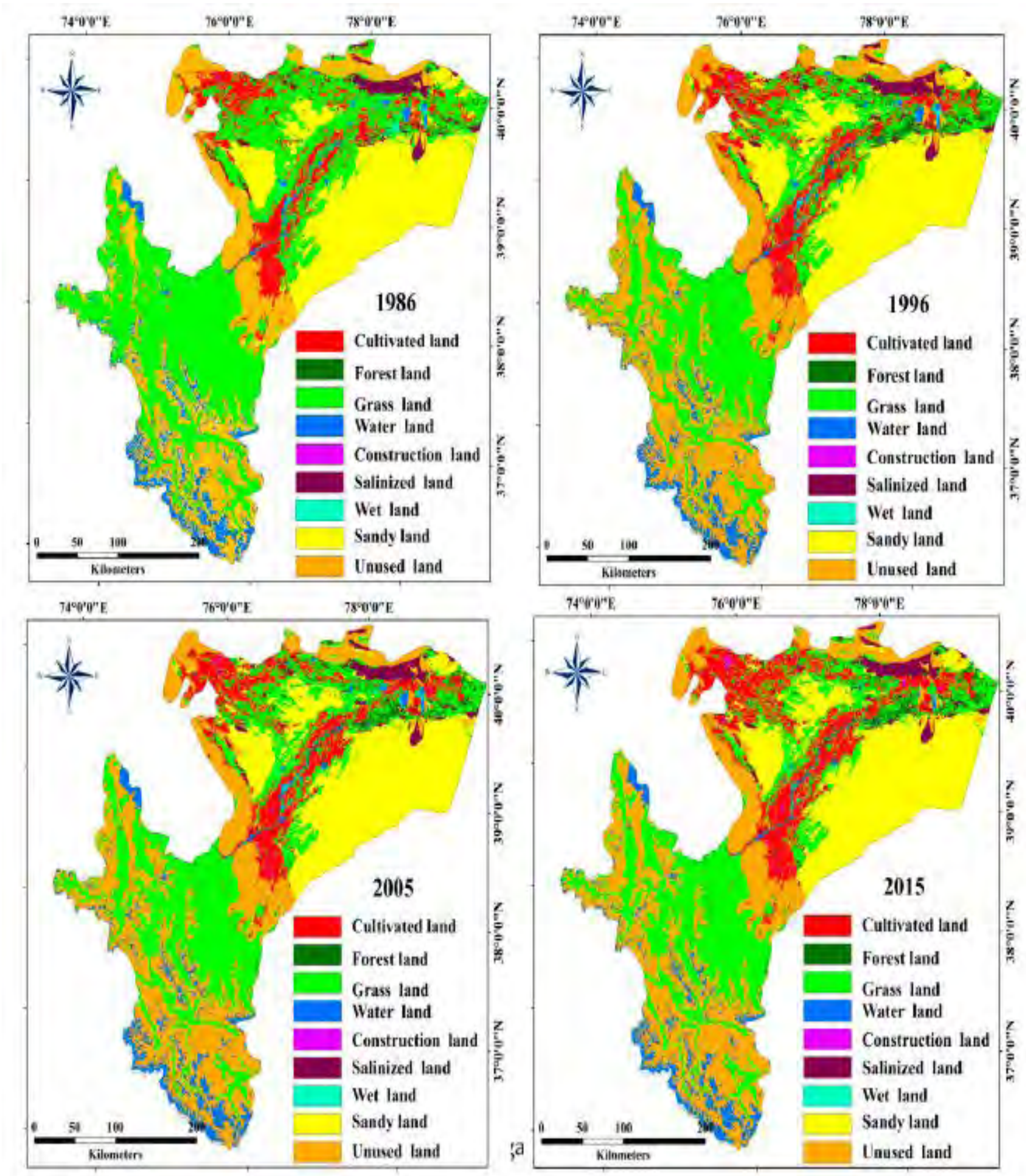


Figure 2.10 Land-use maps of the Kashgar region for 1986, 1996, 2005, and 2015 (Source: Mamat et al. 2018)

The results of Ecosystem service values showed during the four periods, the total ESV of the Kashgar region rose from $10,845.3 million U.S. in 1986 to $11,218.6 million U.S. in 1996, declining to $10,127.3 million U.S. in 2015. An overall increase in ecosystem service value, of about $373.31 million U.S., occurred in the first 10 years (1986–1996) and a loss was about $1091.3 million U.S. in the following 20 years (1996–2015).

Gashaw et al. (2018) estimated the impacts of land-use changes on Ecosystem Service Values in the Andassa watershed of the Upper Blue Nile basin of Ethiopia. Their findings were the gradual expansion of cultivated land and build-up area and withdrawal of forest, shrubland, and grassland during the 1985–2015 periods.

Table 2.6 LULC Types from 1985 to 2015 Periods (Source: Gashaw et al. 2018)

Study Periods	Land Use Types (ha)				
	Cultivated Land	Forest	Shrubland	Grassland	Built-up Area
1985	36820	2068	15377	4461	35
2000	42925	1504	10447	3789	101
2015	45108	1138	8992	2850	672

After analyzing land-use change, they assessed the change in ESV. The changes in ESV from 1985 to 2015 periods for each LULC type and total ESV were evaluated and presented in the following table:

Table 2.7 Effects of LULC changes on the total ESV (Source: Gashaw et al. 2018)

LULC Categories	1985 ESV	%	2000 ESV	%	2015 ESV	%
Cultivated Land	8.31	31.0	9.68	42.9	10.17	48.4
Forest	2.04	7.6	1.48	6.5	1.12	5.3
Shrubland	15.17	56.5	10.31	45.7	8.87	42.2
Grassland	1.31	4.9	1.11	4.9	0.84	4.0
Built-up	0	0	0.00	0	0.00	0

In this study, they showed that the ESV of cultivated land increased between the 1985 and 2015 periods in the selected watershed. Conversely, the ESV of forest, shrubland, and grassland over these periods has been reduced.

Rimal et al. (2018) showed that the ecosystem is heavily dependent on the proper management of land use and land cover management. Changing the land use pattern altered the ecosystem services that affected humans and nature. In this study, they analyzed the spatiotemporal variations of land use and land cover and quantified the change in ecosystem services (food production, carbon storage, and habitat quality) in the Koshi River Basin, Nepal from 1996–to 2016.

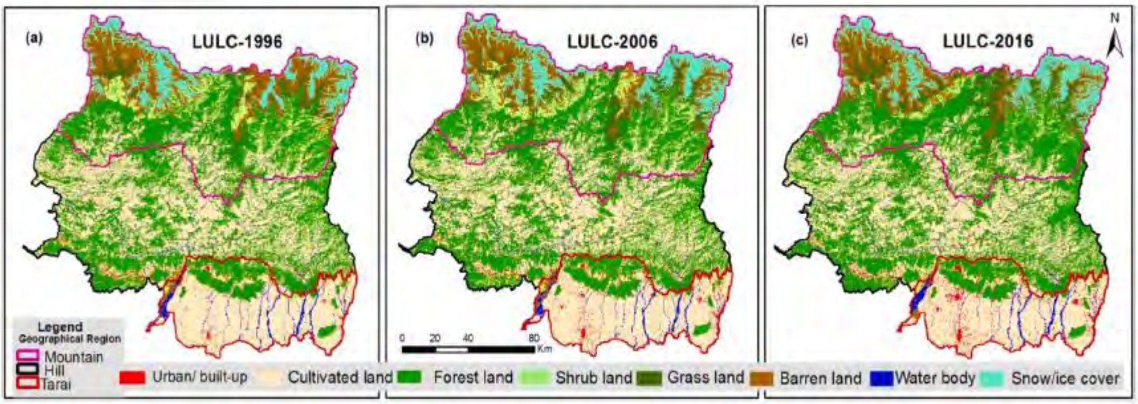


Figure 2.11 Land Use Map of Koshi River Basin

(Source: Rimal et al. 2018)

During the observed period, there was an overall gain in urban areas (190 sq. km), forests (773 sq. km), and grassland (431 sq. km); loss of cultivated land (220 sq. km) and shrublands (847 sq. km).

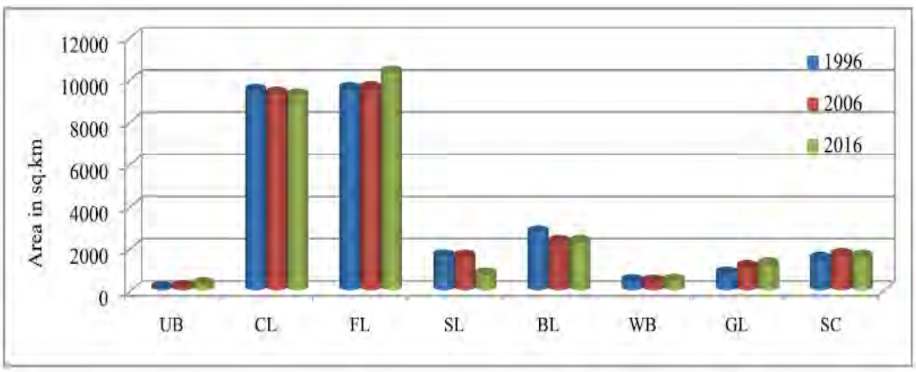


Figure 2.12 Trend of Land Use Map of Koshi River Basin

(Source: Rimal et al. 2018)

As a result of the land cover changes, while food production and carbon storage showed a declining trend, overall habitat quality in the basin increased.

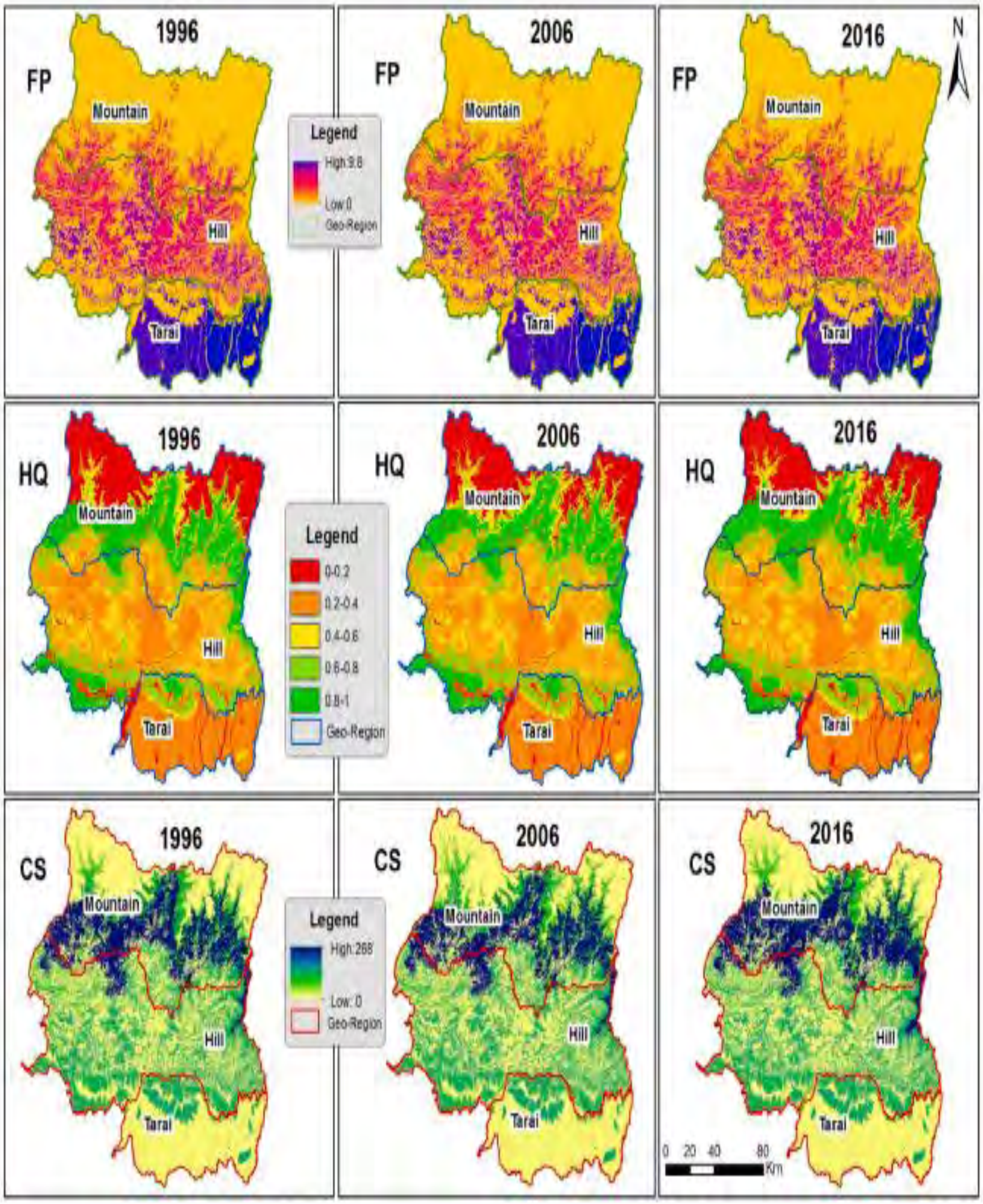


Figure 2.13 Changes in Ecosystem Services

(Source: Rimal et al. 2018)

Zang et al. 2010 studied the impact of urbanization and rural-urban migration on ecosystem services. In this study, he used the universal valuation method developed by Costanza and then used the Xia method which was applied in China. Then he compared these two methods and showed that different valuation methods generate different results. The first method showed that due to urbanization the total ecosystem service value decreased 29% (2.26% annually) from 1990 to 2005. In the second approach, the rate is estimated to be 15.7% (1.13% annually)

Table 2.8 ESVs in 1990, 2000, and 2005, and their changes from 1990 to 2005 using Costanza's Valuation Method (Source: Zang et al. 2010)

Land Use Type	1990 (10^6)$	2000 (10^6)$	2005 (10^6)$	1990-2005		
				Change (10^6)$	%	% Per Year
Agricultural	849.7	871.3	876.8	27.1	3.19	.21
Forest	336.9	318.9	284.4	-52.5	-15.57	-1.12
Grassland	168.4	153.1	164.9	-3.5	-2.11	-0.14
Wetlands and water	18028.5	16201.7	12432.3	-5596.1	-31.04	-2.45
Urban	0	0	0	0	0	0
Barren	0	0	0	0	0	0
Total	19383.5	17544.9	13758.4	-5625.1	-29.02	-2.26

Table 2.9 ESVs in 1990, 2000, and 2005, and their changes from 1990 to 2005 using Xie's valuation method (Source: Zang et al. 2010)

Land Use Type	1990 (10^6)\$	2000 (10^6)\$	2005 (10^6)\$	1990-2005		
				Change (10^6)\$	%	% Per Year
Agricultural	6,089.7	6244.0	6283.7	194.0	3.19	.21
Forest	2,329.7	2205.2	1967.0	-362.7	-15.57	-1.12
Grassland	501.1	455.4	490.4	-10.6	-2.11	-0.14
Wetlands and water	8,035.1	7221.0	5541.0	-2494.2	-31.04	-2.45
Urban	0	0	0	0	0	0
Barren	25.3	26.4	28.8	3.4	13.5	0.85
Total	19383.5	16151.9	14310.9	-2670.1	-15.72	-1.13

Toless et al. 2021 assessed the linkages between ecosystem service provision and land-use change in the Fincha watershed, North-Western Ethiopia. Within this watershed, land use/land cover (LULC) changes and their linkages with ecosystem services were analyzed for a period of more than three decades (1987–2019). The findings revealed that; cultivated land, waterbody, settlement, and sugar cane plantation increased whereas wetland, forest land, and bare land reduced. The total ecosystem service values were dominated by cultivated land, which contributed 42.9% of the values in 2019.

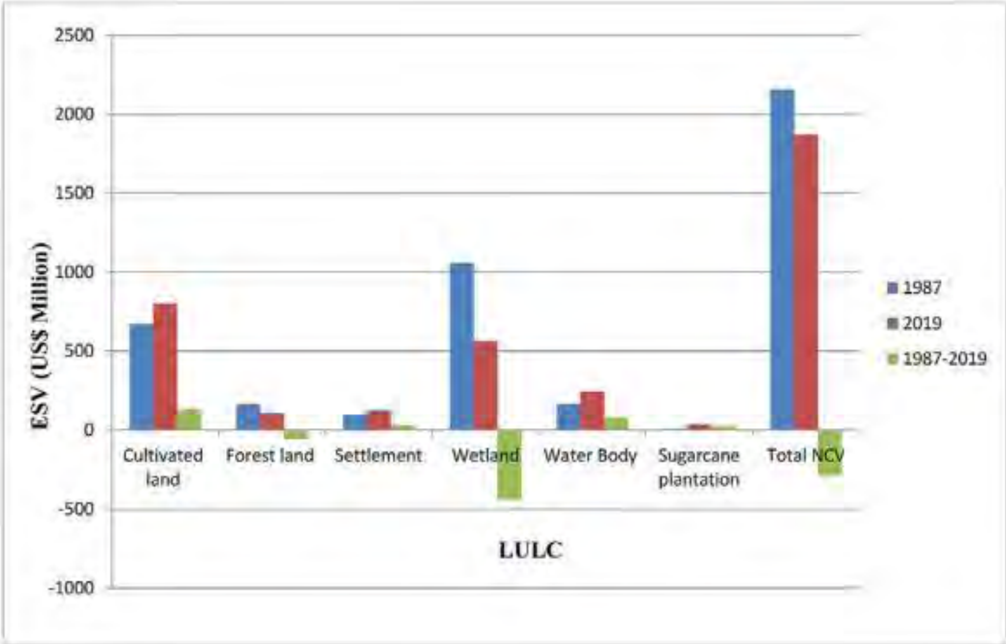


Figure 2.14 Changes in Ecosystem Service Valuation (US$ Million) in Fincha watershed, North-Western Ethiopia

(Source: Toless et al. 2021)

2.6 Studies on Land Use Change and Its Impact on Ecosystem Services in Bangladesh

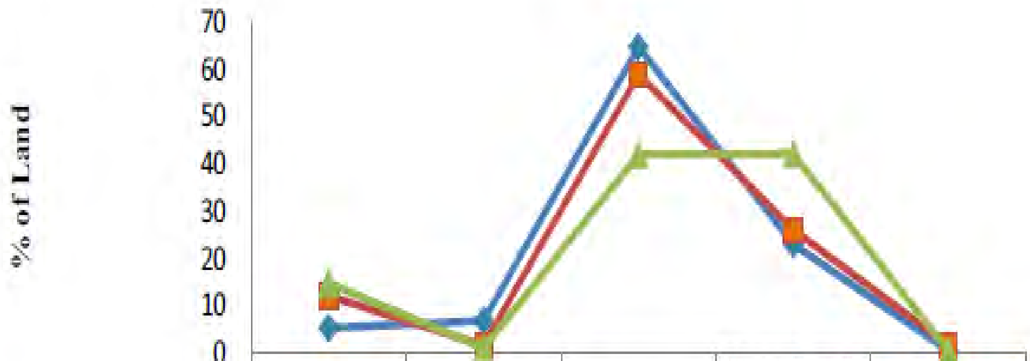
The land is one of the important input resources which is changing around the world. Since the liberation in 1971, the land use pattern in Bangladesh is changing rapidly. High population growth, rapid urbanization, and development have been directly associated with the change in land use across the country. These changes in land use have induced significant impacts on agriculture, crop production, food and water supply, and the livelihood of the community. According to BBS, the total land area of Bangladesh increased from 14.28 Mha to 14.84 million Mha during 1976-77 to 2010-11 periods but cultivable land decreased from 9.39 Mha to 8.52 Mha at a rate of 0.27 percent annually (Hasan et al. 2013).

Table 2.10 Availability of Land during 1976-77 to 2010-11 (Source: Hasan et al. 2013)

Year	The land area of Bangladesh (million ha)	Cultivable land (million ha)
1976-77	14.28	9.39
1980-81	14.29	9.38
1985-86	14.48	9.44
1990-91	14.84	9.72
1995-96	14.84	9.72
2000-01	14.85	8.40
2005-06	14.84	8.42
2010-11	14.84	8.52

Different studies were conducted to detect and determine the land-use change in Bangladesh.

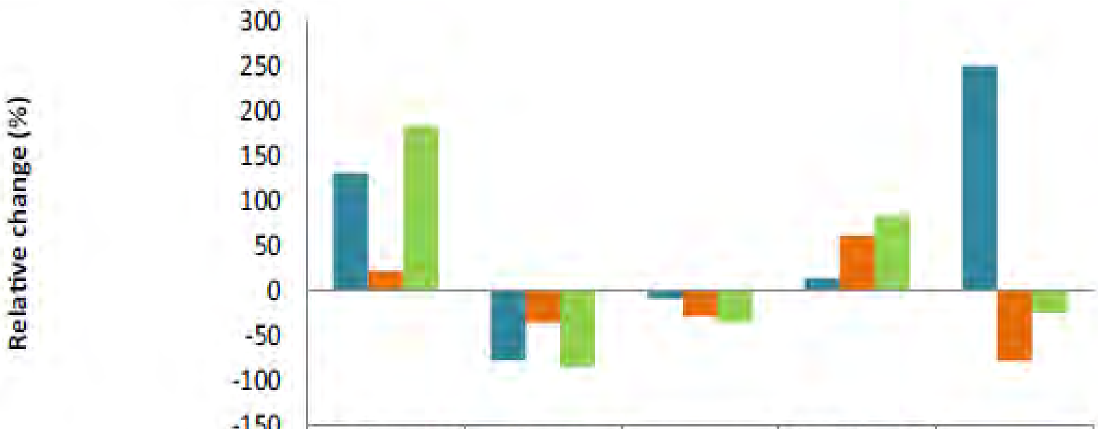
Chowdhury et al. 2018 assessed the land-use changes in Halda Watershed which is located in the South-Eastern Region of Bangladesh. Halda is considered the third main river of Chattogram after the Karnafuli and the Sangu. In this study, they attempted to analyze the land-use change over the last 40 years using multispectral satellite data. For this study, they classified the study area into five land use classes: settlements, waterbody, vegetation, agricultural land, and bare soil. In the analysis, they showed that from 1999 to 2017, vegetation covers and water class in the watershed area decreased by 35.10% and 85.47% respectively, whereas agricultural class increased by 83.29%. Besides, within this time frame, the share of settlements also increased by 182.49% which was the highest category of land-use changes.



	Settlements	Water Body	Vegetation	Agricultural Land	Bare Soil
% of LULC 1978	5.21	6.8	64.62	22.93	0.44
% of LULC 1999	12.02	1.56	58.84	26.02	1.56
% of LULC 2017	14.71	0.99	41.93	42.03	0.34

Figure 2.15 Temporal Pattern of Land Use of Halda Watershed

(Source: Chowdhury et al. 2018)



	Settlements	Water Body	Vegetation	Agricultural Land	Bare Soil
% change in 1978-1999	130.88	-77.28	-9	13.5	250.2
% change in 1999-1017	22.35	-36.05	-28.74	61.48	-78.38
% change in 1978-2017	182.49	-85.47	-35.1	83.29	-24.28

Figure 2.16 Relative changes in Land use In Halda Watershed

(Source: Chowdhury et al. 2018)

Akber et al. 2018 assessed the impact of land-use change on ecosystem services of southwest coastal Bangladesh. The study area included three districts: Khulna, Satkhira, and Bagerhat covering 1,206,036 ha area they did that analysis by combining Landsat data and published value coefficients of different ecosystems. Land use categories were estimated from dry season satellite images from 1980 – to 2016.

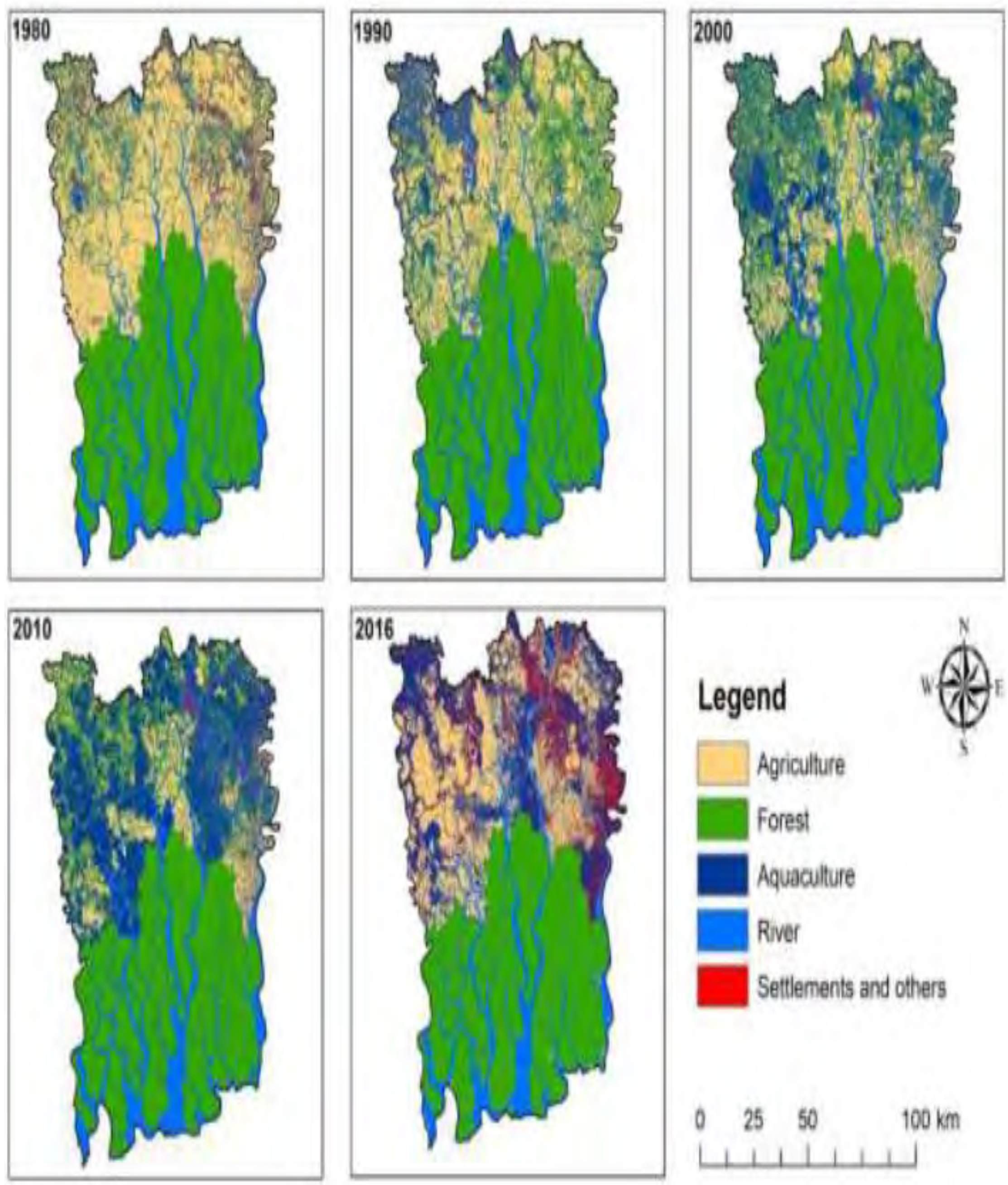


Figure 2.17 Land use maps in 1980, 1990, 2000, 2010 and 2016

(Source: Akber et al. 2018)

The result revealed that there has been a considerable decrease in the area of agriculture which was about 253,928 ha. The largest change is observed in the area of aquaculture. In 1980, aquaculture was the smallest land use category at 5,053 ha and which rapidly increased by 277,085 ha by 2016. Meanwhile, the total value of ES decreased from US$ 90.45 to 88.22 billion. The decline of agriculture was the largest contributor (US$ 1.41 billion) to the loss of ES, followed by deforestation (US$ 0.94 billion).

Table 2.11 Total Estimated Ecosystem Service Values (Source: Akber et al. 2018)

Land use category	ESV (US$ × 10^9/year)					ESV (US$ × 10^9/year) change (1980-2016)
	1980	1990	2000	2010	2016	
Agriculture	2.89	2.63	2.3	1.7	1.48	-1.41
Forest	85.02	85.01	84	83.86	84.08	-0.94
Aquaculture	0.01	0.02	0.08	0.19	0.26	0.25
River	1.94	1.9	1.92	1.87	1.85	-0.09
Settlements and others	0.59	0.83	0.84	0.76	0.55	0.04
Total	90.45	90.39	89.14	88.38	88.22	-2.23

Islam et al. 2015 also studied the changes in agricultural land and its implication for ecosystem services.

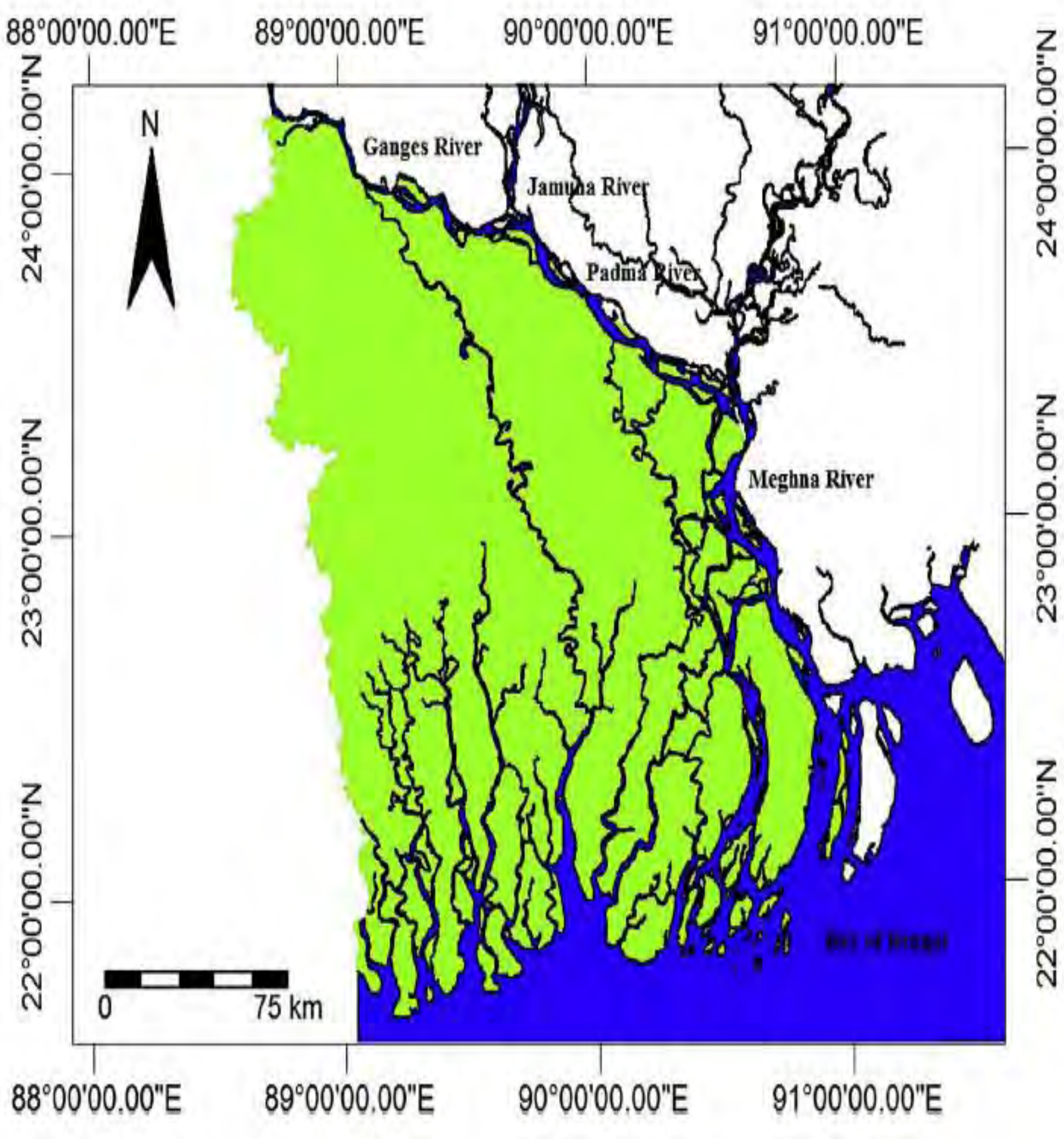


Figure 2.18 Location of Ganges Delta

(Source: Islam et al. 2015)

For this study, the land was categorized into four groups: Agricultural lands, Forestry, Wetlands, Settlement & others. The Landsat images of 1980, 1989, 1999, and 2008 were analyzed by Open source software, Integrated Land and Water Information System (ILWIS) and the Maximum likelihood technique of supervised classification was to determine the changes.

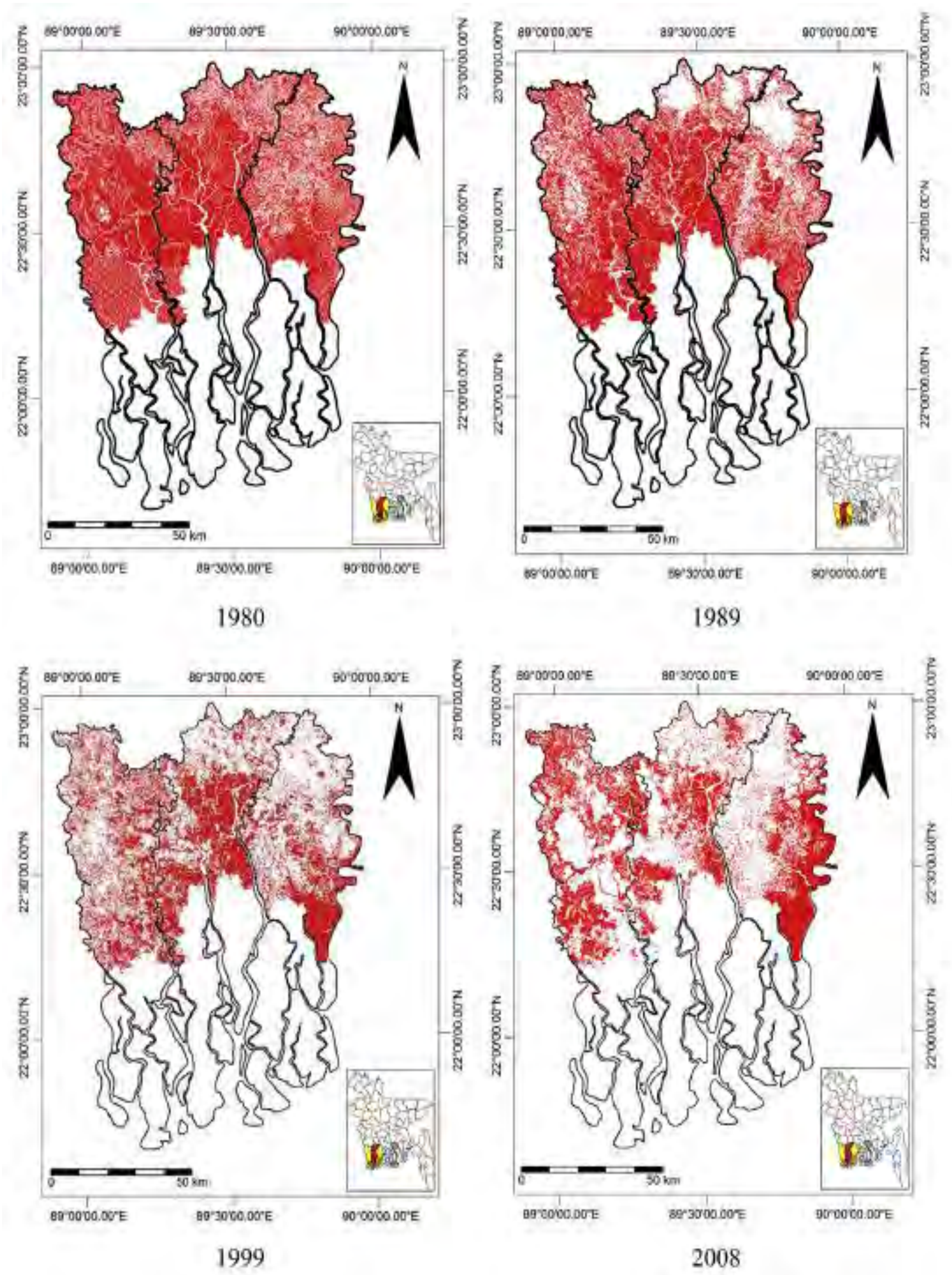


Figure 2.19 Spatial Coverage of Agricultural Lands in the Ganges Delta

(Source: Islam et al. 2015)

The results revealed with time agricultural lands decreased by approximately 50%.

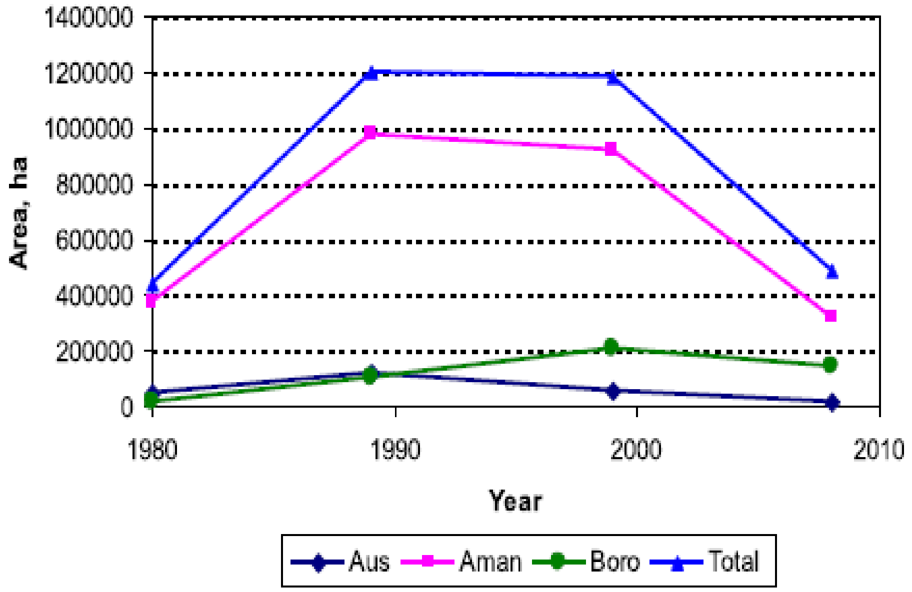


Figure 2.20 Temporal Change of Rice Cultivated Area in the Study Area

(Source: Islam et al. 2015)

The results also showed that wetlands increased by 500% mainly due to the growing popularity of saltwater shrimp farming. The settlement & others land use type has also been increased to nearly 5% during this period.

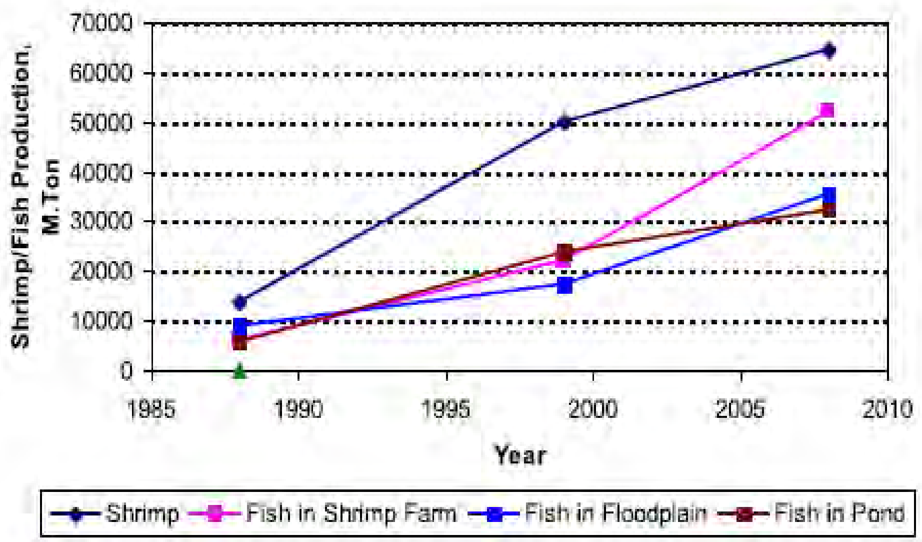


Figure 2.21 Temporal Change of Shrimp and Fish Production in the Study Area

(Source: Islam et al. 2015)

Maliha (2016) studied the changes in land use and soil properties and their impact on rice yield in Dacope Upazila of Khulna district. She used a supervised classification technique to analyze Landsat images of 1988, 1996, 2009, 2010, and 2014 to determine the land-use change in Dacope Upazila. She also used several Participatory Rural Appraisal (PRA) tools to collect necessary information regarding the land-use change. Observed dominant land use patterns in the study area were bare land, shrimp cultivation, and agricultural land. She analyzed that bare land in 1988, shrimp cultivating land in 1996, and agricultural land in 2014 was the highest in the study area which means that economically profitable shrimp cultivation has been reduced and agricultural practice is beginning to flourish over the last few years.

CHAPTER THREE

STUDY AREA

3.1 Introduction

The salient features of Khulna City, particularly its location, origin and growth, demographic situation, climatic condition, Geological setting, and other important issues are discussed in this chapter.

3.2 Geographic Characteristics

Khulna city is located on the banks of the Rupsha and the Bhairab rivers. It is in the southwest part of Bangladesh. Geographically, Khulna lies at 22"49'north latitude and 89"34'east longitudes. Khulna is bounded on the north by the Bhairab River and Fultala Upazila, on the east by the Rupsha River, on the south by the Rupsha River, and the west by Dumuria Upazila (BBS, 2011).

3.3 Origin and Growth

There are many views regarding the origin of the name Khulna. Some state that the name originated from the Khalloneswari temple of Dhenapati Chand Swadagar, an inhabitant of Ujani Nagar on the bank of the Rupsha River. Others state that Khulna derived its name from the fishermen who used to cross the river Bhairab, the sea Goddess and to short Khulno-was. and from that onwards, the name of Khulna emerged.

Khulna obtained its status as a formal town after the establishment of the municipality in 1884 during British Rule. In 1842, it was the sub-divisional headquarter of Khulna and upgraded into a district headquarters of Khulna district in 1882. Khulna attained the status of a metropolitan city in 1984 through the Khulna Municipal Corporation Ordinance of 1984 and then in 1990, it was declared as a City Corporation by a bill passed by the National Parliament (Nargis, 2001).

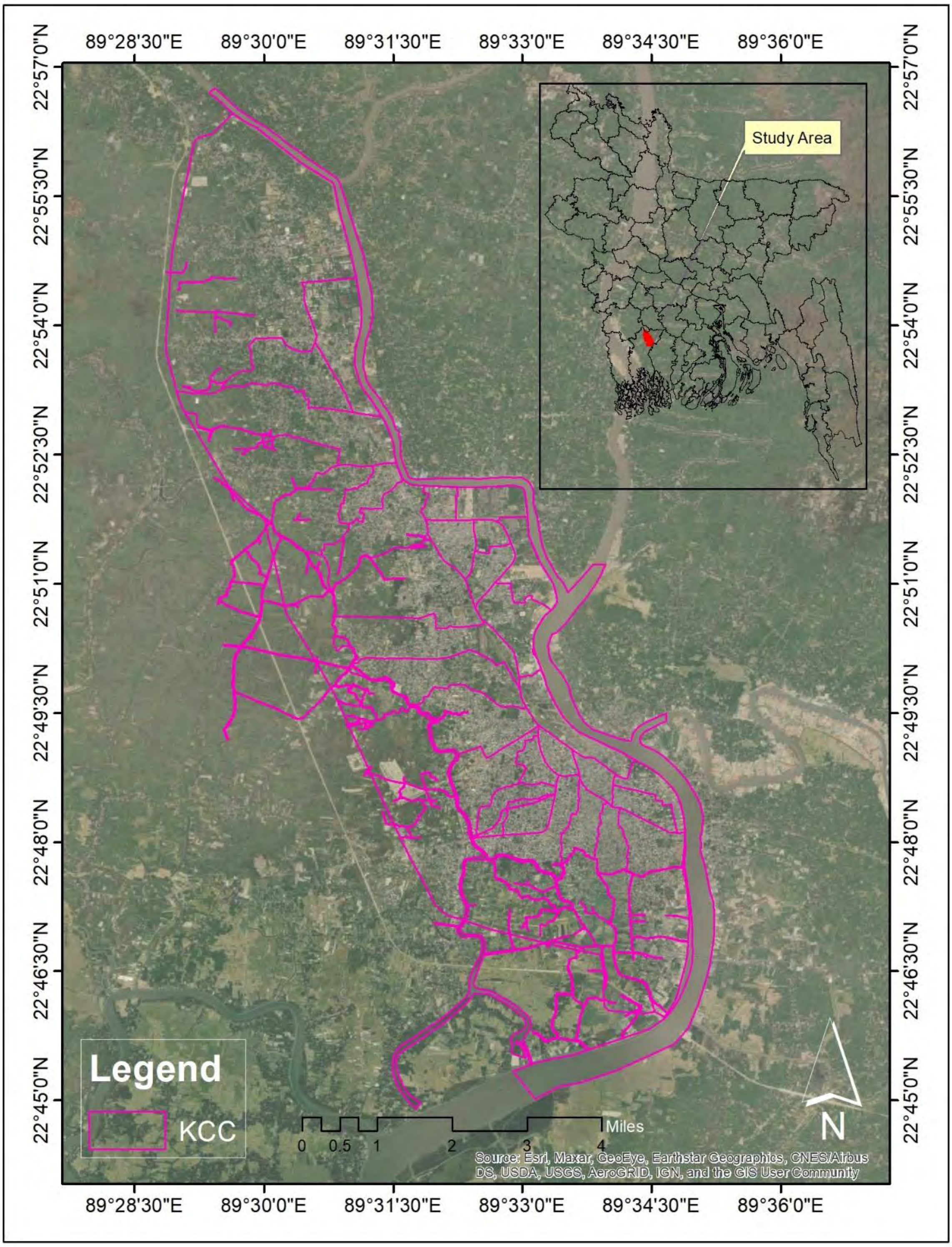


Figure 3.1 Study Area Map

3.4 Administrative Unit

Khulna city is the administrative hub of the Khulna district. The total area of the city is 6478 ha. Khulna City comprises 31 wards within 5 Thanas. From Table 3.1, it is shown that Khalishpur and Khulna Sadar Thana equally comprise the highest number of wards (13) and the lowest number of wards (5) in Daulatpur Thana. Table 3.2 shows that Ward no 3 has the largest area and ward no 11 has the smallest area.

Table 3.1 Thanas Comprising Different Wards of Khulna City (Source: Khulna Development Authority, 2002)

Thana	Ward within Thana Boundary	Area (sq. km)
Daulatpur	1, 2, 3, 4, 5	4.06
Khalishpur	5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16,21	12.73
Khanjahan Ali	1, 2, 3, 4, 5, 6, 9, 14, 16	9.22
Khulna Sadar	19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31	11.25
Sonadanga	14, 16, 17, 18, 19, 20, 21, 24, 25, 26	7.63

Table 3.2 Area of Different Wards of Khulna City (Source: Khulna Development Authority, 2002)

Ward	Area (sq. km)	Ward	Area (sq. km)	Ward	Area (sq. km)
1	2.10	12	0.66	23	0.51
2	2.12	13	1.01	24	1.52
3	3.73	14	2.69	25	0.76
4	1.98	15	1.57	26	.66
5	0.74	16	2.27	27	0.83

Ward	Area (sq. km)	Ward	Area (sq. km)	Ward	Area (sq. km)
6	2.15	17	2.29	28	0.76
7	0.46	18	1.58	29	0.66
8	0.91	19	0.49	30	1.18
9	3.54	20	0.50	31	3.66
10	0.81	21	1.37		
11	0.37	22	0.66		

3.5 Demographic Feature

3.5.1 Population

There has been a steady growth rate in Khulna city between the years 1901-and 1961. A sharp rise in population was observed in 1974 by the socio-political change due to the liberation war. From 1991 to 2001, the population in Khulna city increased because of the combined effect of natural growth and migration. Hereafter, the population count decreased in Khulna city from 2001 to 2011 because of the declination of heavy industries. Table 3.3 shows the chronology of population growth in Khulna city.

Table 3.3 Population Trend of Khulna City (Source: Nargis, 2001 & BBS, 2011)

Year	Population (In Thousand)	Growth Rate (%)
1901	10.43	
1911	18.17	5.55
1921	23.50	2.57
1931	28.00	1.75
1941	34.00	1.94
1951	42.00	2.17

Year	Population (In Thousand)	Growth Rate (%)
1961	80.22	6.42
1974	437.30	13.04
1981	561.95	3.58
1991	663.34	1.66
2001	884.00	3.50
2011	751.00	1.70

3.5.2 Literacy Rate

Table 3.4 Literacy Status of Khulna City (Source: BBS, 2011)

Year	Literacy Rate (%)
1981	49.8
1991	59.6
2001	59.9
2011	72.7

The above table shows that more than 50 percent of the population has not gone beyond the primary level of education. The literacy rate in Khulna Conurbation is found increasing due to the establishment of schools, colleges, and universities.

3.5.3 Occupation

The people of Khulna city are engaged in different professions. According to the Khulna city master plan project, above 14 percent are in service (both public and private sectors). 12 percent are in business and 2 percent are hawkers and day laborers, and 1.3 percent are self-employed. About 23 percent of the total people of Khulna city are housewives, 2.7 percent are pension holders and 36 percent are students.

3.6 Geological Setting

The natural environment has an impact on shaping the physical setting of the city and its pattern of growth. Khulna city is located in the southwest region of the country, which has been developed by the process of siltation from a network of rivers. Some of the physical aspects of the city are given below:

- **Land:** Land surface of Khulna city is characterized by six geomorphic units a natural levee, floodplain, old meander complex, bar, tidal marsh, and back swamp. Natural levees are well developed along the Bhairab-Rupsha banks and occupied by the buildup areas of the city. The low-lying areas extend mainly towards fringe areas of the city characterized by swampy areas, currently used for agricultural purposes that are poorly drained and have persistent water logging problems (Nargis, 2001).
- **Soil:** Khulna district is formed entirely by the deltaic action of the Ganges which brought mud and limestone from the Himalayas. The area is composed of coarse to very fine sand, silt, and silty clay up to a depth of 300m with peaty soil and calcareous as well as non-calcareous soil at the top (Roy et al, 2005).

3.7 Hydrology

Khulna City area is bounded by the river of Bhairab on the northeast, Rupsa on the southeast, and Pasur further down south. The Atharobanki River meets with Rupsa and the Atai River meets with the Bhairab River on the central east. The Rupsha River flowing along the city is the main natural drainage for the city. Besides the Bhairab and Rupsha Rivers, a few other rivers namely Chitra, Nabaganga, Atharobanki, and Modhumati are also of relevance to Khulna City concerning surface water hydrology. The majority of the rainfall occurs during the monsoon (June to October). So the main source of freshwater for Khulna City during the dry season is the flow diverted from the Ganges to the Gorai River. The Rupsa-Bhairab-Pasur are active tidal rivers with a strong current that carries coarser sediments from upstream and finer sediments mainly clay from downstream by flood tide (Roy et al, 2005).

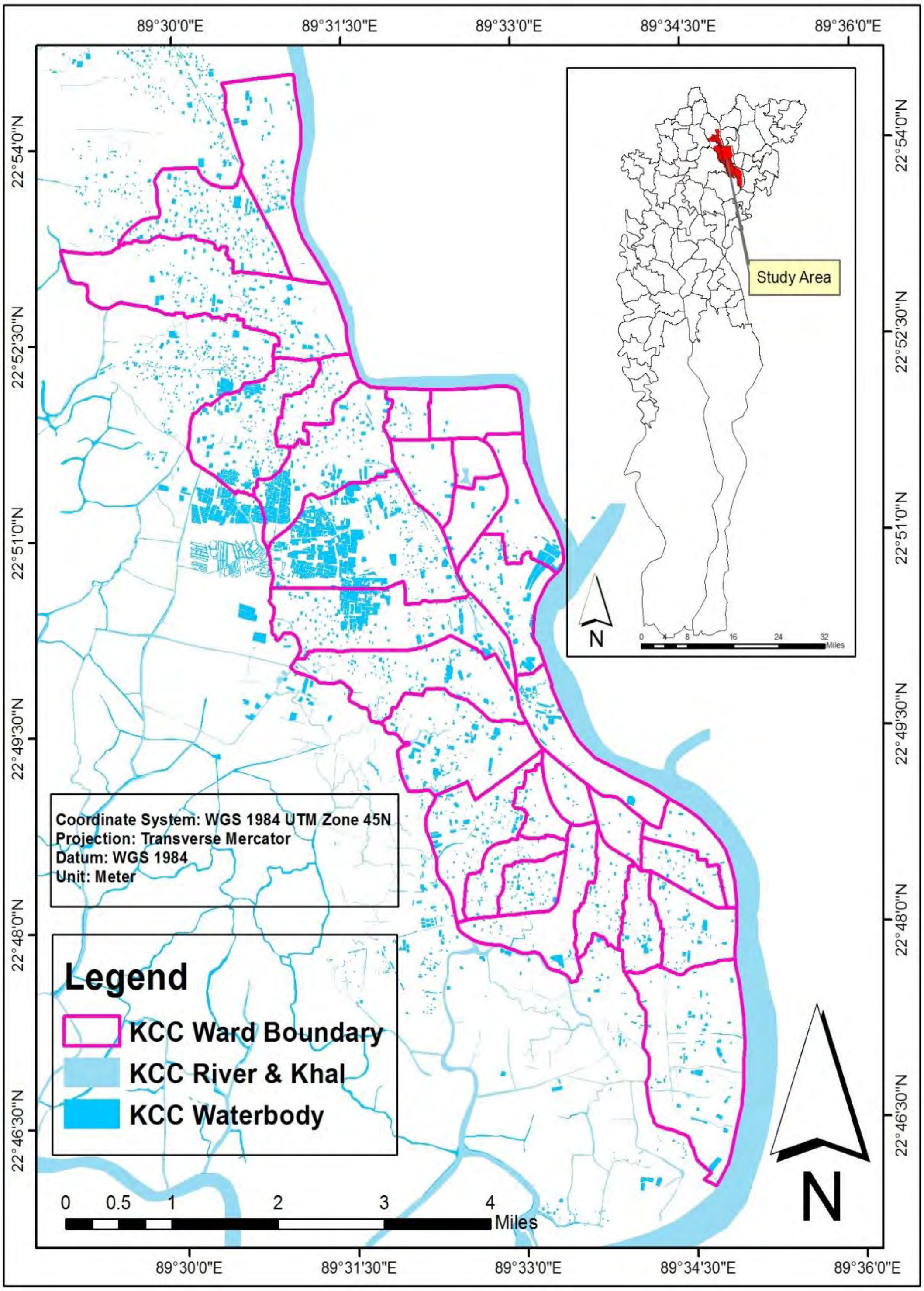


Figure 3.2 River and Khal of Khulna City

3.8 Drainage

There were significant numbers of natural canals around Khulna City. But in course of time, unplanned spatial activities and habitation are causing encroachment on retention areas and natural drainage paths with little or no care for the natural drainage systems.

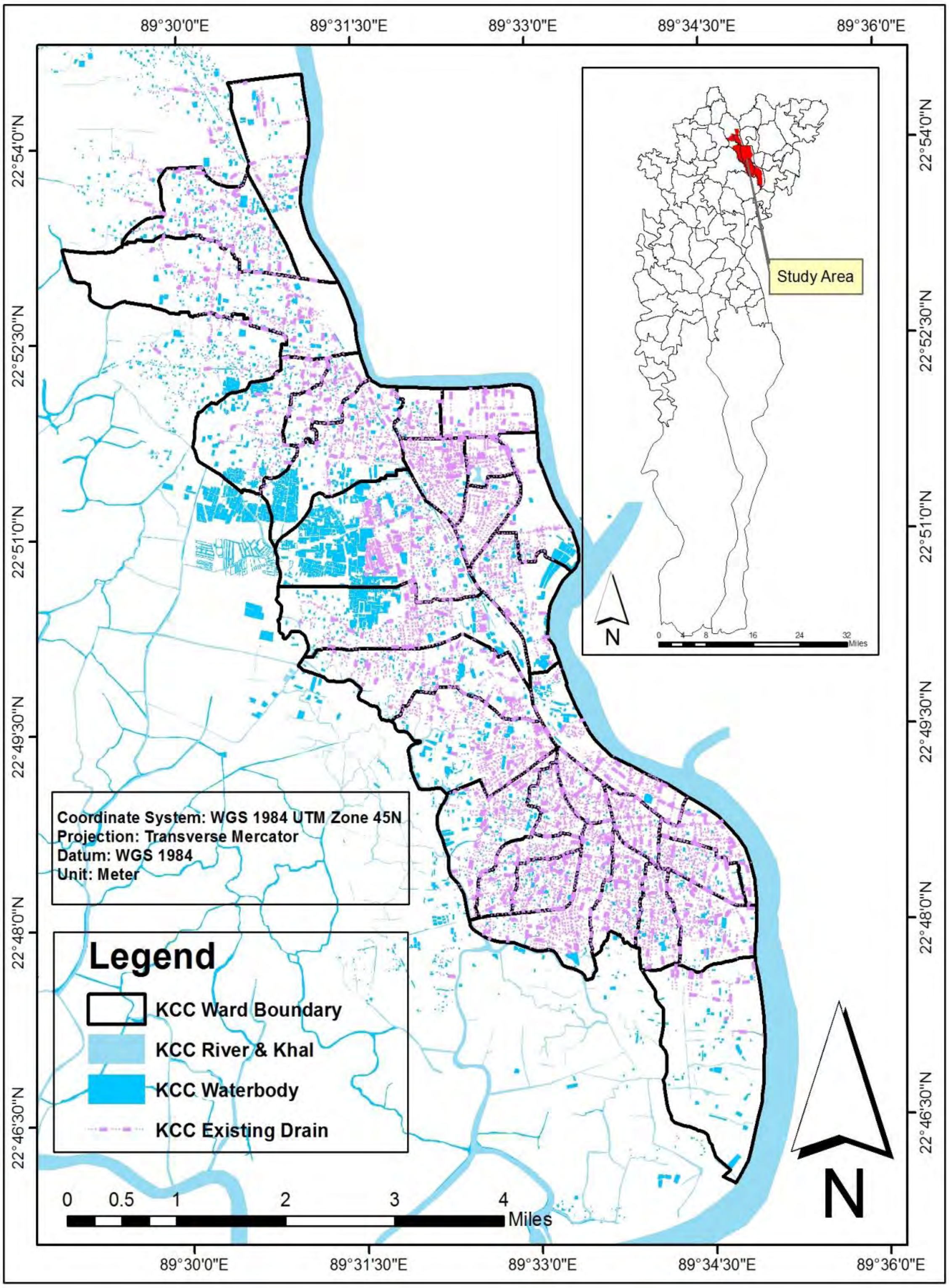


Figure 3.3 Existing Drainage Network

There are about 528 kilometers of drainage networks in the KCC area. Of this, about 64 km is pucca, about 52 km semi-pucca, and about 381 km are katcha. The existing drains in the KCC area discharge into the nearby khals, rivers, low-lying areas, and beels. There is no underground storm water drainage system within the city. There are 6 regulators and 8 sluice gates that drain out storm water from KCC. 4 regulators drain out storm water into the Rupsha River and the other two regulators drain into the Khudir Khal, the upstream of Gollamari River (Zannat, 2012).

3.9 Water Supply Condition

The primary source of water supply in the KCC area is mainly the groundwater extracted through production and hand tubewells. The secondary source of water supply is surface water extracted from rivers, ponds, and wells. The coverage of pure drinking water supply is well over 90 percent.

Only 30 percent of the households in the KCC area have access to the piped water supply; 64 percent have access to the hand tube wells and only 6 percent use water from secondary sources. In areas outside KCC, 89 percent of the households have access to the hand tube wells and only 11 percent use water from secondary sources (KWASA)

Table 3.5 Existing Water Supply Installations (Source: KWASA)

Description	Existing Installation
1. Overhead Water Tank	5 Nos.
2. Production Tubewell	60 Nos.
3. Deep Tubewell (Hand)	1850 Nos.
4. Shallow Tubewell (Hand)	3800 Nos.
5. Distribution Pipeline (75-300 mm Dia)	262 Km

3.10 Sanitation

Fifty-two percent of the households in the KCC area have access to a sanitary latrine comprising a septic tank; 24 percent of the households use a pit and bucket latrine. The remaining 24 percent have unsanitary katcha and surface latrines.

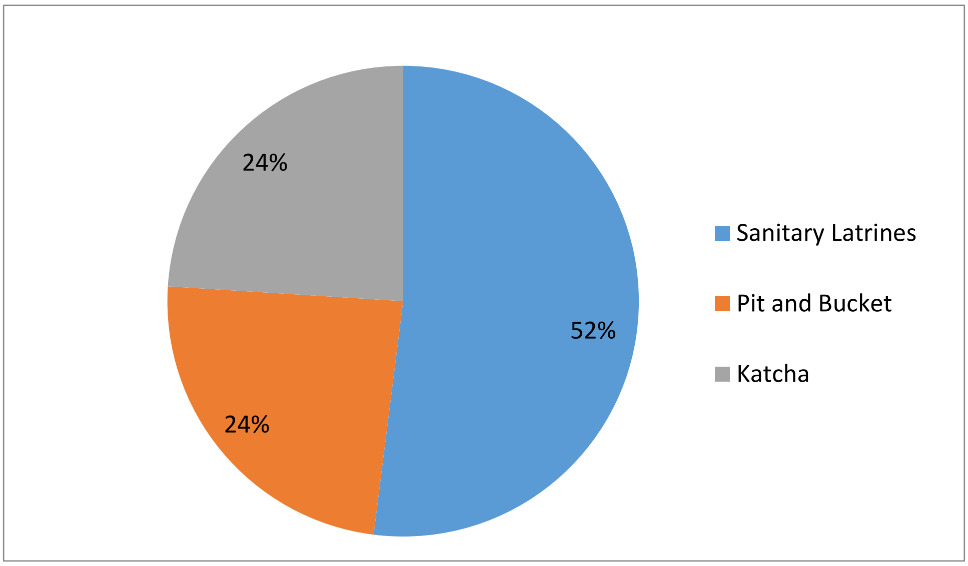


Figure 3.4 Existing Sanitation Types

(Source: KWASA)

3.11 Climate

A tropical environment exists in Khulna Conurbation. Remarkable changes in temperature can be found with the changes of seasons in the Khulna conurbation.

3.11.1 Temperature

The average temperature is 29.6^0 C. May is the hottest month of the year. January is the coldest month with temperatures averaging 19.1^0 C. In June, there is a sharp fall in temperature due to the outbreaks of monsoon.

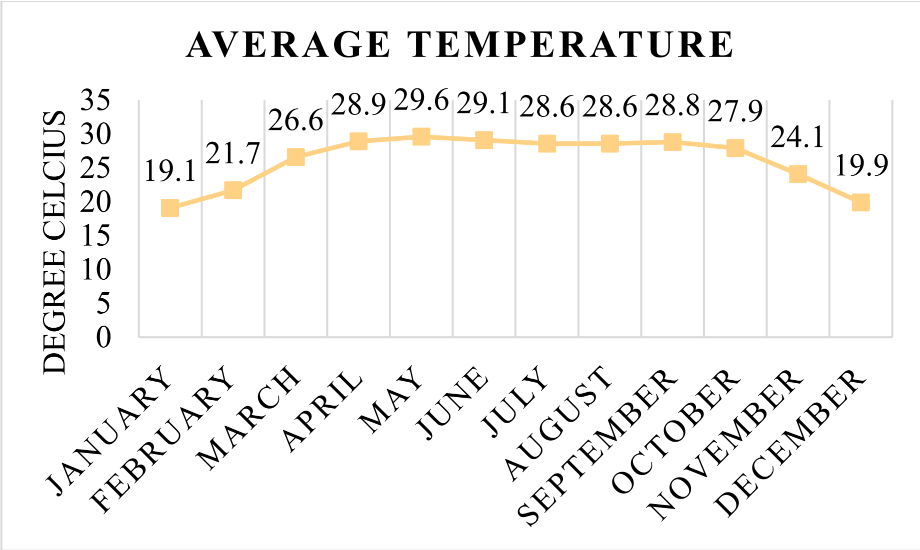


Figure 3.5 Average Monthly Temperature

(Source: BMD. 2020)

3.11.2 Rainfall

Khulna receives an average rainfall of about 180mm. The main source of rainfall is the southwestern monsoon. During March-May some rainfalls also occur due to the Nor'wester effect. During December and January, little rainfall is recorded.

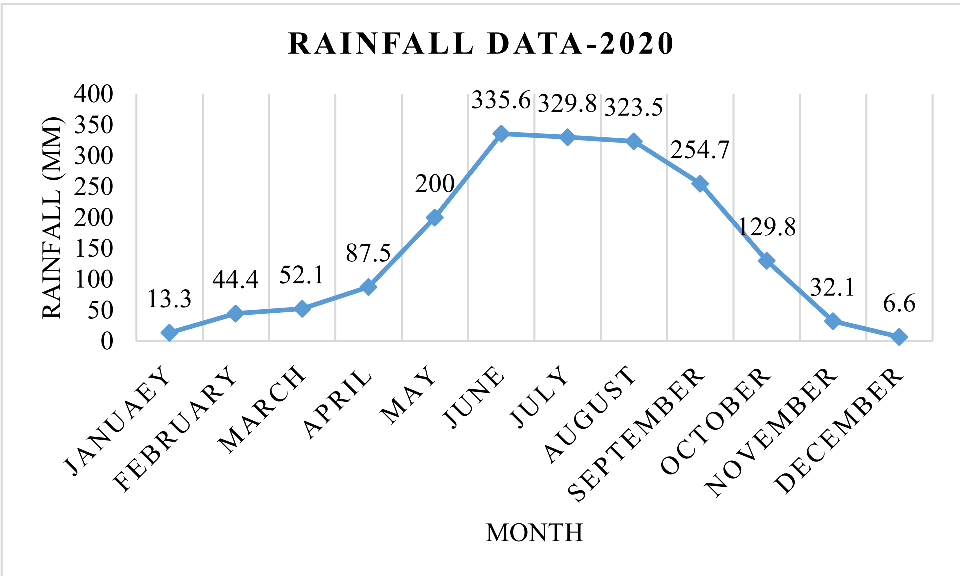


Figure 3.6 Average Monthly Rainfall Data of 2020

(Source: BMD. 2020)

CHAPTER FOUR

METHODOLOGY

4.1 Introduction

This chapter discusses the methodologies of the research sequentially. The method used, methodology applied and steps followed are explained elaborately in this chapter.

4.2 Selection of Study Area

Khulna is the divisional city of Bangladesh. It is the third-largest city in Bangladesh and it has great importance for industry and seaport. Having great economic importance, the city is growing haphazardly. The excessive growth rate tends to change the pattern of land which imposes an impact on the city's ecosystem services and values. But there is still enough scope for guided development of the City. So Khulna has been selected as the study area.

4.3 Land Use Change Analysis

Due to the unavailability of Landsat images for the year 1985, Landsat satellite images of 1987, 1996, 2007, and 2018 were analyzed to determine the land-use changes. The satellite images were collected from the official website of the United States Geological Survey (USGS). The images were taken from November and December because this is the dry season; so the sky remains free from clouds. The projection system was Universal Transverse Mercator (UTM). The supervised classification techniques were used to delineate the current and previous land use of the study area

Table 4.1 Detail of Landsat Images

Satellite Name	Path and Row	Date	Resolution (m)
Landsat Multispectral Scanner (MSS)	138 and 44	24-12-1987	60
Landsat Thematic Mapper (TM)	138 and 44	16-02-1996	30
Landsat Enhanced Thematic Mapper Plus (ETM+)	137 and 44	23-02-2007	30
Landsat Thematic Mapper (TM)	137 and 44	20-01-2018	30

4.4 Land Use Classification

In this study land use was classified into four categories including Build up Area, Water Bodies, Vegetation, and Rivers as those are the main types of land uses in the study area.

Table 4.2 Land Use Classification Scheme

Land Use Type	Classification Scheme
Build Up Area	Residential area, mixed area, industry, transport
Water Bodies	Permanent open water, Streams, Khal
Vegetation	Park, Stadium, Urban Green, Crop Field
Rivers	Lake and Rivers

4.5 Accuracy Assessment

The confusion matrix and ground-truthing method will be used to assess the accuracy of land use classification. A confusion matrix is defined as the method of describing the performance of a classification model on a data set where true values are known **(Source: Patel & Kaushal, 2012).**

$$\text{User's Accuracy}= \frac{\text{Number of Correctly Classified Pixel in each Category}}{\text{Total Number of Classified Pixels in that Category (Row Total)}} * 100$$

$$\text{Producer's Accuracy}= \frac{\text{Number of Correctly Classified Pixel in each Category}}{\text{Total Number of Classified Pixels in that Category (Column Total)}} * 100$$

$$\text{Overall Accuracy}= \frac{\text{Total number of Correctly Classified Pixels}}{\text{Total Number of Reference Pixels}} * 100$$

On the other hand, ground-truthing is a method of comparing the pixel of a satellite image to the present condition on the ground with the help of GPS.

4.6 Assessment of Ecosystem Services

A lot of studies have been conducted to estimate the value of ecosystem services in the past few decades. Among them, the ecosystem service valuation model presented by Costanza et al. 1997 is considered as the robust method to estimate the economic value of ecosystem services. They identified 17 ecosystem services from 16 biomes to calculate ecosystem service values. Although the method presented by Costanza et al. 1997 received some critiques due to the low estimate of farmland unit value and uncertainties, the model presents the most comprehensive set of initial approximations for ecosystem service valuation (Rahman & Szabo, 2021).

To evaluate the ecosystem services, the values of each land use type will be compared with different biomes identified in the world ecosystem. The valuation coefficient in the most representative biome will be used as a surrogate for each category. In this study, urban biome for 'build-up area', cropland for 'vegetation', wetland biome for 'water bodies', and river or lakes for 'river' will be used. Then the updated value of world ecosystem services will be applied. The total value of the ecosystem services will be calculated by using the following formula:

$$ESV = \sum (Ak * VCk) \ldots\ldots\ldots\ldots\ldots\ldots \quad (4.1)$$

Where ESV is the estimated ecosystem services value, A_k is the area (ha) and VC_k is the value coefficient for each land use category.

CHAPTER FIVE

LAND USE CHANGE ANALYSIS

5.1 Introduction

Land-use changes in 1987, 1996, 2007, and 2018 are analyzed from Landsat satellite images using ArcGIS software.

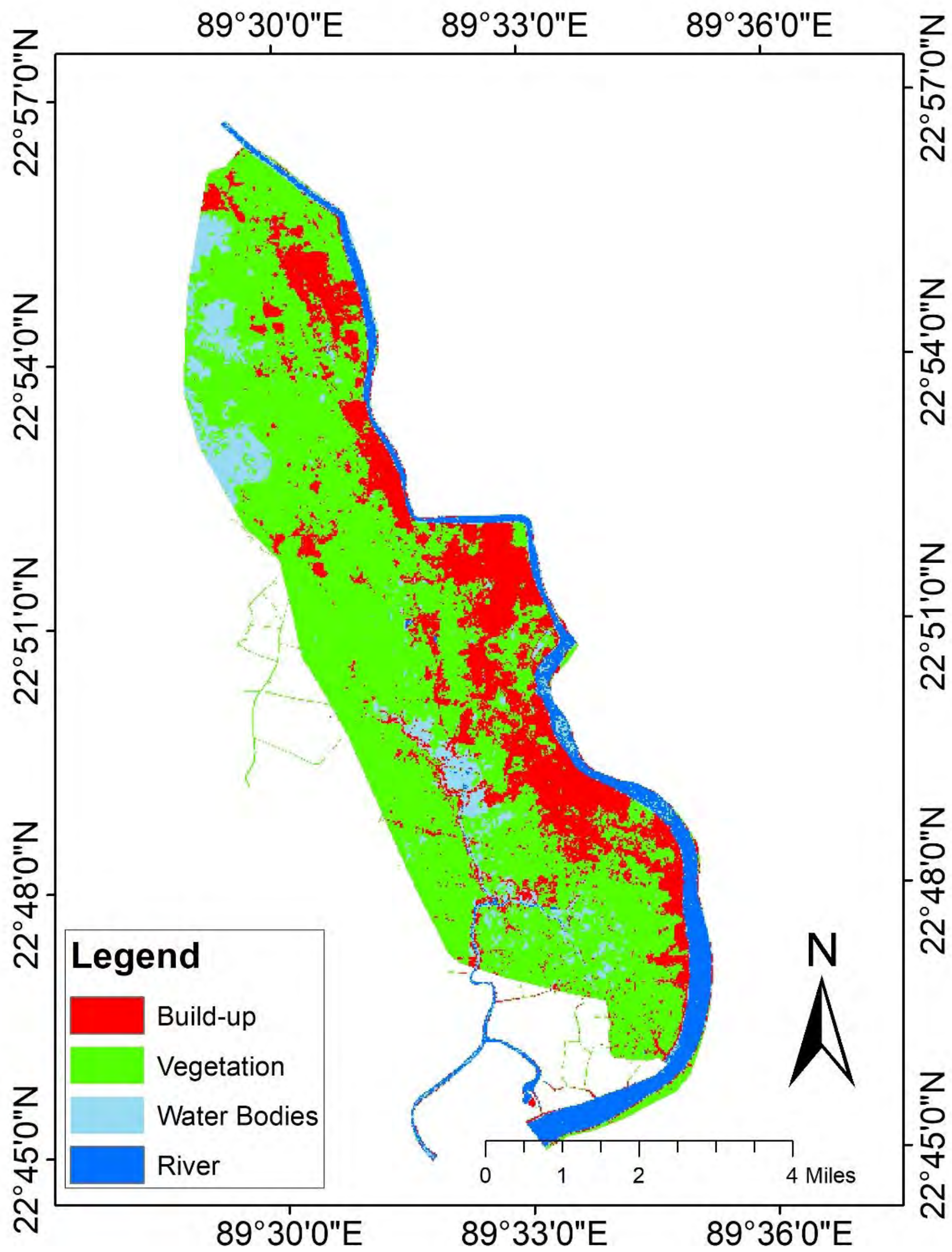


Figure 5.1 Land Use Map of Khulna City Corporation in 1987

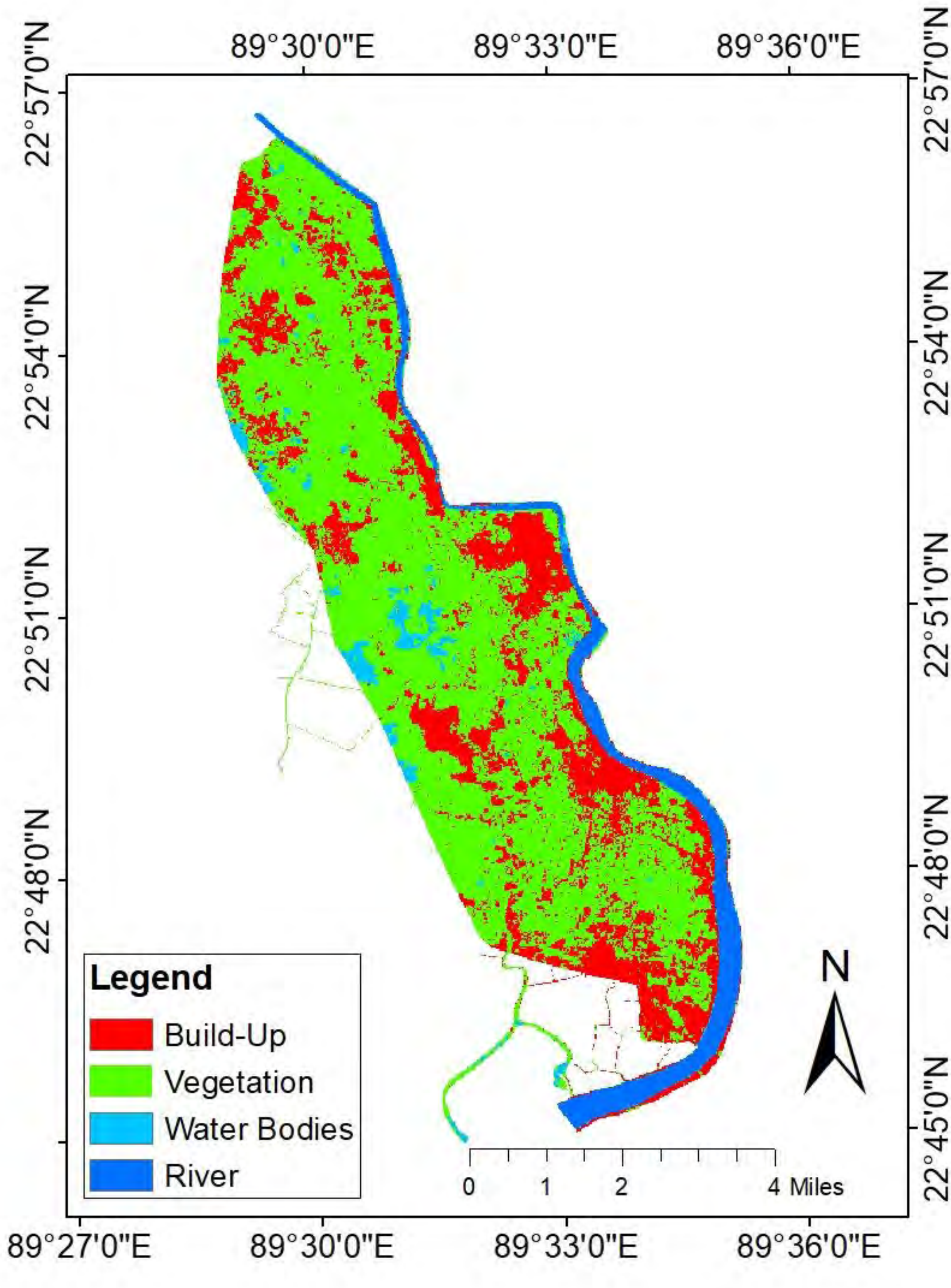


Figure 5.2 Land Use Map of Khulna City Corporation in 1996

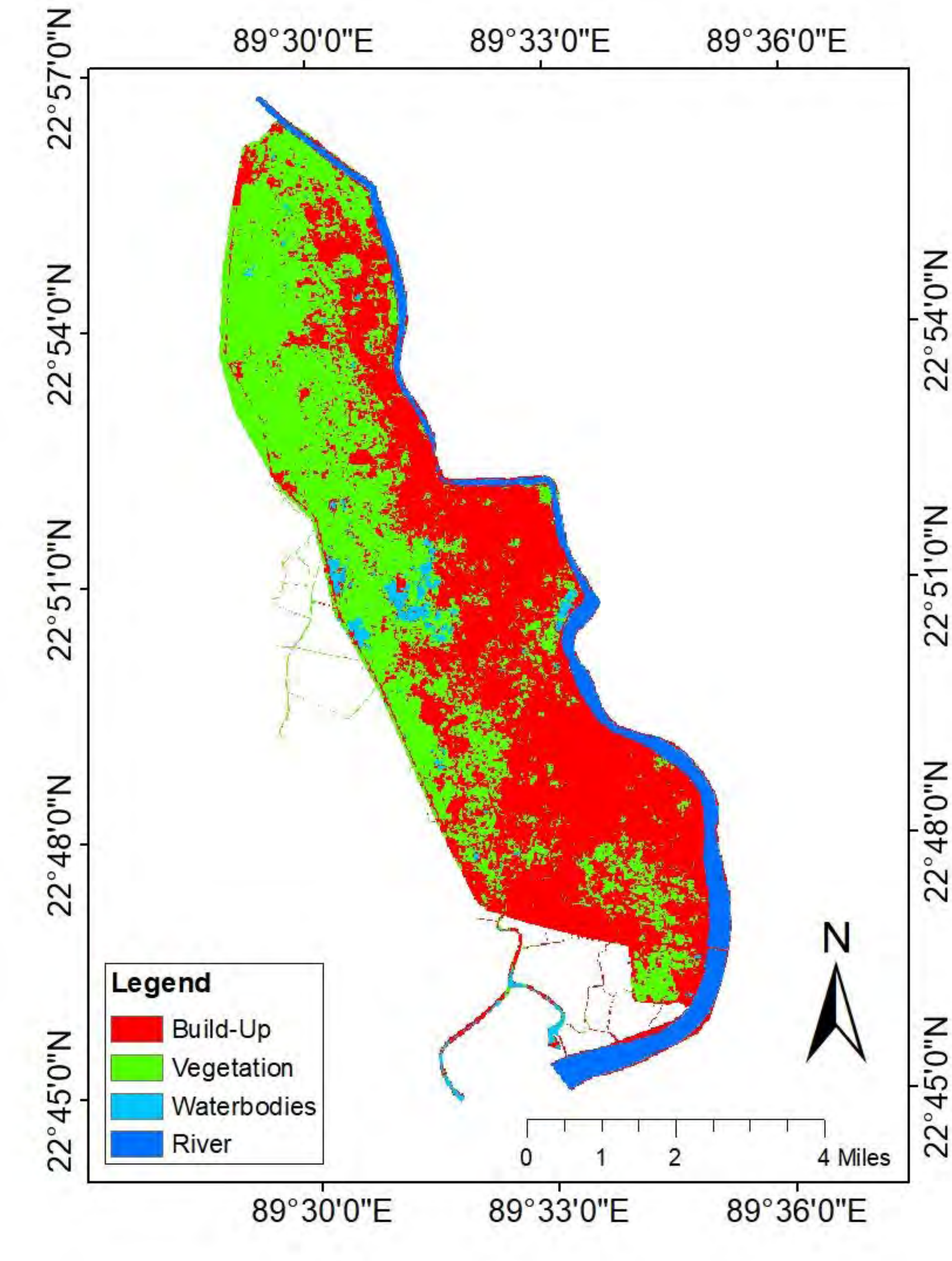


Figure 5.3 Land Use Map of Khulna City Corporation in 2007

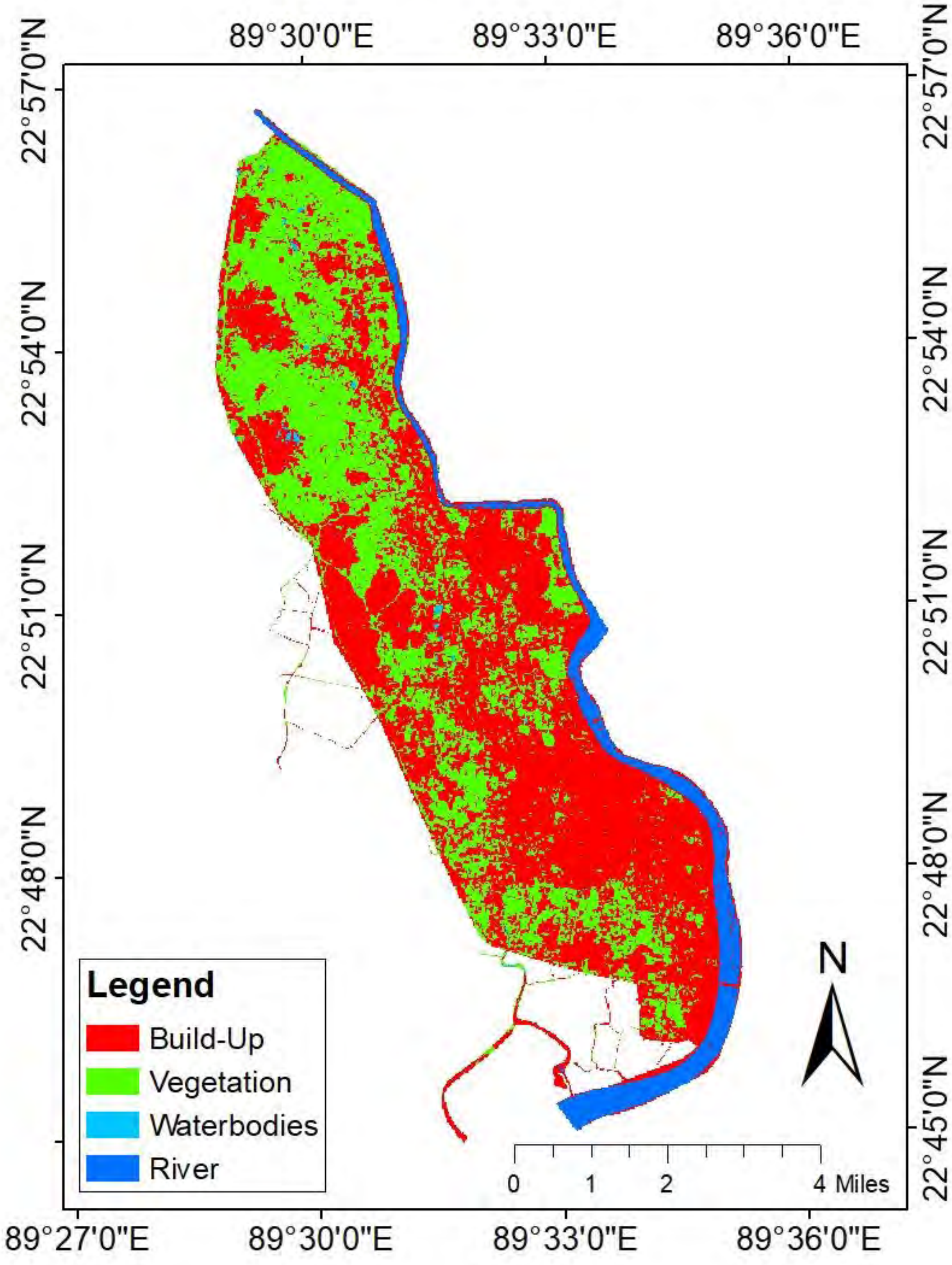


Figure 5.4 Land Use Map of Khulna City Corporation in 2018

5.2 Assessment of the Land Use Change

The extracted data showed that Land-use and land cover changed noticeably from 1987 to 2018 in Khulna City Corporation area. During this time, a significant decrease is noticed in vegetation. The change in the vegetation area from 1987 to 1996 is not significant because of less reduction. But after that, it showed a rapidly decreasing trend and in 2018 it reduced to 3597 ha due to urban sprawling.

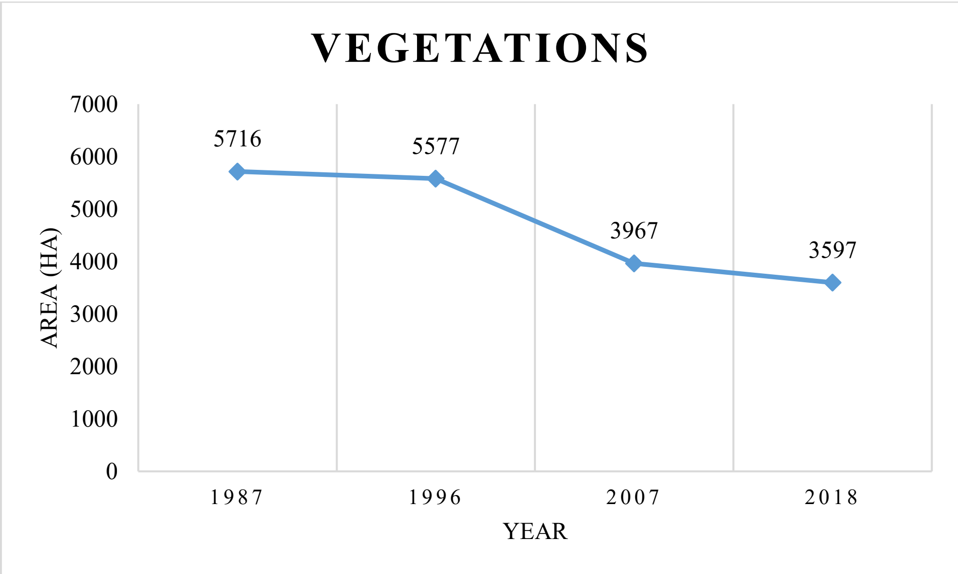


Figure 5.5 Temporal Change of Vegetation in Khulna City Corporation from 1987 to 2018 (Source: GIS Analysis, 2018)

The Build-up area showed an increasing trend from the period of 1987 to 2018. It can be visually interpreted that, the built-up area increased in the northwest and middle parts of the city. In 1987, the total build-up area was 1342 ha and in 2018 it increased to 4332 ha which is more than three times. This situation indicates the lack of effective growth management in Khulna city.

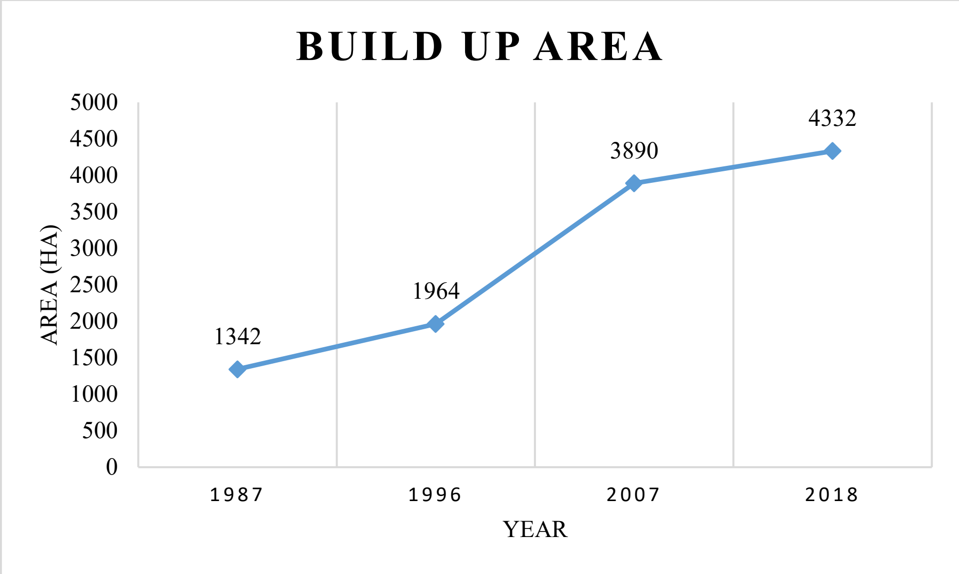


Figure 5.6 Temporal Change of Buildup Area in Khulna City Corporation from 1987 to 2018 (Source: GIS Analysis, 2018)

The river area decreased from 784 ha to 692 ha from 1987 to 2018 due to the expansion of the buildup area, dumping of waste into the river, and adjacent canal which reduced the navigability of the river.

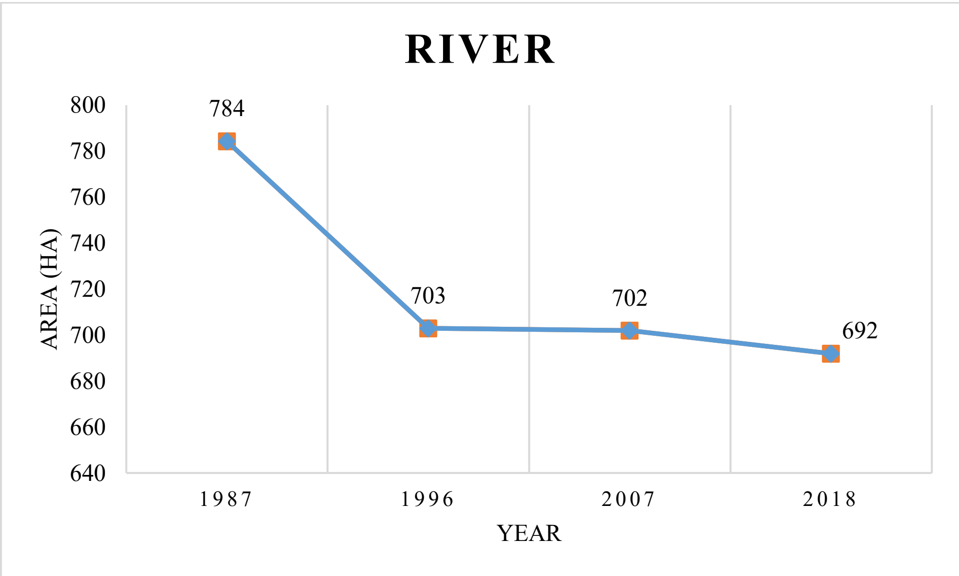


Figure 5.7 Temporal Change of River in Khulna City Corporation from 1987 to 2018 (Source: GIS Analysis, 2018)

The wetland area decreased from 940 ha to 172 ha from 1987 to 2018. The reduction happened due to the expansion of the build-up area specially the construction land. Waterbody area was also replaced by vegetation or agricultural land but their amount was less than the buildup area.

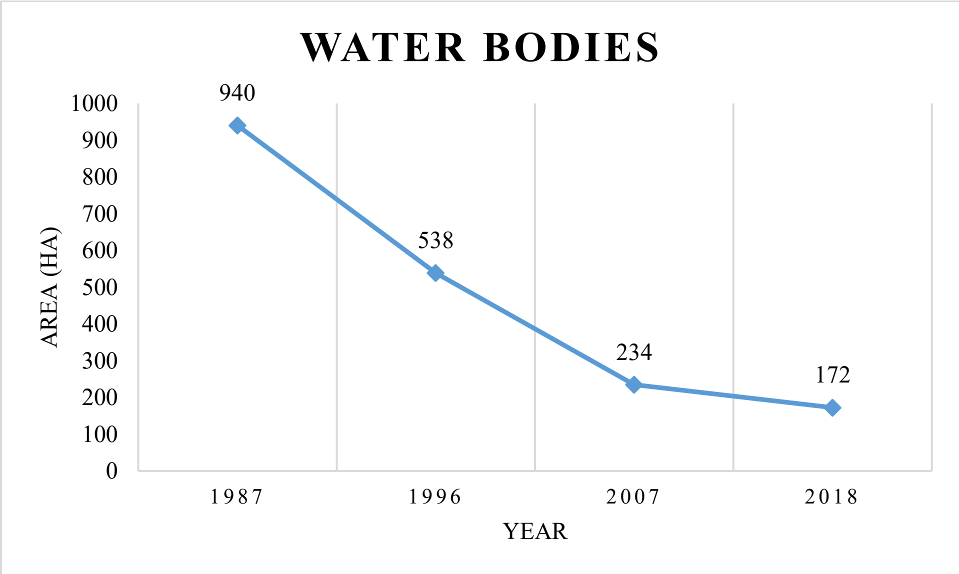


Figure 5.8 Temporal Change of Water Bodies in Khulna City Corporation from 1987 to 2018 (Source: GIS Analysis, 2018)

5.3 Accuracy Assessment

To measure the accuracy of land use, confusion matrix and ground-truthing techniques were used. For the confusion matrix, ArcGIS 10.7 windows based software was used.

5.3.1 Confusion Matrix

A confusion matrix (also known as an error matrix) visually represents the difference between the actual and predicted classifications of a model. It is used to easily recognize how often a classification system mislabels one classification as another. In this matrix, each row defines the producer's accuracy and each column represents the user's accuracy. The following formulas were used to measure the accuracy of land use classification:

Table 5.1 Confusion Matrix for Accuracy Assessment of the Land Use Classification of the Year 1987

Land Type	Build Up	Vegetation	River	Water Bodies	Classification Overall	Producer's Accuracy	Overall Accuracy
Build Up	42	5	2	4	53	0.79	86%
Vegetation	2	34	0	1	37	0.92	
River	0	2	6	0	8	0.75	
Water Bodies	0	1	0	8	9	0.89	
Truth Overall	44	42	8	13	107		
User' Accuracy	0.95	0.81	0.75	0.61			

Table 5.2 Confusion Matrix for Accuracy Assessment of the Land Use Classification of the Year 1996

Land Type	Build Up	Vegetation	River	Water Bodies	Classification Overall	Producer's Accuracy	Overall Accuracy
Build Up	40	4	0	3	47	0.85	83%
Vegetation	2	29	0	3	34	0.85	
River	0	1	8	0	9	0.89	
Water Bodies	2	3	0	12	17	0.71	
Truth Overall	44	37	8	18	107		
User' Accuracy	0.91	0.78	1	0.67			

Table 5.3 Confusion Matrix for Accuracy Assessment of the Land Use Classification of the Year 2007

Land Type	Build Up	Vegetation	River	Water Bodies	Classification Overall	Producer's Accuracy	Overall Accuracy
Build Up	36	5	2	5	48	0.75	81%
Vegetation	2	36	0	2	40	0.90	
River	0	1	7	0	8	0.87	
Water Bodies	2	1	0	8	11	0.72	
Truth Overall	40	43	9	15	107		
User' Accuracy	0.90	0.83	0.78	0.53			

Table 5.4 Confusion Matrix for Accuracy Assessment of the Land Use Classification of the Year 2018

Land Type	Build Up	Vegetation	River	Water Bodies	Classification Overall	Producer's Accuracy	Overall Accuracy
Build Up	36	4	0	5	45	0.80	82%
Vegetation	1	27	1	0	29	0.93	
River	1	0	12	0	13	0.92	
Water Bodies	4	3	0	13	20	0.65	
Truth Overall	42	34	13	18	107		
User's Accuracy	0.85	0.79	0.92	0.72			

5.3.2 Ground Truthing

As a dynamic area, the land use pattern of Khulna City Conurbation is changing continuously. So it is difficult to assess the accuracy of old satellite images. For reasonable and acceptable accuracy, the satellite image of 2018 was taken. In this research, 50 sites were randomly selected throughout the study area for ground-truthing including, 15 vegetation areas, 2 river sites, 15 sites of water bodies, and 18 sites of buildup areas. Then, the field data were compared with the land use map of 2018. The results showed that of 50 sites, 44 sites were matched with the land use map of 2018 and the accuracy was 88%.

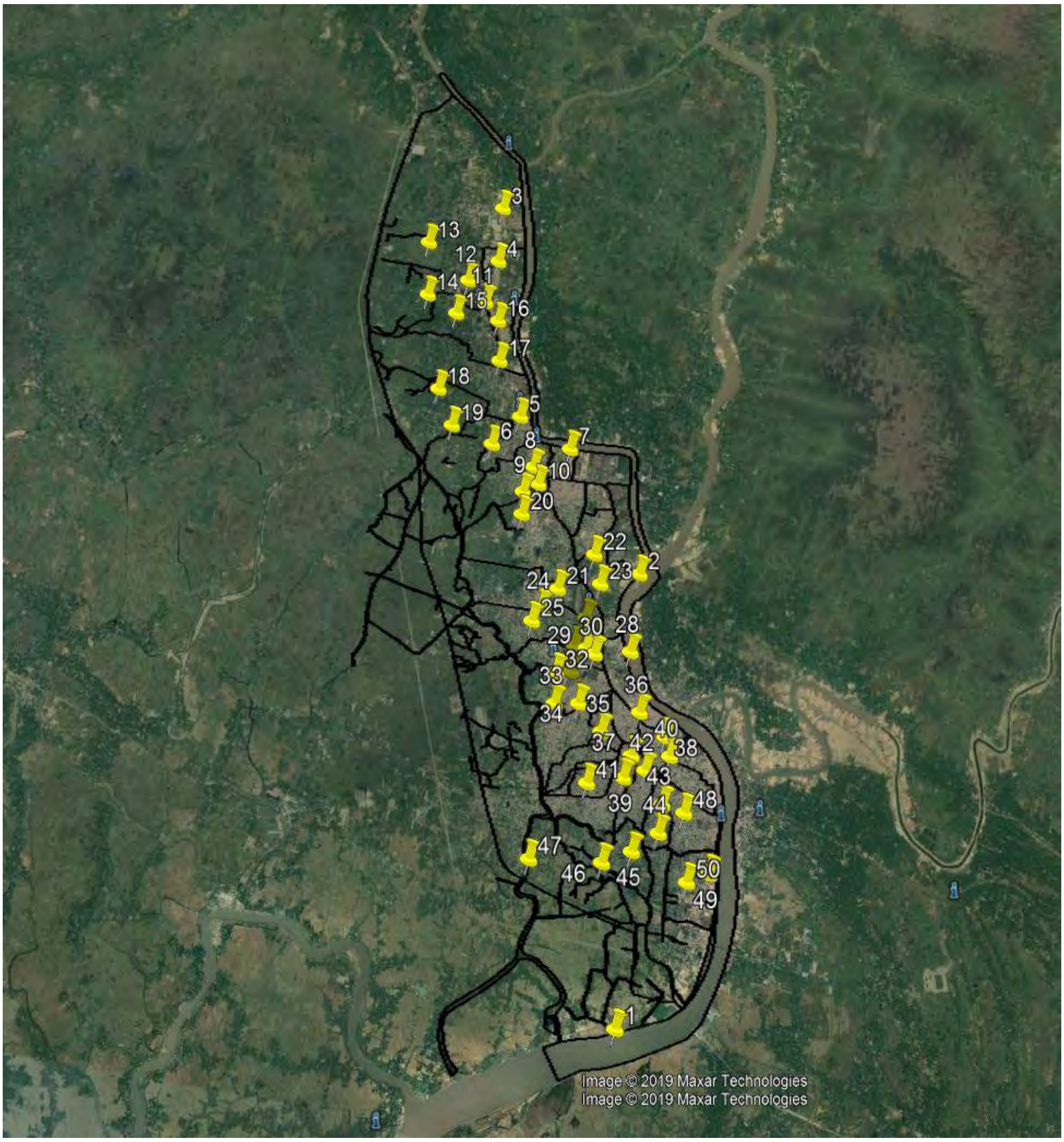


Figure 5.9 Ground Truthing Location

Table 5.5 Comparison of Field Data against Model Data for Land Cover Map of the Year 2018

Number of Sites	Model Data	Field Data	Accuracy (%)
1	River	River	88%
2	River	River	
3	Build Up	Build Up	
4	Build Up	Build Up	
5	Build Up	Build Up	
6	Build Up	Build Up	
7	Build Up	Vegetation	
8	Build Up	Build Up	
9	Water Bodies	Water Bodies	
10	Water Bodies	Water Bodies	
11	Water Bodies	Build Up	
12	Water Bodies	Water Bodies	
13	Vegetation	Vegetation	
14	Vegetation	Vegetation	
15	Vegetation	Vegetation	
16	Build Up	Build Up	
17	Build Up	Build Up	
18	Water Bodies	Build Up	
19	Water Bodies	Water Bodies	
20	Water Bodies	Water Bodies	
21	Vegetation	Water Bodies	
22	Vegetation	Vegetation	
23	Vegetation	Vegetation	
24	Build Up	Build Up	
25	Build Up	Build Up	
26	Build Up	Build Up	
27	Build Up	Build Up	
28	Build Up	Build Up	
29	Water Bodies	Water Bodies	

Number of Sites	Model Data	Field Data	Accuracy (%)
30	Vegetation	Vegetation	88%
31	Vegetation	Vegetation	
32	Vegetation	Vegetation	
33	Vegetation	Vegetation	
34	Vegetation	Vegetation	
35	Water Bodies	Vegetation	
36	Build Up	Build Up	
37	Build Up	Build Up	
38	Build Up	Build Up	
39	Build Up	Build Up	
40	Build Up	Build Up	
41	Water Bodies	Water Bodies	
42	Build Up	Build Up	
43	Build Up	Build Up	
44	Vegetation	Vegetation	
45	Vegetation	Build Up	
46	Vegetation	Vegetation	
47	Vegetation	Build Up	
48	Build Up	Build Up	
49	Build Up	Build Up	
50	Build Up	Build Up	

CHAPTER SIX

IMPACT OF LAND USE CHANGES ON ECOSYSTEM SERVICES

6.1 Introduction

Land-use change has a significant impact on the world's ecosystems. Changes in ecosystem goods like vegetation, forests, agricultural land, wetlands, and grasslands have significant impacts on the provision of ecosystem services and values and biodiversity conservation. Millennium Ecosystem Assessment (2005) studied 24 ecosystem services worldwide and found 15 of them are deteriorating (Fisher et al. 2009). Because of human interference, the structure and functions of the ecosystem are changed more rapidly in the second half of the twentieth century than at any other time in human history. The magnitude of these changes is growing as both population size and intensity of economic activity increase (MA, 2005).

Before the 60s or 70s, the process of spatial growth of Khulna city was not so complicated. But after the liberation war, Khulna city is changing rapidly. The city has gone through radical changes because of urbanization and land-use changes. In the process of urbanization, the physical characteristics of the city are changing as wetland and lowland, open spaces, and agricultural land are transformed into urban build-up and construction land which impacted exiting ecosystem services and values.

The living status of people is also affected by land use changing patterns. People who are involved in agricultural work and fishing were reduced. On the contrary, the number of private and public jobholders, small businessmen, shopkeepers, auto-rickshaw drivers, and poultry farmers showed a significant increase in economic solvency. Educational, medical, communication networks, water supply, and sanitation facilities have improved because of development. Rapid urbanization caused the demise of the wetland of the city. Wetlands are the city's main surface-water drainage system. As the wetlands are receding Khulna city is becoming more vulnerable to urban waterlogging and flooding. Besides, playing fields and parks were reduced, and existing ones are not properly managed. This reduced the aesthetic value of the city. For a particular area, the presence of all the ecosystem services might not possible. In this research, the impact of land-use changes on provisioning services and regulating services are discussed.

6.2 Impact of Land Use Changes on Provisioning Services

6.2.1 Impact of Land Use Changes on Vegetation

In this research, the type of vegetation land use is classified as agricultural land, urban greeneries park, and playground. The following figures (6.1 & 6.2) have shown how the city's vegetation is changing over time.

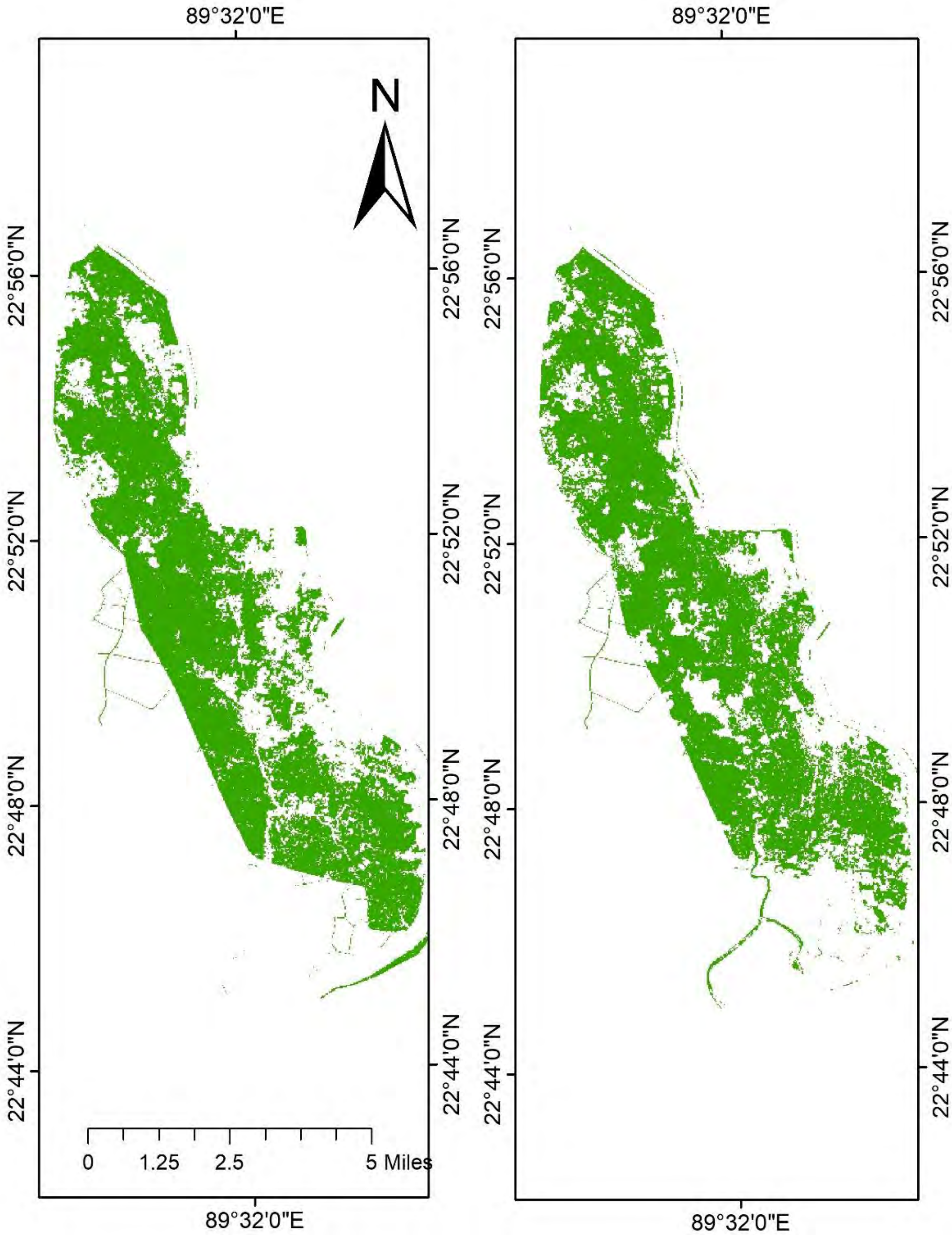


Figure 6.1 Changes in Vegetation from 1987 to 1996

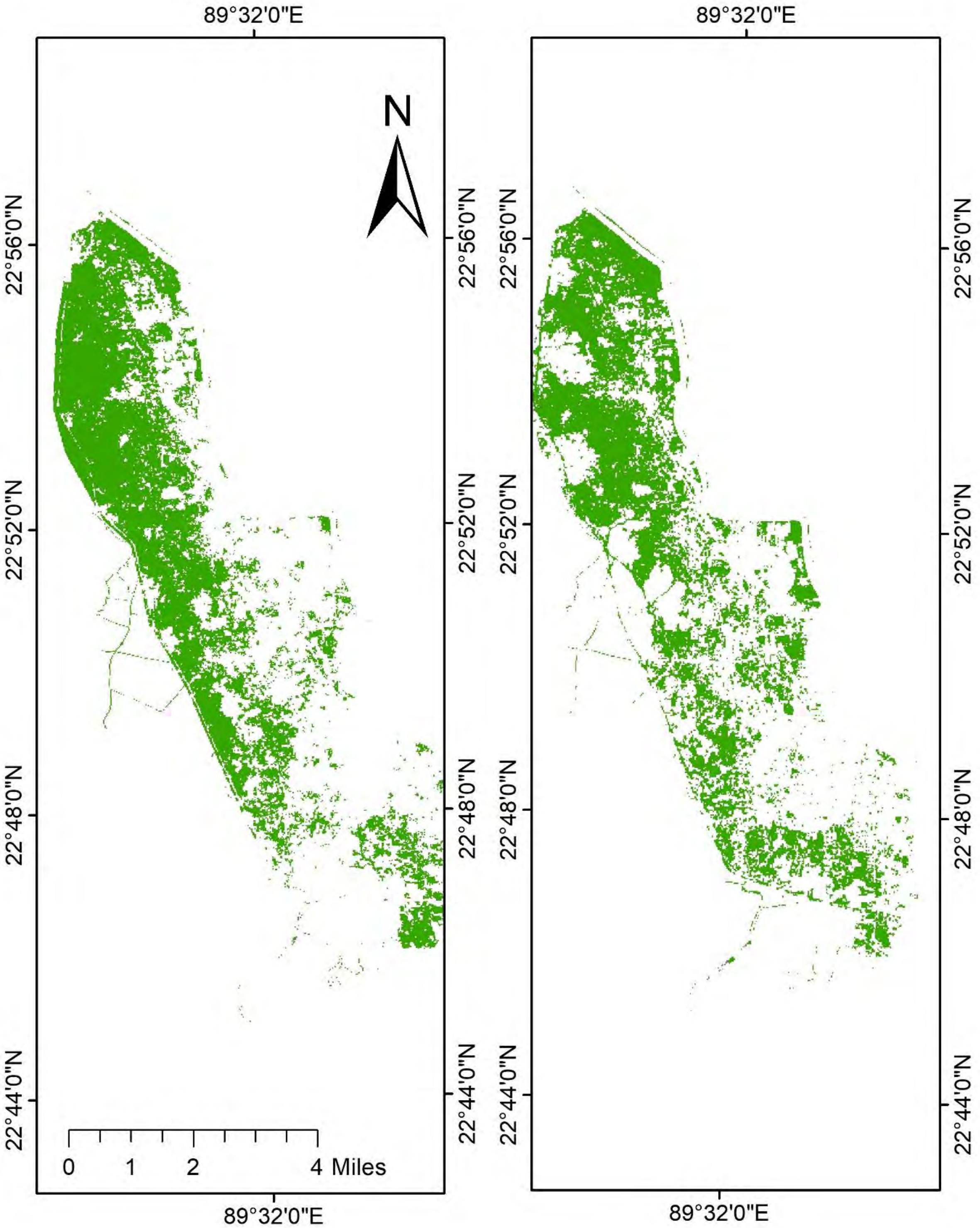


Figure 6.2 Changes in Vegetation from 2007 to 2018

Extracted data showed that vegetation area decreased from 5716 ha in 1987 to 3597 ha in 2018 in the Khulna Conurbation area.

Among the vegetation area, agriculture is one of the vital ecosystem services. Agricultural systems are the principal interface between human and environmental interactions (De Clerck et al. 2016). Agricultural land use accounts for one-third of the global terrestrial surface (approx. 4.9 billion ha). Agricultural ecosystems provide humans with food, fiber, fuel, etc., and are thus fundamental for human survival (Hoffman et al. 2018).

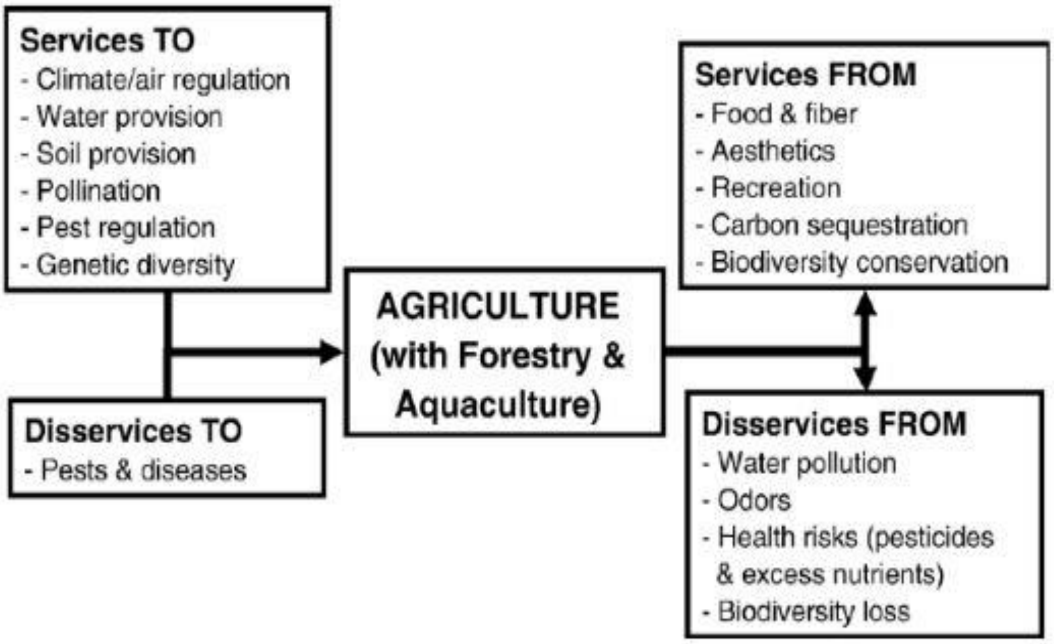


Figure 6.3 Ecosystem Services to and from Agriculture (Source: Swinton et al. 2007)

The increasing trend of urbanization has caused substantial changes in cultivable land. Globally, a strong trend of urbanization has been observed since 1900. Estimates show that only 10% of the global population was living in urban areas in 1900. This grew to 30% in 1950 and 47% in 2000 (Alam, 2018). This increasing trend of urbanization is defined as a decisive factor in land-use change. This land-use changing trend is found in Khulna Conurbation which affects the city's agriculture too.

Rice is the main agricultural crop in Khulna Conurbation. Aush, T. Aman, and Boro are the main three types of rice cultivated here. **(Figure 6.4)** showed the gradual trend of cultivable land from the period of 1996 to 2018.

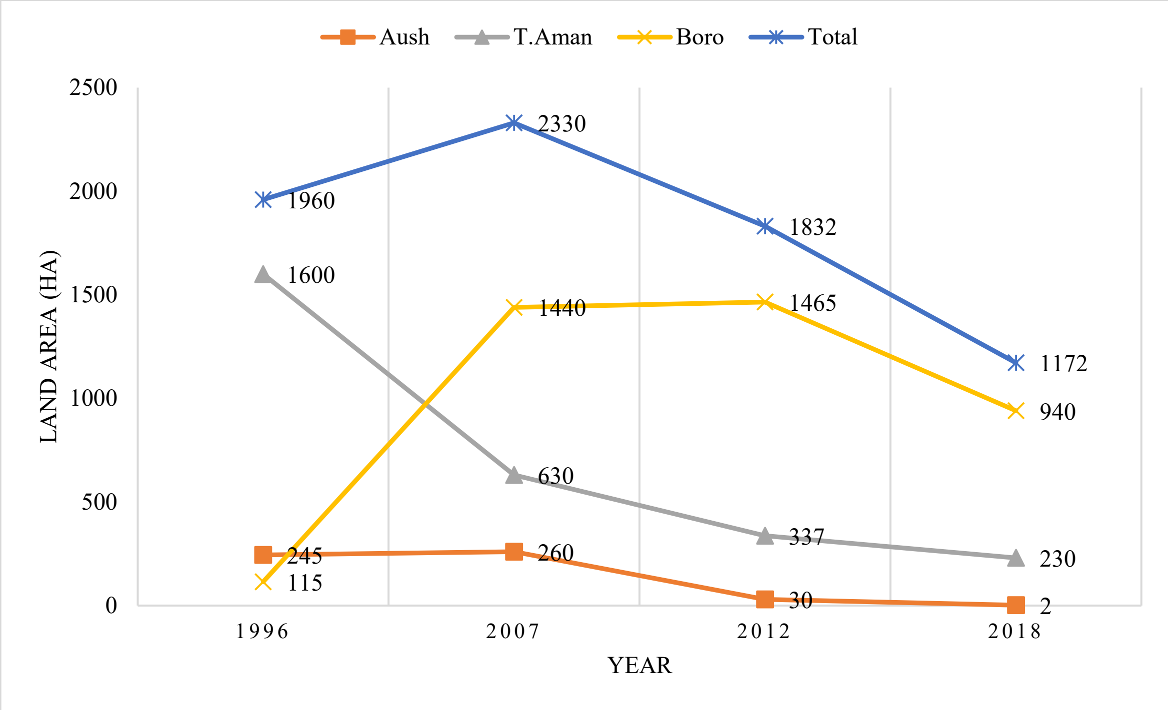


Figure 6.4 Temporal Changes of Agricultural Land in Khulna Conurbation

(Source: Khulna Agricultural Extension Office, 2019)

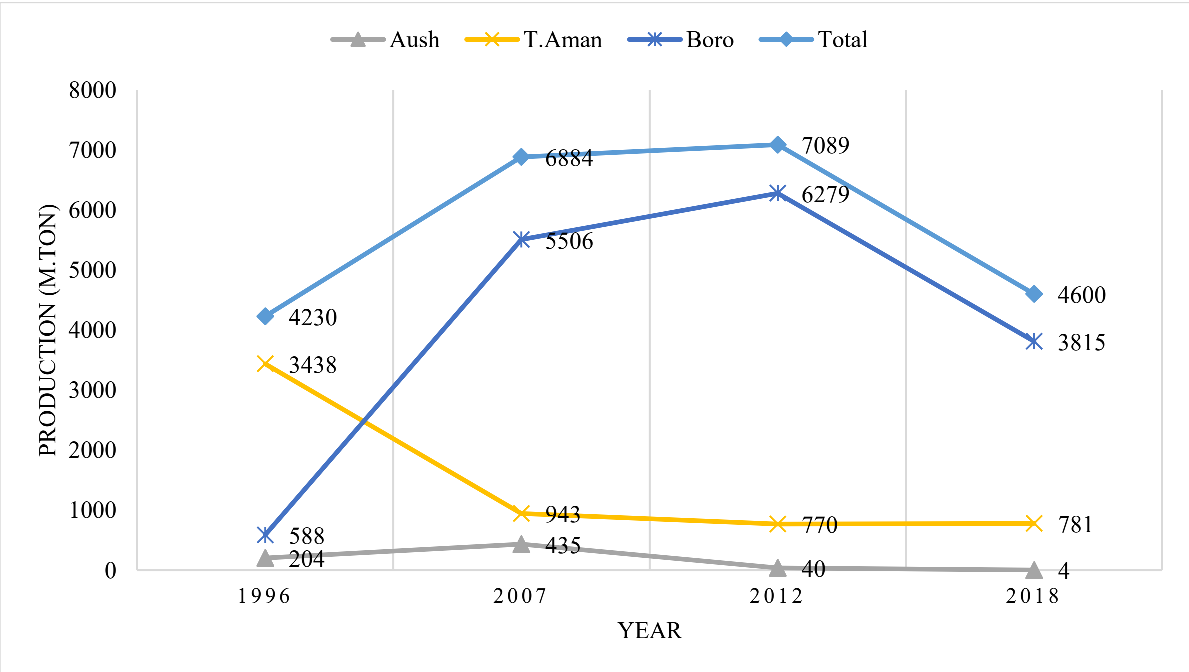


Figure 6.5 Temporal Changes in Rice Production in Khulna Conurbation

(Source: Khulna Agricultural Extension Office, 2019)

(Figure 6.4 & 6.5) showed that from 1996 to 2018 the area of Aush and T. Aman were decreased so were the production. On the other hand, the total area of Boro production increased from 1996 to 2012 and then gradually decreased due to the rapid urbanization and spatial expansion. A total of 788 ha of agricultural land was lost in Khulna Conurbation within 22 years.

(Figure 6.6) showed the data on rice production from the period 1990 to 2015 in the Khulna district. During this period, Aush production decreased from 156720 metric tons to 33762 metric tons, Aman production decreased from 421658 metric tons to 294510 metric tons but Boro production increased from 77457 metric tons to 518963 metric tons.

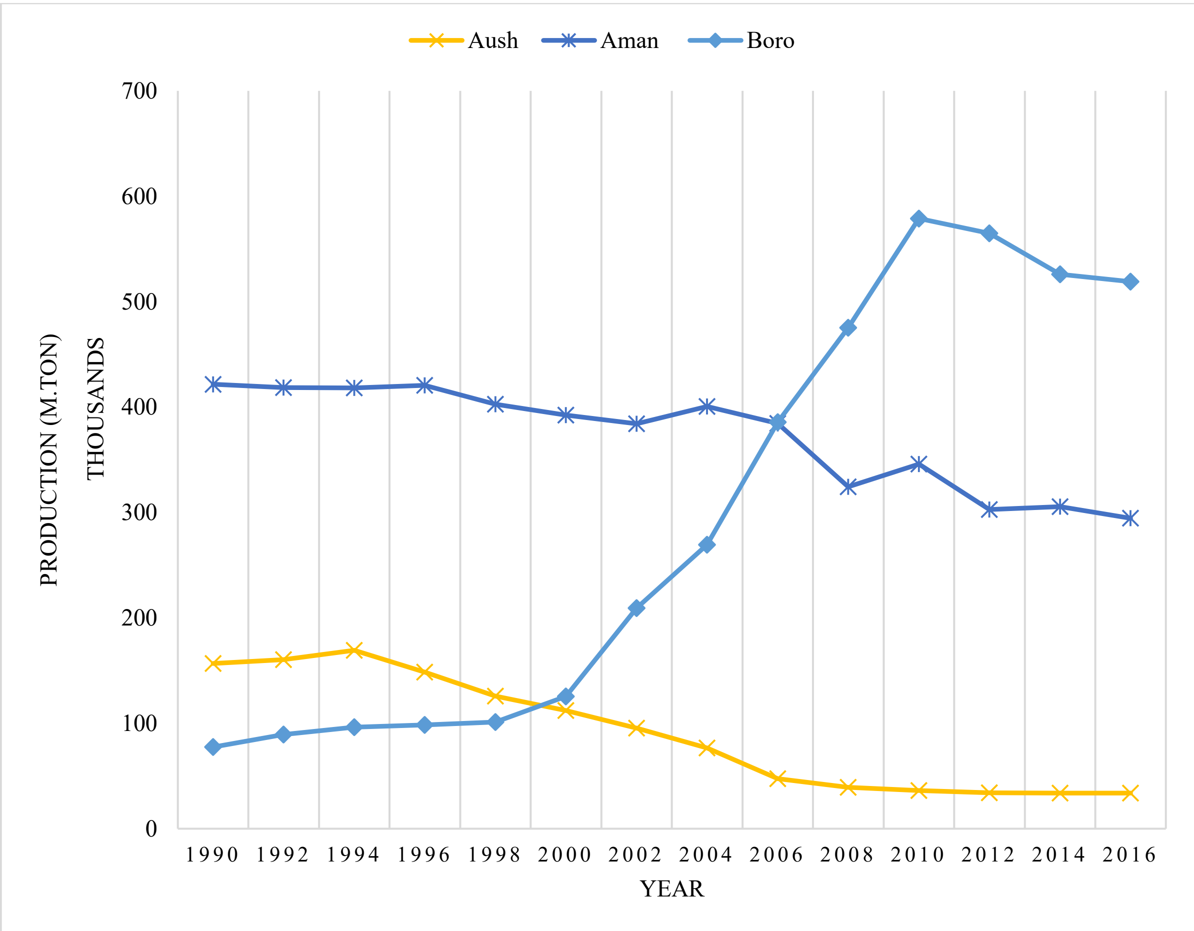


Figure 6.6 Temporal Changes in Rice Production in Khulna District

(Source: Khulna Agricultural Extension Office, 2019)

Other main types of crops are also grown in Khulna Conurbation such as pulse, oilseeds, and vegetables. (**Figure 6.6**) shown a decreasing trend in production land. The area of oilseeds production increased from 1 hectare to 6 hectares during the time frame of 2007 to 2018. Similarly, the area of pulse production decreased from 157 hectares in 1996 to 67 hectares in 2018. But the increasing trend was shown in vegetable production area from 113 hectares to 165 hectares from 1996 to 2018.

Khulna Conurbation is also famous for the production of fruits such as jackfruit, banana, pineapple, guava, papaya, lime, lemon, etc. Though relevant data on the production of fruits were not available but their presences were noteworthy.

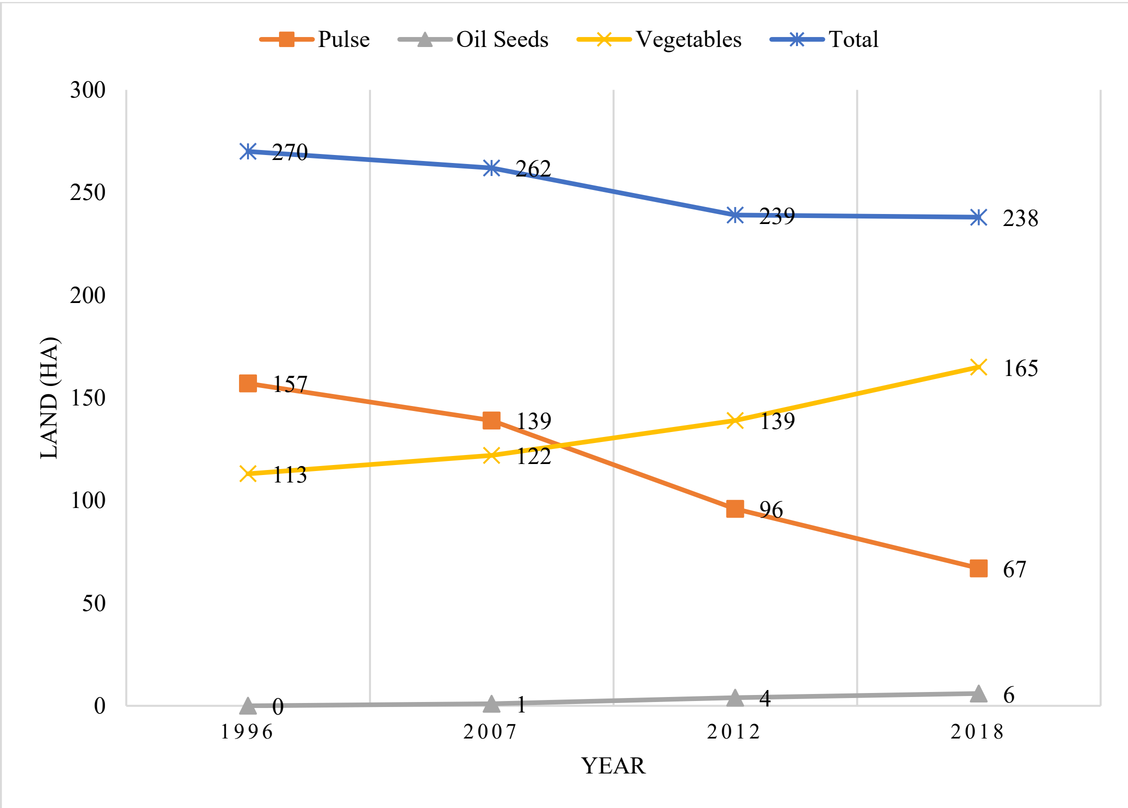


Figure 6.7 Temporal Changes of Other Crops in Khulna Conurbation

(Source: Khulna Agricultural Extension Office, 2019)

6.2.2 Impact of Land Use Changes on Livestock

The following figure showed the reduction of cows and goats in the study area. Continuous change in the use of land reduces the pasture land and availability of natural food. Although modern methods and technology are introduced, the cost is too expensive to raise livestock.

The growth in livestock population mainly occurred in the poultry sector as expected. This is largely due to a combined effect of the government's emphasis as well as actions of the non-governmental organizations (e.g., BRAC, CARE-Bangladesh) to promote commercial poultry rearing involving mainly women (Begum & Alam, 2014).

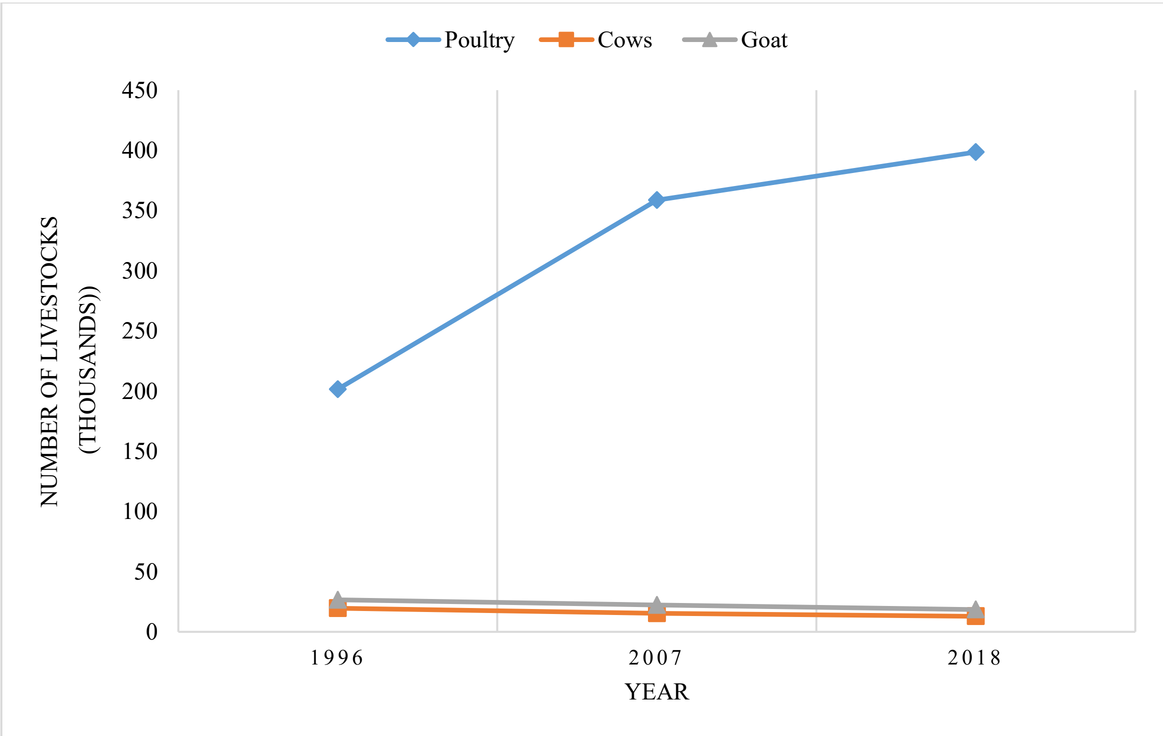


Figure 6.8 Temporal Changes of Livestock in Khulna Conurbation

(Source: Khulna District Livestock Office, 2019)

6.2.3 Land Use Change Impact on Fisheries

The fisheries of Khulna consist of inland open water fisheries and freshwater aquaculture. As there is a lack of historical data before 2000 in the Khulna District Fisheries Office, the data were used for this research from 2000 to 2018. The evidence showed that the production of captured and cultured fisheries in the Khulna district increased during this period. Khulna district has huge potential for freshwater aquaculture fisheries. The culture fisheries of the Khulna district include ponds, beels, canals, nurseries, and rice fields. Not only that the seasonal water bodies also act as a tremendous source of fisheries augmentation in the Khulna district (Kashem et al, 2017).

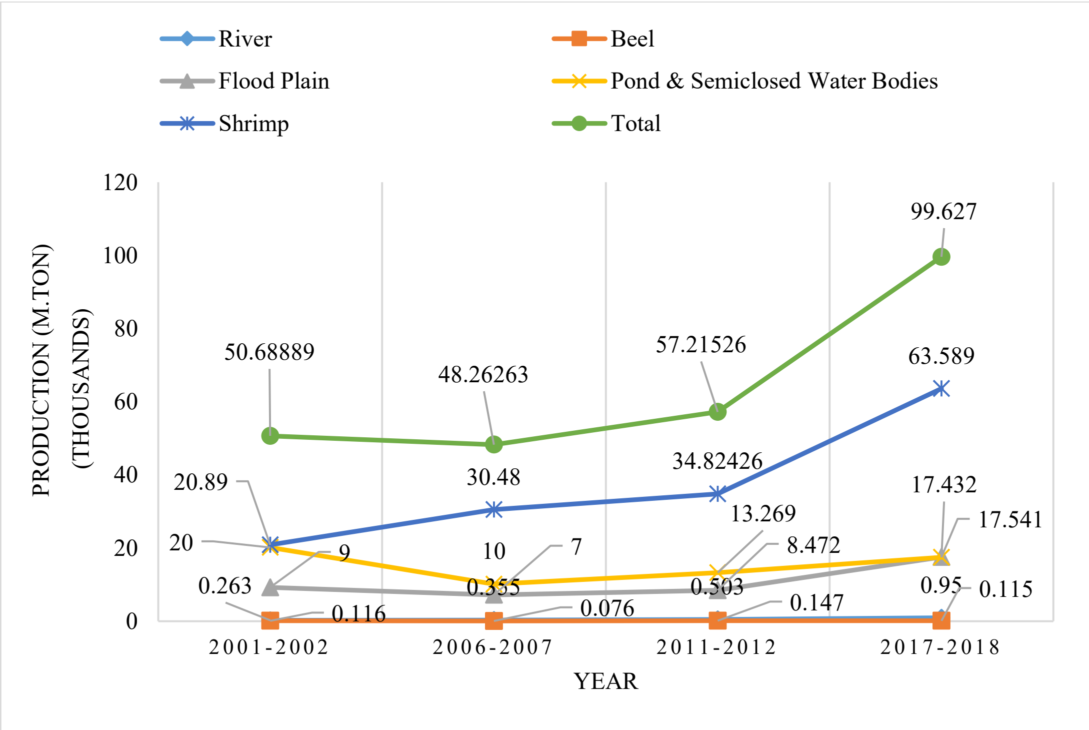


Figure 6.9 Temporal Change of Fisheries Production in Khulna District

(Source: District Fisheries Office)

But the condition is quite different in the Khulna Conurbation area in comparison to the other Upazillas in the Khulna district. Here the production of captured fisheries was reduced due to the degradation of wetland, municipal waste to the river, etc. **(Figures 6.9 & 6.10)** showed how the production area and production decreased during the last 10 years.

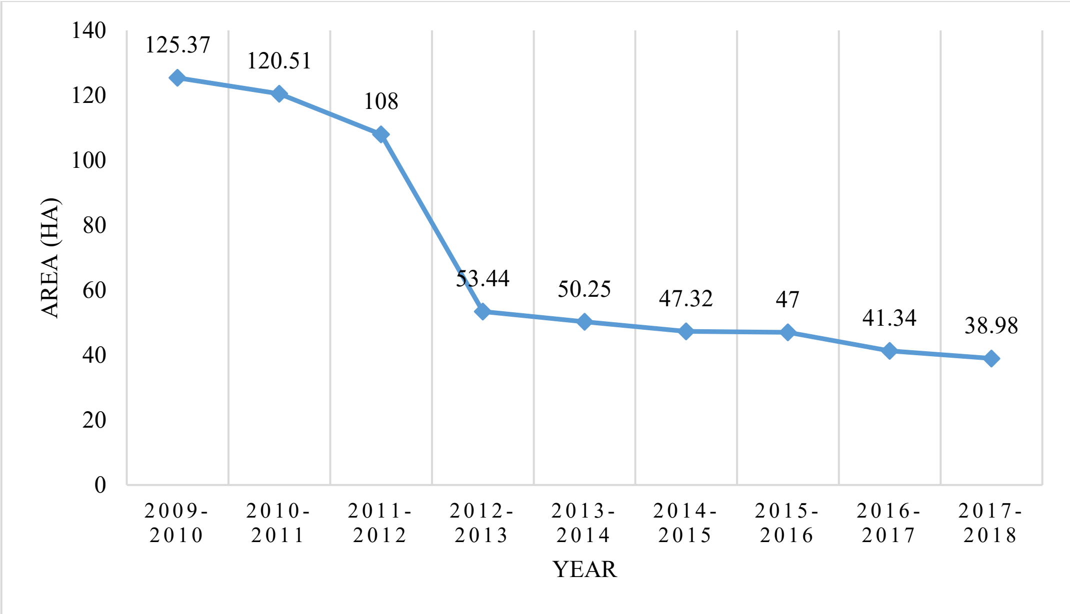


Figure 6.10 Temporal Change of Capture Fisheries Production Area in Khulna Conurbation

(Source: District Fisheries Office)

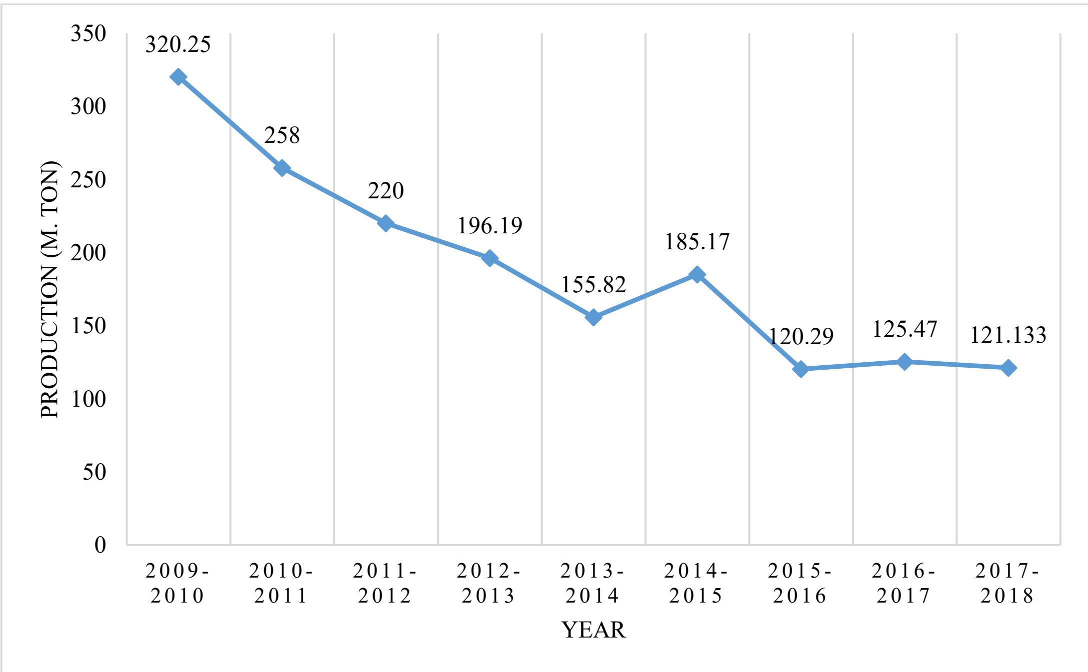


Figure 6.11 Temporal Change of Capture Fisheries Production in Khulna Conurbation (Source: District Fisheries Office)

On the other hand, the cultured fisheries are increased in this region. The following figure shows that production increased from 30 metric tons to 241 metric tons in the last 15 years. Assistance from local government and great employment opportunity have encouraged people to involve in cultured fishing (District Fisheries Office, 2018).

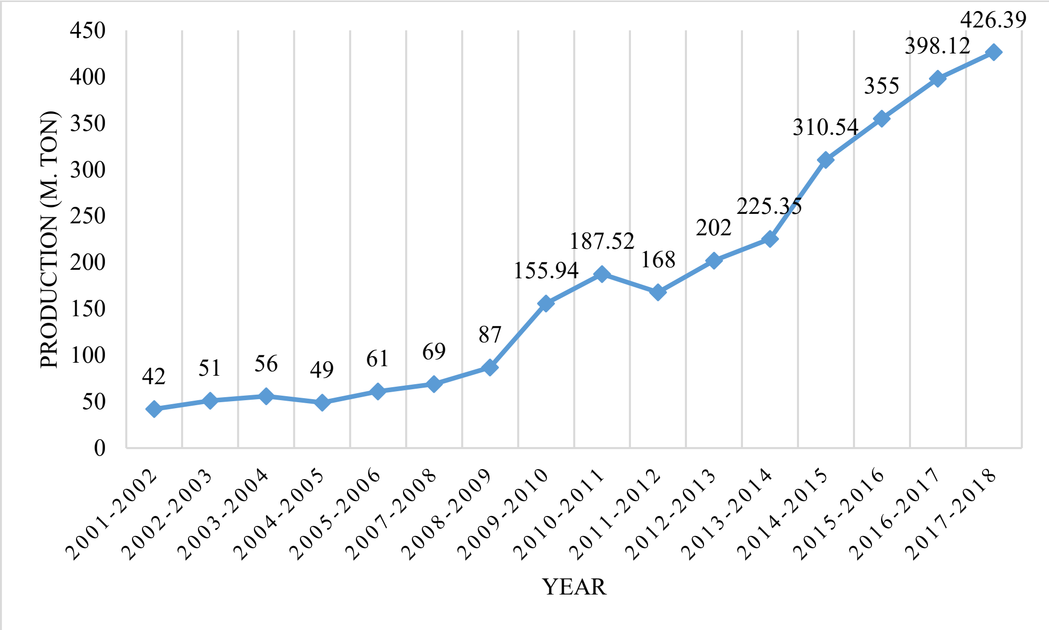


Figure 6.12 Temporal Change of Culture Fisheries Production in Khulna Conurbation (Source: District Fisheries Office)

6.3 Impact of Land Use Changes on Regulating Services

6.3.1 Impact of Land Use Changes on Natural Drainage

Khulna city is surrounded by two major rivers; Rupsha and Mayur and canals which are acted as freshwater resources, transport, and fishing ground of the city. Continuous encroachment by the land invader on the canal and adjacent Mayur River acts as an influential factor in deteriorating the natural drainage of Khulna city (KUET, 2016).

Figure 6.13 Canal Encroachment by Land Invader

Besides, the lack of poor garbage management, the people dump their waste into the nearby ponds, canals, and drains which makes the channel very narrow reduced the aesthetic beauty of the city. The existing narrow drainage fails to drain out the water runoff which results in waterlogging (Rabby et al, 2017).

Figure 6.14 Waste Disposal on Drain

(Source: Daily Star, 2017)

Figure 6.15 Waste Disposal on Canal

(Source: Daily Star, 2017)

The waterlogging problem is severe in ward nos. 1, 5, 6, 14, 15, 20, 21, 23, 27, and 30. Areas like Sonadanga**,** West Tutpara, Royal More, Shibbari, Goborchaka, TB Cross Road, Khalsihpur, Choto Boyra, Bania Khamar, Mia Para, etc. are vulnerable to waterlogging due to moderate to heavy rainfall. It is estimated that almost 30 square kilometers of the total area are liable to waterlogging after heavy rainfall (Rahman et al. 2009).

Figure 6.16 Water Logging In Royal More of Khulna City

(Source: Daily Star, 2017)

Figure 6.17 Water Logging at the KDA office of Khulna City

(Source: Daily Star, 2017)

The following figure showed the gradual change in the wetland area in Khulna city:

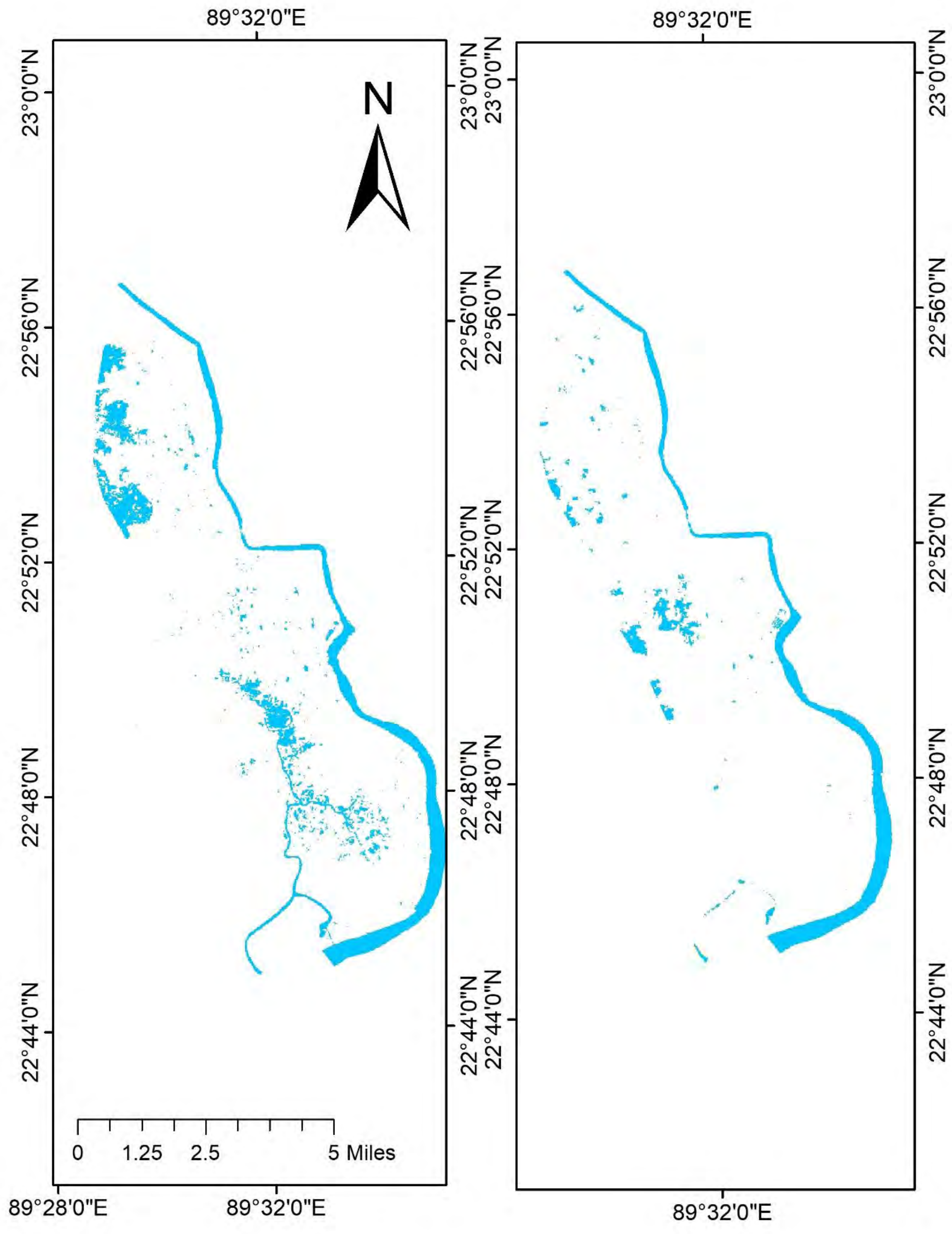


Figure 6.18 Wetland Changes from 1987 to 1996

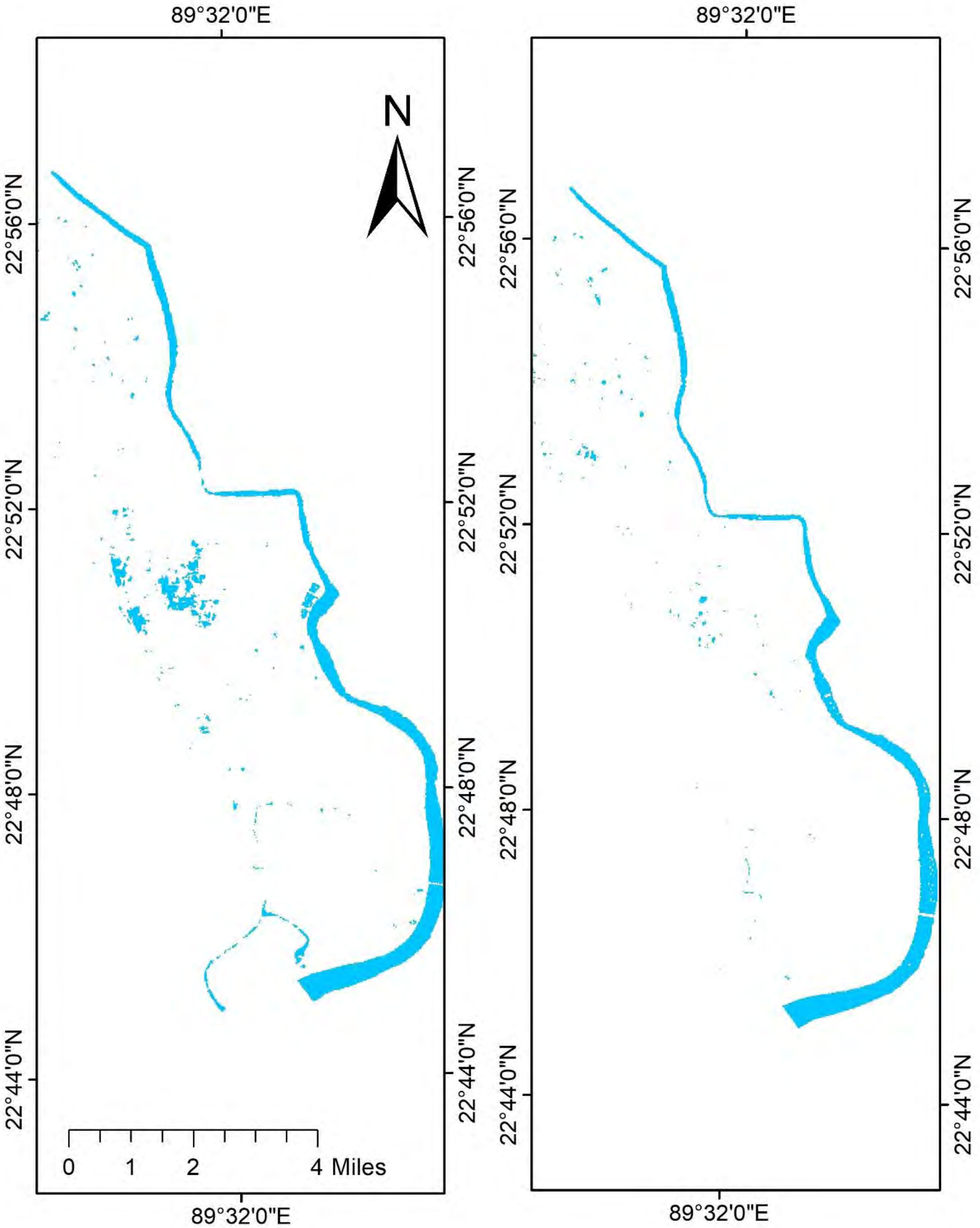


Figure 6.19 Wetland Changes from 2007 to 2018

Extracted data showed the massive change in wetland area from 940 ha to 172 ha and in rivers from 784 ha to 692 ha. The following table shows how the existing canal changed with time:

Table 6.1 Temporal Changes of Existing Canal of Khulna Conurbation

SI	Canal Name	Canal Area (acre)		
		2005	2010	2015
1	Arrongghata Khal	30.60	27.84	23.90
2	Khudiyar Khal	27.91	24.74	25.15
3	Deyana Chowdhury Khal	2.77	2.47	1.61
4	Bastuhara Khal	7.51	5.51	5.25
5	Duyani Khal	5.01	4.78	3.87
6	Baitkamari Khal	1.67	1.43	0.48
7	Taltala Khal	2.43	1.80	1.57
8	Kaderer Khal	10.36	9.08	10.36
9	Nirala Khal	24.64	22.85	18.32
10	Dubir Khal	6.49	6.25	5.31
11	Chori Chora Khal	3.98	3.14	2.01
12	Kholabaria Khal	8.05	4.34	3.47
13	Narikelbaria Khal	11.86	11.39	9.28
14	Harintana Khal	8.89	8.23	5.39
15	Motiakhali Khal	5.53	5.16	3.45
16	Suri Khal	0.82	0.88	0.40
17	Rahangeemari Khal	15.67	13.86	11.17
18	Koyla Tolar Khal	4.94	3.92	3.75
19	Lobonchora 1 No. Sluice Gate Khal	7.38	6.62	4.92
20	Lobonchora 2 No. Sluice Gate Khal	15.22	14.74	11.65
21	Kashembari Khal	23.69	18.41	20.39
22	Mathabhanga Khal	8.66	8.24	6.37

(Source: KUET, 2016)

6.3.2 Impact of Land Use Change on Ground Water Level

Five stations- KHS01 (Lobonchora), KHS05 (TB Boundary Road), KHS06 (Hajratola), KH013 (Khulna Shipyard), and KH023 (Batiaghata) in and adjacent to Khulna Conurbation were selected.

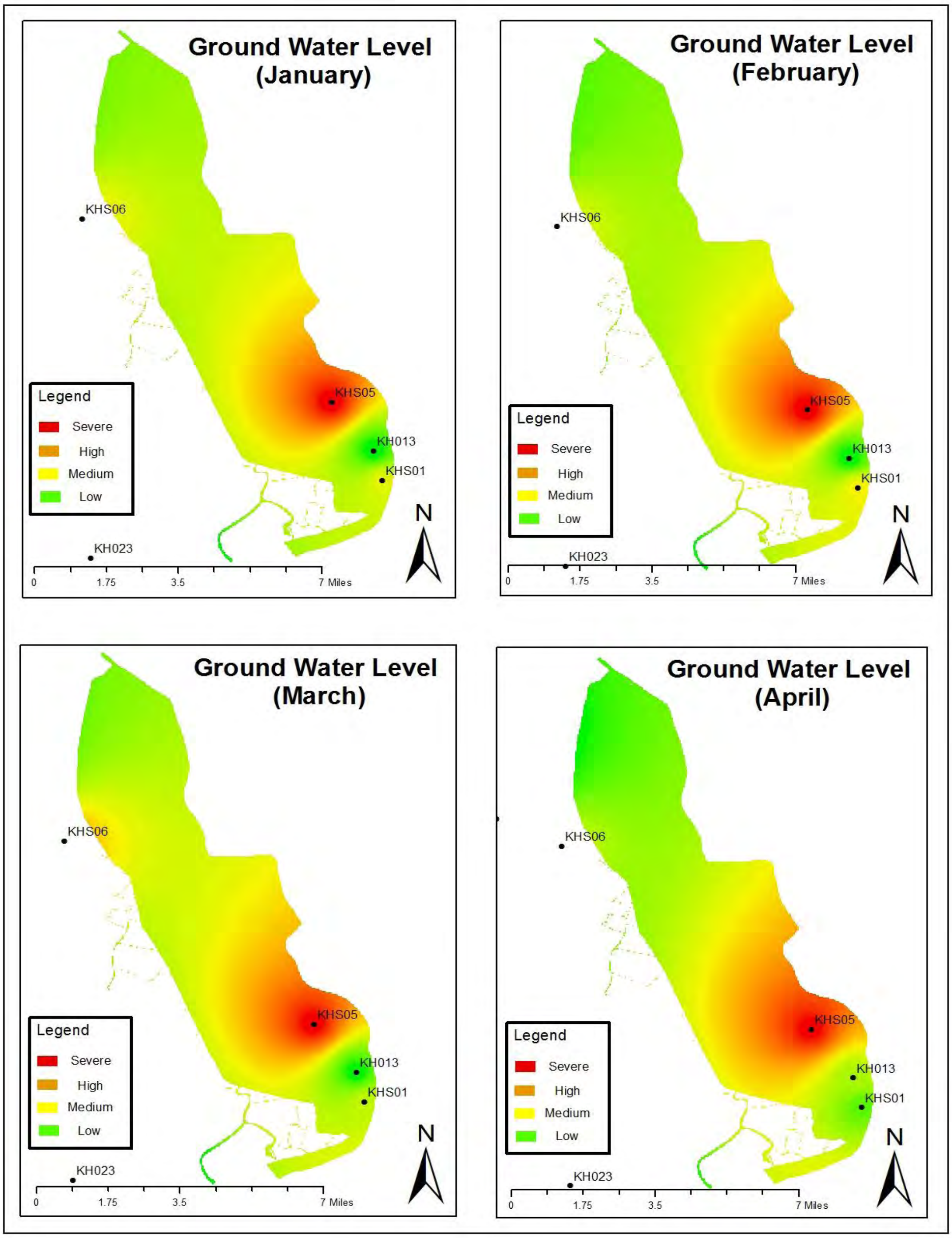


Figure 6.20 Impact of Land Use Change on Ground Water Level in Khulna Conurbation for the last 30 Years

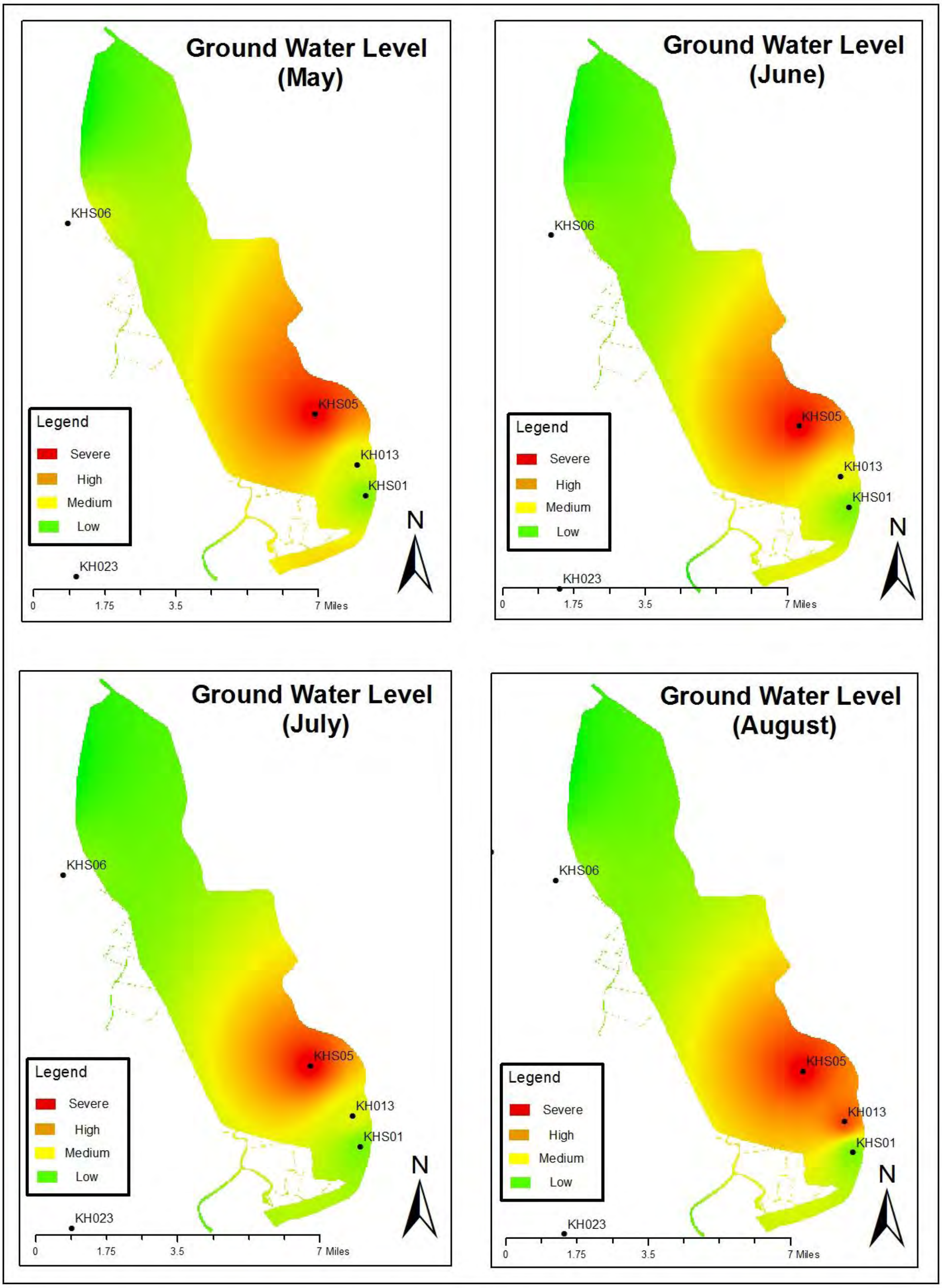


Figure 6.21 Impact of Land Use Change on Ground Water Level in Khulna Conurbation for the last 30 Years

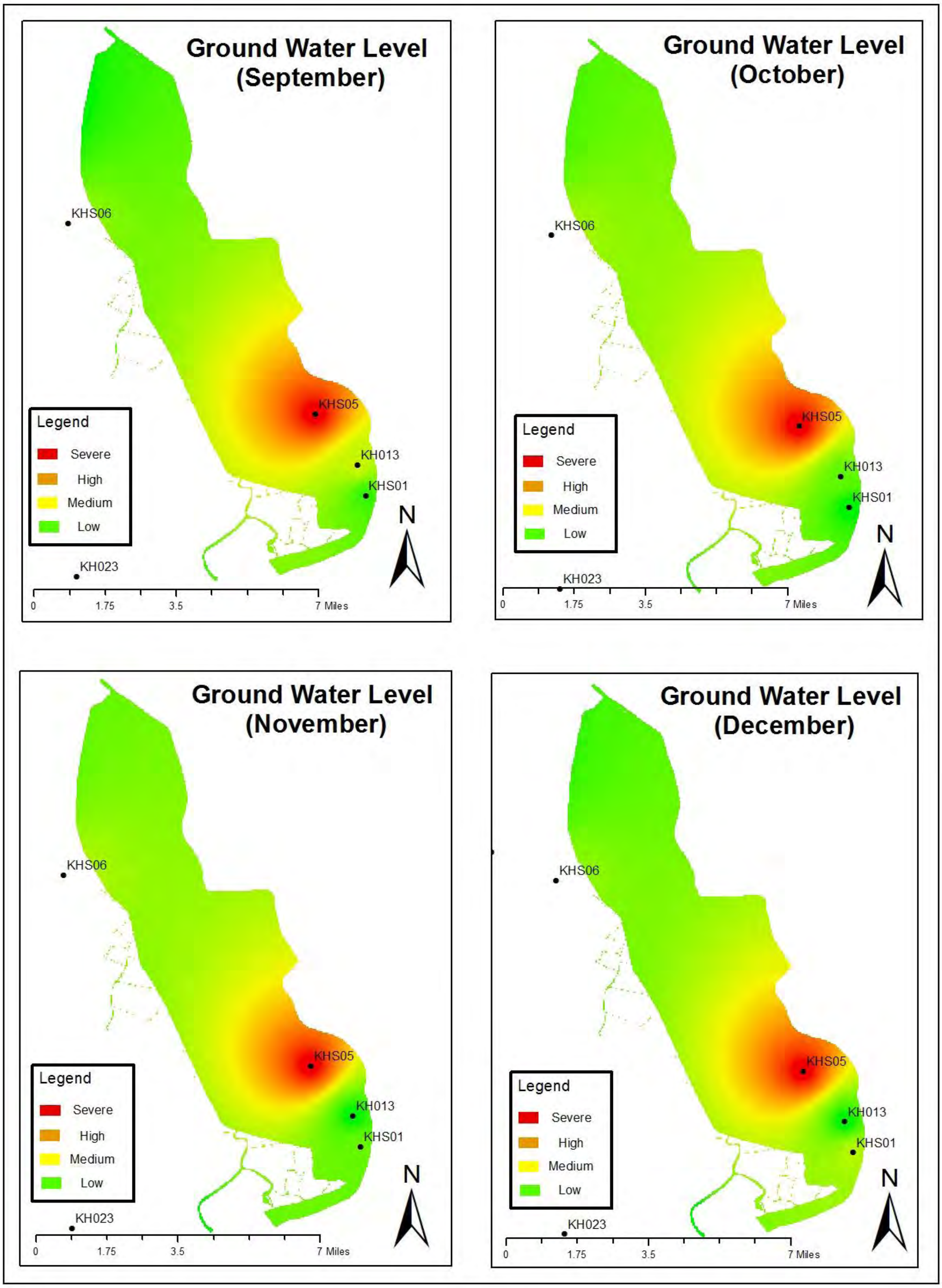


Figure 6.22 Impact of Land Use Change on Ground Water Level in Khulna Conurbation for the last 30 Years

(Figure 6.20, 6.21 & 6.22) displayed the temporal changes in the groundwater level of Khulna city. The results showed the severe impact of land-use changes in the south-western part of the city, especially in wards 19, 20, 21, 23, and 25 which are the hub of the city.

The primary reason is the rapid urbanization and high population growth. Over the last few decades, the urbanization rate increased by 28.49% and the population increased by 37% (Rouf & Jahan, 2014). As the population escalates continuously more land surface and natural water body is covered by urban development. The area became paved and reduce the absorption capacity of the soil.

6.4 Impact on Ecosystem Valuation

The impact of land-use changes on provisioning and regulating services have consequences on the valuation of ecosystem services. In this study, the ecosystem valuation was calculated by comparing the four land uses with the biomes proposed by Costanza et al. 1997 in their valuation method. Here, the 'cropland' biome was used for vegetation; the 'wetland' biome was used for water bodies; the 'river or lake' biome was used for river and the 'urban' for buildup area. **(Equation 4.1)** was used to determine individual ecosystem service from land use and its ecosystem service value coefficient. The following table showed the ecosystem value coefficients of selected land use categories:

Table 6.2 Land Use Categories Equivalents for Biomes and the Corresponding Ecosystem Value Coefficients

Land Use Type	Equivalent Biome	Ecosystem service coefficient (US$ ha−1 per year)
Vegetation	Cropland	5567
Build Up	Urban	6661
Water Bodies	Wetland	952
River	River or lake	12512

To determine the ecosystem service value, the value of the ecosystem service coefficient was multiplied by the area of existing land use categories which were obtained from land use analysis in ArcGIS software.

Table 6.3 Total Estimated Ecosystem Service Values (ESV in US$ × 10^6/Year) For Each Land Use Category and the Changes from 1987 to 2018

Land Use Type	**ESV (BDT × 10^6/year)**				**ESV (BDT × 10^6/year) Change**		
	1987	**1996**	**2007**	**2018**	**1996**	**2007**	**2018**
Vegetation	2736.52	2670.30	1900.6	1722.58	-66.22	-770	178.02
Build Up	768.84	1124.88	2228.26	2485.4	356.04	1103.38	257.14
Water Bodies	76.97	44.03	19.18	14.10	-33	-24.84	-5.07
River	843.66	753.36	751.64	743.90	-90.3	-1.72	-7.74

By utilizing the value coefficients and area of land use categories, the ecosystem services values of Khulna Conurbation in 1987, 1996, 2007, and 2018 were determined. The total ecosystem value for existing land use of Khulna Conurbation in 1987 was 442.6 crore **BDT,** 459.2 crore **BDT** in 1996, 490 crore **BDT** in 2007, and 496.6 crore **BDT** in 2018. From 1987 to 2018, the ecosystem service values for all land use categories were negative except for urban build-up. The largest amount of declination was observed in the case of vegetation which was about 101.4 crore **BDT.** Similarly, the ecosystem service value of water bodies and rivers also decreased during this period. On the contrary, the ecosystem services value of urban build-up increased during this period due to massive haphazard development in the study area which influenced the net ecosystem service value.

6.5 Land Use Change Impact on Livelihood

The livelihood of the local people is influenced by land-use change. Local people considered nonagricultural activities are more profitable than agricultural activities. As the population escalates, more land is consumed for the accommodation of the people. The agricultural land is decreasing day by day and so is the amount of production. Not only that, they do not consider agriculture a decent profession. For this reason, the farmers opt for the following nonagricultural professions:

Auto Rickshaw: In recent years, the number of Battery-operated rickshaws has increased in Khulna. People choose it because they consider it a more convenient and easier mode of income than agricultural work. According to the concerned, the number of registered rickshaws in KCC city is 17,000 (KCC, 2018).

Easy Bike: Easy bike is another popular mode of transportation because of less fair and it covers the highest coverage of area than any other mode of public transport.

Saw Mills: The number of sawmills is increasing day by day in Khulna Conurbation. There are 9 sawmills all over Khulna Conurbation. The mills are running throughout the year and offer regular earnings. On the other hand, farming is seasonal and has to depend on nature mostly for its crops.

Shop: Shopkeeping is another source of non-agricultural earning sources. It saves labor and time. There are several types of shops such as grocery shops, tea stalls, Flexi load, cylinder gas, etc. Even less educated people or the farmer can run and manage the business with the help of their family members.

Poultry Farm: Poultry farming is very common in the inner part of the city. Young and the women are engaged in poultry farming. Different Government organizations and Local NGOs are trained to increase their skills and abilities.

CHAPTER SEVEN

CONCLUSION & RECOMMENDATION

7.1 Conclusion

Khulna is a newly developed city and also has great economic importance and is facing many anthropogenic activities. This study revealed the land use changes and their impact on ecosystem services and values of Khulna Conurbation.

- The present study showed that in Khulna Conurbation the build-up area increased at the expense of vegetation land, water bodies, and rivers.
- The vegetation area decreased from 5716 ha to 3597 ha during the period 1987 to 2018. Overall 37% of vegetation area was removed within 31 years.
- The Build-up area increased by 223% from 1987 to 2018 due to rapid development in the city, especially in the north-western and middle parts of the city.
- Water Bodies decreased by 82% from 1987 to 2018 because of encroachment, urban development, waste disposal, etc. The river area is also decreased during the period 1987 to 2018 from 784 ha to 692 ha (11.7%)

This type of land-use change has a great impact on ecosystem services and values which are given as below:

- A total of 788 ha of agricultural land was lost in Khulna Conurbation within 22 years but the production was increased because of the use of hybrid seeds, insecticides, pesticides, etc.
- Due to the reduction of pasture land, the number of cows, and goats decreased. On the other hand, the involvement of the Government and other NGOs increased the growth of the poultry sector.
- Almost 200 metric tons of production of capture fisheries were reduced because of the wetland degradation. At that time the production of culture fisheries increased from 155.94 metric tons to 426.39 metric tons.

- Land use change had an impact on the natural drainage system of Khulna Conurbation which resulted in severe water logging problems in wards nos: 1, 5, 6, 14, 15, 20, 21, 23, 27, and 30.

- Due to the rapid urbanization and high population growth rate, the few wards of the city faced serious groundwater depletion.

- The ecosystem service value reduced ecosystem services of some of the existing land uses such as vegetation, water bodies, and rivers.

- Different non-agricultural activities such as easy bike and auto-rickshaw pullers, shopkeepers, saw millers, poultry farmers, and other private entrepreneurship were increased in this area.

7.2 Recommendations

- As there were no previous studies of ecosystem services and valuation in Khulna Conurbation, there is a great opportunity to conduct more studies of the nearby regions and make a comparison among the regions.

- The present study has determined the four types of land uses and their ecosystem value. In future studies, more types of land use and its ecosystem services can be added.

- The development authority and the policymakers should take the development of old Khulna city as a lesson learning and should consider different urban planning techniques and principles for the further development of the city and follow different conservation acts regarding the environment and ecosystem for the enhancement of the ecosystem services.

- Because of the climate change variation, Khulna Conurbation may face some natural disaster-induced problems such as salinity intrusion, and further degradation of agricultural land and production. Necessary steps like designing a proper coastal zoning system, planning a cropping pattern of the area by analyzing the seasonal salinity situation, and searching for an appropriate land-use system through GIS analysis should be taken to avoid future disaster-related problems.

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