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Frequent Change of Land-Use Pattern and Its Effect on Ecology and Ecosystem in the South-West Coastal Area of Bangladesh

Krishna Rani Barai

Abstract

The ecosystem of the South-West coastal area of Bangladesh is resourceful and unique. Regrettably, this distinctive area is vulnerable to numerous climatic factors, for instance, sea water intrusion, temperature variation, unpredictable behavior of rainfall, and frequent occurrence of cyclones and drought. Undesirably, the effects of those climatic factors have been enhancing on account of human behavior, one of which is the frequent change of land-use pattern in this area. The land-use pattern of the coastal Bangladesh has been changed continuously over the last 60 years in order to increase the agricultural production for improvement of livelihood. The unrealistic improvement projects (coastal embankment project, increased unscientific shrimp cultivation, and so on) brought the unforeseen disaster in the area. As a result, the salinity level of the area has been increased considerably, resulting in decreased production of different kind of crops and vegetables. Unstable economy and the emergence of calamities, leading to damage to ecology and ecosystem, made livelihood insecure in the area.

Keywords: land-use change, salinity, shrimp farming, coastal area, ecology, ecosystem

1. Introduction

Land degradation is an urgent environmental issue in many countries. Frequent changes in land-use pattern and soil salinity have contributed to land degradation in the coastal area of Bangladesh. This chapter is intended to unfold the scenario of land-use pattern changed over a long period in the South-West coastal area of Bangladesh and how it influenced the soil salinity by practicing shrimp farming. In addition, this chapter describes the ecological and socioeconomic conditions of the area in response to those changes. Furthermore, it includes some policy recommendations and management approaches to maintain productive agriculture in the area.

2. Land use and land cover (LULC)

Land-use refers to how people are using the land, for example, settlement, agriculture, mining, etc., whereas land cover refers to the surface cover on the ground,

such as forest, vegetation, open water, bare soil, etc. Land-use includes the management and modification of natural environment or wilderness into manufactured environment, for example, settlements and seminatural habitats like productive fields, pastures, and managed woods.

3. LULC change (LULCC)

Land-use and land cover change (LULCC) is the conversion of different types of land-use and is the result of complex interactions between humans and the physical environment. LULCC might be a major driver of global alteration and has a considerable impact on ecosystem processes, biological cycles, and biodiversity.

4. Importance of coastal Bangladesh

4.1 The coast of Bangladesh

Bangladesh coast consists of 19 districts which cover 32% of the total area of the country [1]. The population in the coastal area is expected to increase from 36.8 million in 2001 to 60.8 million by 2050 [2]. This coastal belt has miscellaneous natural resources counting the largest mangrove forest in the world (Sundarbans), salt, coastal fisheries, and other minerals. Additionally, this part of the country has a high exploration prospective for both onshore and offshore natural gas [3]. The resourceful ecosystems of this coastal area maintain the livelihoods of the local communities. Moreover, this region has the potential for tourism, ports, and other developments [4]. But this region is highly exposed to various climatic factors, such as temperature fluctuation, erratic behavior of rainfall, increased frequency of cyclones, drought, and saltwater intrusion [5].

4.2 Agriculture in the coastal area of Bangladesh

Agriculture is the major sector in the economy of Bangladesh, and over 30% of the net cultivable land is in the coastal area [6]. In the past, people were interested to cultivate not only local varieties that are saline tolerant but also other varieties with greater plant height and comparatively low production cost and are tasty and above all easily manageable. The local rice varieties are categorized into two types, one for planting in the freshwater shrimp farms and another for other agricultural lands. *Jotabalam* and *ghunshi* varieties are selected to be cultivated in the shrimp farms. On the other hand, *ashfall* and *benapol* varieties are designed for planting in other agricultural lands.

5. Salinity issue

Soil salinity is one of the most common causes of soil degradation, which is getting worse day by day [7]. Usually soil salinity refers to surface or near-surface salt accumulation [8]. It is defined as the concentration of dissolved salts, mainly chlorides and sulfates, in soil or water [9]. It is practically expressed as practical salinity unit (PSU) which depends on the water temperature and conductivity [10]. It is also expressed as ppt (parts per thousand). The characterization of soil salinity is normally done by spectrometer through measuring the electric conductivity (EC) in a saturated soil paste or in aqueous extracts with different soil/water ratios [11].

5.1 Soil salinity situation in the coast of Bangladesh

Out of 2.85 million hectares of the coastal and offshore lands, about 1.05 million hectares of arable lands are affected by varying degrees of salinity [6]. From another study, it is found that the salinity-affected area has increased from 8330 km^2 in 1973 to 10,560 km^2 in 2009, of which about 4530 km^2 is affected by a higher level of salinity (more than 8 dS/m), indicating 43% of the total salt-affected areas are facing challenges for agricultural practices even with salt-tolerant rice varieties [12]. Huge economic loss, damage to rice crops, and difficulties in drinking water supply systems in many villages of the coastal districts are the common problems caused by salinity [5].

Salinity is one of the most significant problems in the South-West coastal belt which is denoted as a food-deficit area of Bangladesh. Both the diversity of food and the net food production have declined significantly over the last decades [13]. It is reported that the worst salinity conditions are found in Khulna, Bagerhat, Satkhira, and Patuakhali districts [12]. Around 70% of the land in Barisal and Khulna divisions was affected by different degrees of salinity [14].

5.2 Major causes of salinity in the coastal area

Generally salinity can develop naturally (primary salinity), but human interference accelerated the movement of salts into rivers and onto land (secondary salinity). The spatial inconsistency of soil salinity over the landscape is highly sensitive and controlled by a variety of factors: soil factors (parent material, permeability, depth of water table, groundwater quality, and topography), management factors (irrigation and drainage), and climatic factors (rainfall, temperature, and humidity) [15]. Hence it is difficult to assess human interference on land salinity separately as it is highly integrated with environmental complexity [16].

Secondary salinity is mostly related to inequitable exploitation of natural resources, global climate change, and land-use changes, such as overgrazing and excessive utilization of land and water resources [17]. Land-use changes disturb hydrologic conditions which in turn alter the land salinity pattern of the area [18]. Thus poor land and water management system in irrigated farmlands leads to secondary salinity worldwide [19].

Bangladesh is one of the most vulnerable countries in salinity issue. The major causes of saline intrusion in water and soil include cyclone and storm surge, sea level rise, and shrimp farming practices [5]. Thus, shrimp farming is one of the major causes of secondary salinity in Bangladesh.

6. How shrimp farming influences the economy and LULC in the coastal Bangladesh

Shrimp industry is mostly concentrated in tropical developing countries making shrimps as a major export item for the Western countries [20]. This industry has experienced amazing growth over the last decades [13]. In the Asia-Pacific region, it is one of the highest growing economic activities [21].

Shrimp farming plays an important tool for poverty reduction and livelihood improvement for some households, but it has an adverse impact on coastal environment [22, 23], particularly in Southeast Asia. Two major environmental impacts of shrimp culture are the consumption of resources and the subsequent release of wastes into the environment [24, 25]. Other impacts include reduced water flow, soil salinization, diminution and salinization of ground- and surface water, depletion of wild fish and shrimp populations, extinction of wild vegetation, and biological pollution of native shrimp stocks [20, 22, 23]. The topsoil (0–20 cm) of

the shrimp ponds are mostly affected by salinity, and it is decreasing further inland [26]. In Asia, shrimp farming has been far away from success as the industry claims, especially when environmental costs are internalized [27].

Shrimp is denoted as the "golden price" in Bangladesh, because of its valuation in the international market. Shrimp production got the position as the second largest export business in Bangladesh by earning US$456 million in 2006 [28]. The fisheries' part, together with shrimp, contributes about 6% of the GDP and 5% of the national export earnings, with shrimp alone contributing about 93% of the sectoral export earnings [29]. This enlighten why the coastal areas were declared as a "free zone" for shrimp cultivation in 1994 by the Bangladesh government [30]. Subsequently, shrimp cultivation extended noticeably. In favor of example, shrimp was cultivated on 39% of the land of the Shyamnagar *Upazila* (subdistrict) of Satkhira District in 2002. It had enlarged to 57 and 62% by 2007 and 2011, respectively [13]. It is also reported in a recent analysis that 83% of the paddy field of 1988 was converted to different other land-use type in 2017, of which 23% is converted to water bodies [31].

7. LULC situation in the South-West coastal area of Bangladesh

7.1 Land and land-use pattern in Bangladesh

Land is the basic natural resource that provides not only the habitat and nourishment for living organisms but also a major focus of economic and livelihood activities. With the increasing population, land is being converted from agricultural purposes to other uses (such as housing, roads, and urban development), and this trend is expected to continue. Around 220 ha of arable land are converted to industrial establishment, house, road construction, etc. every day [32]. Between 1973 and 2000, at least 86,000 ha of land were lost into river/estuarine erosion though this is compensated by land generated through accretion [33].

The Bangladesh Bureau of Statistics regularly publishes land-use pattern where importance is mainly focused on agriculture. Here, land-use system is usually determined by physiography, climate, and land height in relation to water level [34]. All these together make a highly complex environment characterized by five main land types: net cropped area, current fallow, current waste, forest, and area not available for cultivation. Besides this, the Soil Resources Development Institute (SRDI), Bangladesh, produces agricultural land-use maps for the country identifying many different types of agricultural land-use. An indicative land zoning consisting of the following eight zones was recommended by PDO-ICZMP [35]:

1. Agricultural zone

2. Shrimp (brackish-water) zone

3. Shrimp (sweet-water) zone

4. Salt-shrimp zone

5. Forest zone

6. Mangrove (including Sundarbans) zone

7. Urban and commercial zone (industrial, port, export-processing zones, and ship breaking yards)

8. Tourism zone

7.2 How the LULC changes occurred in the coastal area of Bangladesh

Over the last 60 years, the land-use pattern of the coastal Bangladesh has changed repeatedly. In agricultural sector, rice was the main crop in the area, in the 1950s, [6]. However, rice production decreased regularly, because of tidal flooding and rising salinity [36]. With the help of the World Bank and other funding bodies, the Coastal Embankment Project was established between 1960 and 1980 to increase rice production in the coastal areas [37]. Regrettably, this project formed harmful impacts on the ecosystems of the area. Even though rice production increased immediately after the construction of embankments, the production had dropped another time by the 1990s. The major reason behind this decreased production was the congestion throughout the drainage system in the land area behind the embankments due to poor maintenance and inadequate management [38]. Consequently, the rice cultivators changed their livelihood to shrimp (black tiger) cultivation. This change of land-use again smashed the ecosystems of the area, as paddy fields and several parts of the mangrove forest were transformed to shrimp farm [39]. Therefore, the salinity of the area increased noticeably because of the enlarged shrimp cultivation. This change had an adverse effect on crop production as well as local vegetation, fish, and plant diversity over the last decade in the area [13].

Moreover, 30-year satellite data demonstrates that paddy field was the foremost category (37%) in the 1980s, which is continuously decreased to 9% in 2017. On the contrary, water bodies were the least dominant category in the 1980s (17%), but they constantly enlarged to be a dominant category in 2017 (34%) (**Figure 1**). There is another interesting finding from that research, where each of the LULC categories of 2017 was again split to perceive the land-use type in the 1980s. Thirty four percent of the water bodies in 2017 were water bodies in 1988, 26% water bodies of 2017 were directly transformed from paddy fields, and 40% were indirectly transformed through homestead gardens and settlements/bare land [31]. Therefore,
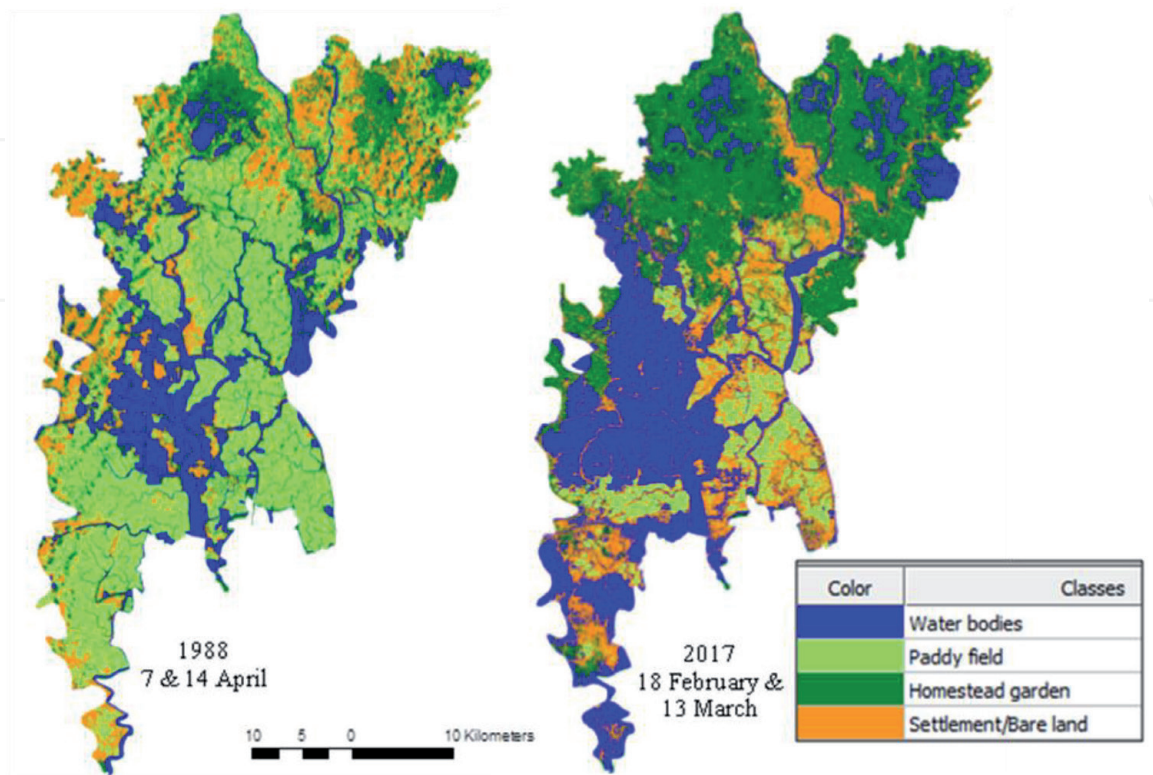
Figure 1.
LULC classification map of Khulna District in 1988 and 2017 (source: [31]).

it is evident that the LULC is changed frequently in the coastal area of Bangladesh, which has a direct effect on the ecology and ecosystem.

7.3 Causes and effects of the LULC changes

There are many reasons of the frequent changes of LULC in the coastal Bangladesh. Two of those are:

1. **Increasing salinity level:** the reason behind increasing salinity level are:

   - The presence of the Bay of Bengal.

   - Lack of proper management of agricultural land and irrigation system

   - Lack of proper management and dredging of river reduce the current of the river, which in turn increases seawater intrusion both in surface water and groundwater gradually. As a result, salinity covers more area progressively.

   - Moreover, soil porosity is reducing in this area. Therefore, groundwater infiltration is lowering, which increases waterlogging in the area. As a result, both the soil and water salinity is increasing continuously. Three major reasons reducing soil porosity are:

     i. The use of huge amount of polythene

     ii. Shrimp cultivation: sometime shrimp cultivators are using salt in the shrimp cultivation pond to avoid some virus and other diseases. This salt creates an invisible layer in the soil.

     iii. Some projects like tree plantation (eucalyptus tree, etc.). Leaves of those trees are not easily decomposable, which create a layer in the soil. Consequently, the porosity is reducing.

2. **Decreasing agricultural production:** agricultural production is decreasing because of two major reasons:

   - Due to poor management of the embankment and sluice gate that was built in the 1960s to the 1980s.

   - Some paddy fields were converted to shrimp cultivation ponds [31]. As a result, the salinity level of the surrounding paddy field of the shrimp cultivation pond increased, which lead to reduced agricultural production.

Frequent changes of LULC have a long-term effect on the paddy field and other vegetation, reducing productivity, biodiversity, and wild varieties.

7.4 How the ecological and socioeconomic condition of the area responded to those changes

LULC in the coastal area of Bangladesh had been changed frequently since the 1960s. The major agricultural conversions were rice to shrimp and shrimp to rice cultivation. Even though both rice and shrimp cultivation create vital

contributions to the GDP of Bangladesh, unregulated shrimp cultivation has had adverse ecological impacts in the area. Shrimp cultivated area like Tildanga *Union* of Dacope *Upazila* in Khulna District lost the ecological balance. Agricultural production along with trees and other vegetation had noticeably declined in the area. Furthermore, both the domestic and wild animals were reduced considerably [31]. This ecological imbalance has a direct and indirect effect on the mass economy and community health of the area. The circumstances are getting worse day by day.

On the contrary, Kamarkhola is a *union* with a similar situation as Tildanga. Therefore, most of the shrimp farmers changed their major livelihood to rice cultivation as both the ecology and economy of the area were destroyed visibly. As a result of shifting occupation, the ecology and the economy of the area got balanced within 10 years. Additionally, the sources of income are more diversified in Kamarkhola, at present, which may decrease the risk of livelihood [31].

8. Policy recommendation and management approaches

There are some recommendations:

1. Designing a proper and scientific coastal zoning system. This will be ecologically and economically feasible to get optimum production to meet the country needs.

2. Formulating a typology for each zone explaining its characteristics in detail.

3. Planning a cropping pattern of the area by analyzing the seasonal salinity situation for the betterment of the production, because soil salinity varies considerably in each season.

4. Searching an appropriate land-use system in the coastal area through the technical support of RS-GIS.

9. Conclusions

Naturally, LULC will change over the time for the seek of development. If LULC is altered totally and frequently, it will damage the ecology and ecosystem of the area. Consequently, the nature will be imbalanced, causing disaster for the area. Therefore, we should use the technology to design the proper land-use pattern considering the natural value of that area rather than going against the nature. Accordingly, both the nature and human being will get benefited from this technology-based planning, and thus, the development will be sustainable.

Author details

Krishna Rani Barai
LoCOS - Loving Care for the Oppressed Society, Batiaghata, Khulna, Bangladesh

*Address all correspondence to: krish_051002@yahoo.com

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