IDENTIFYING THE CAUSES OF WATER LOGGING THROUGH GEO-SPATIAL TECHNIQUES IN CHUNDIA RIVER BASIN, WEST BENGAL

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Abstract:

The Chundia river basin of Purba and Paschim Medinipur district of West Bengal, experiences intensive water logging problem during rainy season that leads to transformation of land use from agriculture to fishery. The objective of the present study is to identifying the various reasons of water logging at lower part of the basin. Natural causes of logging are analysed using different map, standard statistical techniques and geospatial tools. After the study, noticed that at previous scenario water logging is the result of the physical condition of the study area. But at presently, the water logging is increased due to anthropogenic activities in basin area. Prepared land use and land cover map of dry and rainy season of the year 2005 and 2015 based on Google earth quick bird satellite imagery with the help of Arc-GIS (10.1) software shows that agricultural land is reduced by 1049.07 hectare and 1683.14 hectare and fisheries or shallow water bodies are increased by 971.93 hectare and 1606.00 hectare in dry and rainy season respectively during this time period. Introspection on the causes of water logging shows that length of the embankment is increased by 24.92 Km during 2005-15 for the sake of fishery, that again leads to further water logging. Loss of productivity due to continuous water logging, in turns, leads to land use conversion.

Keywords: *Water logging, Land use change, Google Earth, Fishery, Embankment.*

1 Introduction

Water logging considered as an environmental problem that damages the physical condition and opposes the socio-economic development of a particular area (Hassan and Mahmud-ul-islam 2014). It refers that saturation of soil by water or higher availability of moisture in the soil and resulting restriction of the natural air circulation in the soil. On the other hand, water logging means a blocked condition of water on the surface in low lying area (Holden et al. 2009) that is controlled by physiography, geology, climate, soil and irrigation system of the watershed. It is mostly observed throughout India such as West Bengal, Punjab, Uttar Pradesh, Haryana, Andhra Pradesh and so forth that take into account as a Local to Global Issue (Bastawesy and Ali 2013). Water logging is the result of flat and rough levelling of the surface that made by less percolating sandy clay loam soil, (Idah et al. 2009); high level of ground water, over and intensive irrigation, seepage of water from surrounding area, seepage from reservoirs and canals, absence of natural drainage, insufficient surface drainage, heavy rainfall and uneven and plane topography (Dinka and Ndambuki 2014). Damages of Paddy cultivation during rainy season is a common scenario in low lying area that leads to conversion of the land use and land cover.

Land use of an area is largely depends on water availability and drainage system of the particular area (De and Jana 1997). In developing countries, land use and land cover change is very dynamic in nature (Koch et al. 2012; Abera et al. 2018) and continuous process mostly found in river basin area because of fertile soil, favourable environment for agriculture and irrigation facilities (Mango et al. 2011). Pattern and way of land use and land cover change is differing from one place to another place and decade to decade depending on surrounding environment. In earlier period, The changing patterns are forest land, grass land and shrubs land to cultivated land (Koch et al. 2012; Parsa et al. 2016) and forest land to agricultural land and built up area (Daamean et al. 2003; Mango et al. 2011). At present scenario, land use and land cover change means Decreased of natural forest, water bodies (lakes, reservoirs, ponds and stream) and waste land and increased of agricultural land and built up area (such as settlement, road and tourist place) (Prakasam 2010). In developed country, found that the conversion of the land from agricultural, range land and forest land to water bodies, mining area and urban area due to rapid growth and high density of population and demand of the local people (Hernandez et al. 2012). Land use and its changes is also guided by distance from road network, distance from town, distance from water, wish of the land tenure or owner, elevation of the area, and accessibility and availability of water in the local scale (Serneels and Lambin 2001). Land use land cover changes of an area are well identified by using the remote sensing techniques and GIS tools (Gidey et al. 2017; Meshesha et al. 2016) that is an easy accessible method to us for LULC transformation analysis.

Part of Keleghai river basin which extended over Purba Medinipur district faced water logging problem in seasonally (Sahu 2014a). Moyna Block which falling in Chundia river basin area faced the same problem, due to low lying area, low elevation, negative slope, huge amount of rainfall in a short time, high level of ground water, discursive construction of canal and Embankment (Sahu 2014a; sahu 2014b) and rising of ground water level (Chowdary et al. 2008). Agricultural production of the area is totally ruined in rainy season that Forced to change the land use pattern from agriculture to fishery (Sahu 2014b) and temptation is another important factor behind the permanent land use change. So, construction of embankments on the agriculture field is increased day-to-day for conservation of the rain water for fishing cultivation throughout the year. My present research work focused on the impacts of present human activities on the water logging that leads to further transformation of land, agriculture to fishery in Chundia river basin area.

2 Study area

The Chundia river is a tributary of the Keleghai river. The basin is located in the interfluves of the keleghai and kongsabati river which is a lower plain land and water logging affected area. The study area covers 371.11 sq km of two Medinipur district of West Bengal and spreads over Moyna and panskura-I block of Purba Medinipur district and Pingla, Sabang, Debra and Kharagpur-II block of Paschim Medinipur district (Fig. 1). Latitudinal and longitudinal extension of the area is 22^{0}10'00" N to 22^{0}23'27" N and 87^{0}26'03" E to 87^{0}47'34" E respectively.

The study area characterised by alluvial low land of the quaternary to upper tertiary period that constructed during Holocene age (Mukherjee et al. 2009) under the formation of flood plain deposition as a physiographic division of the Bengal basin. The average annual rainfall is 1500 mm (Sahu 2009), and 80-85% of total rainfall is occurred during June to October month. Average ground water level is 3-15 m below the surface and concentration of silt and clayey particles in soil is higher. Throughout the historical past, economic activity of water logged area was mainly based on agriculture, fishing and salt manufacturing. But, at present salt manufacturing activity is abolished and other two activities are keep up their significance.

3 Materials and method

The secondary data has been collected from different sources and followed a systematic methodology for the fulfilment of the research objective. Topographical sheets 73N/7, 73N/11, 73N/12, 73N/15 and 73N/16 (scale- 1:50,000; year of 1971) have been collected from Survey of India (SOI), Kolkata as a basic documents of the study area. ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) DEM (Digital Elevation Model) has been downloaded from the website of United States Geological Survey (https://earthexplorer.usgs.gov) and prepared the contour and elevation map of the study area using Arc-GIS (10.1) software for knowing the characteristics of relief, elevation and Shape of the water logging area.

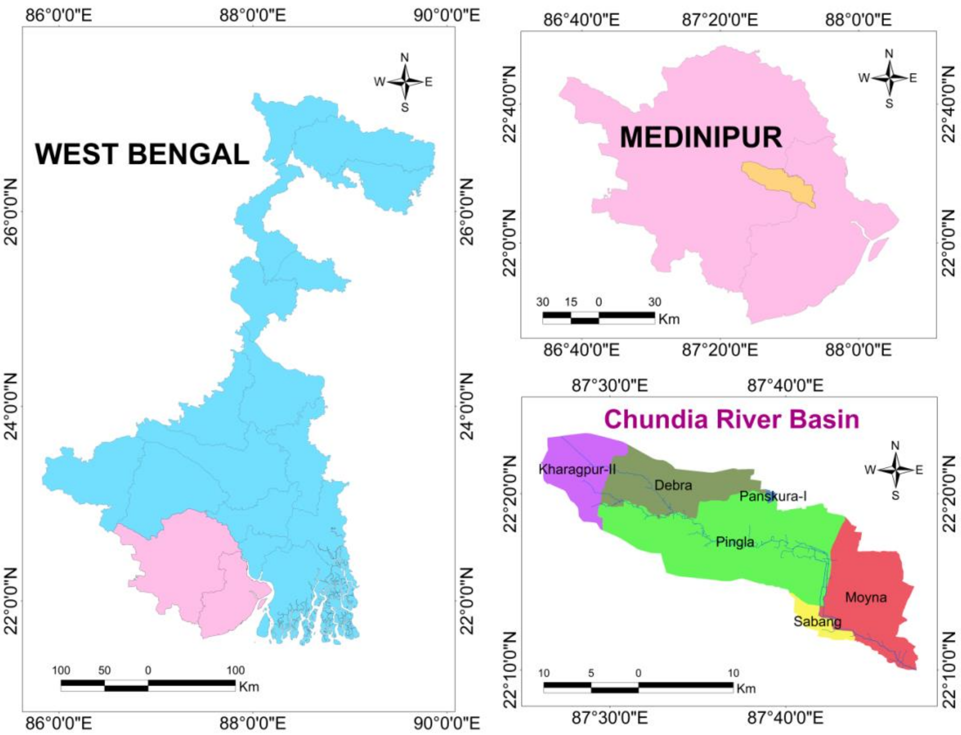


Fig. 1 The study area

Drainage density and embankment density map of the study area has been prepared by the using of Arc- GIS (10.1) software and the value of drainage and embankment density has been calculated using following formula after "Horton".

$$Dd = \sum L/A$$

Where Dd is the drainage density, L represents length of the drainage network and A is the total area of the basin

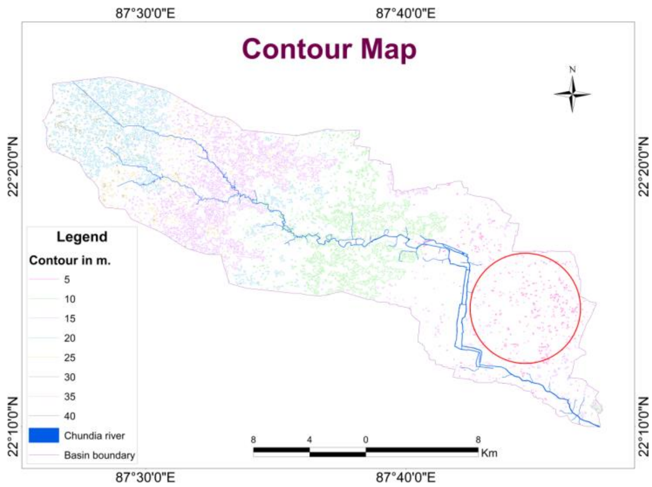
Soil and geo-morphological map has been collected from National Bureau of Soil Survey and Land use Planning (NBSSLUP). Mouza map and block map of the study area has been collected from the website of Land and Land Revenue Department of West Bengal (banglarbhumi.gov.in) to conscious about the land use and land cover oh the previous year. Ground water data has been collected from the website of Central ground water board**,** India (www.cgwb.gov.in).

Google Earth used as prime tools to detect the area of water logging and identifying the all spatial features of the Chundia river basin. Land use/land cover features of the study area has been digitized from Google Earth Quick Bird Satellite Imagery then put in Arc- GIS (10.1) software. In this way, all land use/land cover map of the study area of the year 2005 and 2015 of dry and rainy season has been prepared. Length and area of the land use and land cover features is calculated by using calculate geometry tool in Arc GIS (10.1), this way land use data has been generated. Thirteen (13) land use /land cover types are identified namely agricultural land, betel vine, river, canal, deep water, shallow water, vegetation, road ways, settlement, rail way, platform, brick field and fallow land in the study area. Changing scenario of land use pattern has been identified through the verifying the land use map of dry and rainy season of the year 2005 and 2015. Generated land use data put in MS-Excel for the analysing and comparison of the changing land use pattern scenario seasonally and temporally.

4 Result and discussion

4.1 Elevation

Elevation of an area plays a significant role for the development of the water logging condition. Rate of surface runoff becomes very slow at low elevated and low average slope area as a result higher amount of water is stored over surface and occurred the water logging during low intensity rainfall as well as high intensity rainfall (Cox and McFarlane 1995). For these causes, low lying land area of a country mostly affected by water logging in monsoon season than high land area (Rahman and Debnath 2015). Similarly, the basin area spreads over flat land of the two Midnapore district with low altitude. Height of the river mouth is near about 3 m from mean sea level and relative relief of the area is 38 m. Prepared a contour map (Fig. 2) with 5 m interval from the ASTER DEM and noticed that 5 m contour has been concentrated at the lower part of the basin (circled area) and left hand side of the river, extends over Moyna block. But 10 m contour has been fallen at the surrounding region of Moyna Block as well as in the river bed. That indicates the elevation of the river bed is higher than the lower portion of the Moyna block. From the contour and elevation map (Fig. 3), can argue that lower portion of the basin area is flat because, the gap between two contour is large than the upper portion. Major depression has been located at the water logging region due to low altitude. So, rain water during monsoon season is easily stored in that particular region that prolonged to develop the water logging and flooding condition.



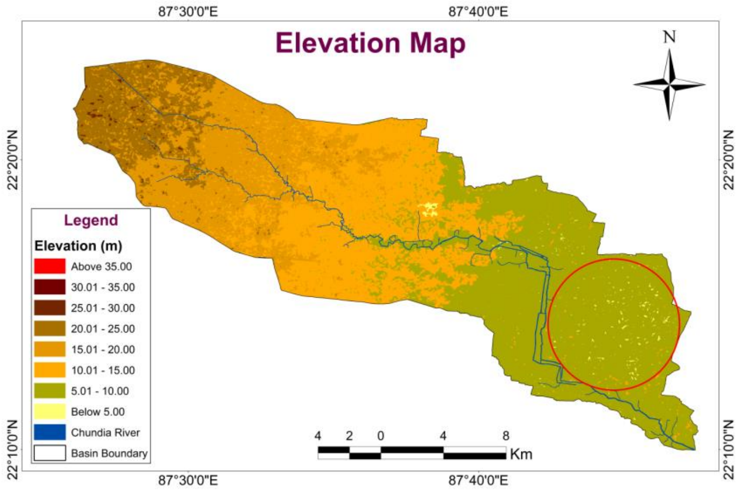


Fig. 2 Contour map Fig. 3 Elevation map

4.2 Shape of the basin

Water logging condition of an area depends on the shape of the basin area. Two major depressions have been identified in the Moyna block, one is located in the central part and another is located in the south east corner of the basin (Mukhopadhyay 1987). To detect the shape of the area, constructed two profiles A-B and C-D (Fig. 4) of the water logging region of Moyna block over ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) DEM (Digital Elevation Model). The profile A-B and C-D has been made from west to east and south to north, respectively. In both profile (Fig. 5), found that middle part (circled area) of the profile is lower than the adjacent part. So, surrounding region of the Moyna block situated with the higher elevation of 10 m. than the central part that look likes a trough. So, water cannot drain out from central part and stored that leads to develop the water logging and flooding condition in rainy season.

4.3 Drainage network

Drainage and canals of an area mitigates the water demand of irrigation for agriculture, but water logging is increased due to seepage from improper managed canals and irrigation system (Kongre and Goyal 2013). In canal Irrigated area, water logging becomes a significant problem due to continuous rising of ground water level (Singh et al. 2012). An inverse relationship has been found between water logging condition and distance from canals that means increasing the distance from canals, decreasing the water logging area (Khorasgani and Karimi 2008). We prepared a drainage network map with elevation (Fig. 6) for analysis of relationship between drainage network and elevation of the area. In the map, shows that most of the canal of water logging area is constructed towards the river valley from lower region. At a region, river is the collector of the water of the watershed. But in this particular area all canals of the water logging region has been unscientifically constructed with counter direction of the slope. So, for this causes water can’t drain by the canal and river.

Total length of the drainage network of study area is 576.31 km and the average drainage density is 1.56 that is mostly condensed in lower right portion of the river bank and upper portion of the basin. Moderate to higher drainage density (2.00) has been found

(Fig. 7) at the water logging region, where drainage density of the basin is 1.56. But water of the lower region cannot easily drain out due to negative slope of the canals. At present, river or canals of the area has been converted to series of pond (Fig. 8 A) for the harvesting of the rainy water for agricultural and fishing purpose during dry season that restricts the flow of water. Many others obstacle factor has been responsible for the water logging, these are- formations of brick kiln (Fig. 8 B) on the river bed, canals covered by water hyacinth (Fig. 8 C), garbage disposal on river bed and higher excavation (Fig. 8 D) from the river bed.

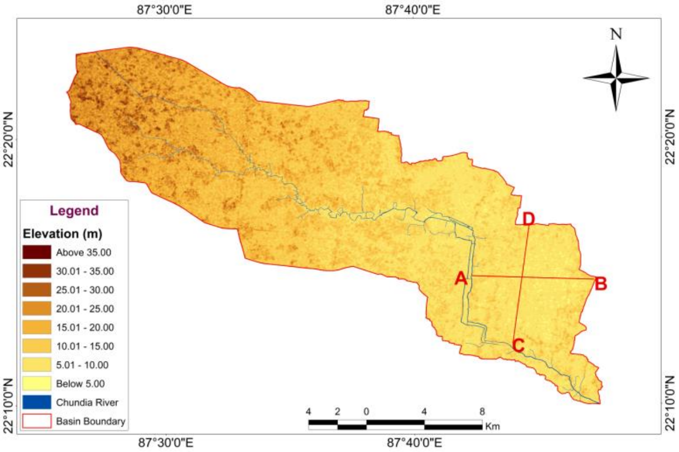


Fig. 4 Location of the profile

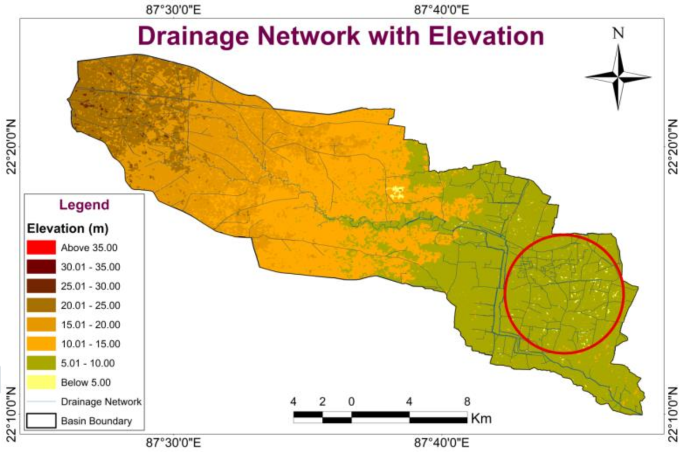


Fig. 6 Drainage network with elevation

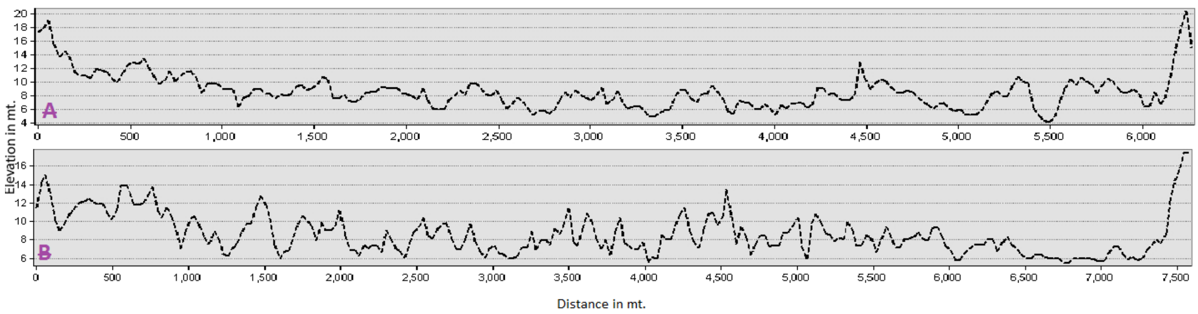


Fig. 5 (A) Profile A-B (West to East) (B) Profile C-D (South to North)

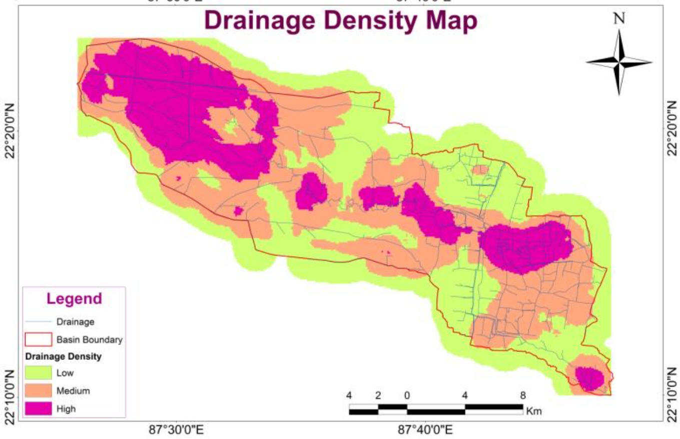


Fig. 7 Drainage density map

4.4 Soil

Characteristics of the soil of an area act as a determinant role to develop the water logging condition. Vertical percolation of the water is differs with the composition of soil texture, mainly depends on the percentage of clay content in soil. Diameter of the capillary tubes is determined by size and arrangement of the soil particles; smaller the soil particles means less porous and lesser rate of infiltration and coarser the soil particles means high porous and higher rate of infiltration (Rezaee et al. 2011). The higher percentage of clay particles (>44%) in soil texture indicates the lower vertical percolation of the water in rice field area (Razavipour and Farrokh 2014). Sometimes, perched aquifer is developed due to concentration of the clay material in the subsoil zone of the soil profile thats increased the level of ground water and developed the favourable condition for the water logging (Cox and McFarlane 1995).Clay particles are most dominating element of the soil that spread over whole Chundia river basin. According to United States Department of Agriculture, the entire basin area has been covered by four types of soil groups (Fig. 9). These are Vertic Haplaquepts (fine clayey), Typic Haplaquepts (Fine clayey), Typic Ustifluvents (Fine Loamy) and Aeric Haplaquepts (Very Fine Clayey). Vertic Haplaquepts and Typic Ustifluvents is fall under group C and Typic Haplaquepts and Aeric Haplaquepts is fall under group D in the hydrological soil group. 97.36 % of the total area is enveloping by soil group D and rest is soil group C. Group D soils have higher runoff potentiality, very low infiltration rate and very low water transmission rate (0-0.05 in/hr).

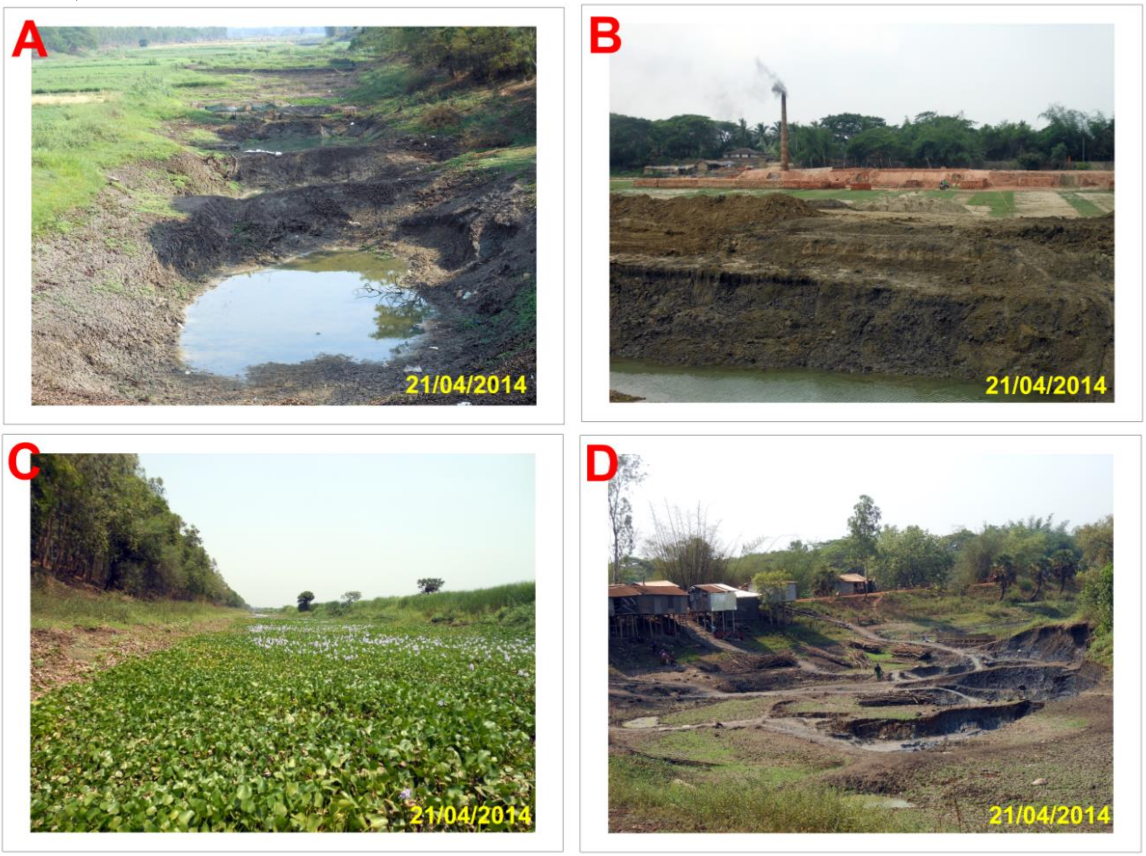


Fig. 8 (A) Canal converted to series of ponds (B) Brick kiln on river bed (C) canal covered by water hyacinth (D) Excavation from river bed

4.5 Geomorphology

Geomorphologically, the study area has been covered by alluvial and deltaic flood plain. The study area divided into three geomorphological characters (Fig. 10), (i) lower alluvial plain (72.84%) spread over upper portion of the basin, (ii) water logging area covered by valley bottom (24.08) and (iii) deltaic flood plain (3.08%). Alluvium is the principal soil element of the upper part but loamy and clayey particles of soil are higher in the lower portion of the basin. Finer particles of the soil performed as a cementing layer against the infiltration and increase the runoff. In some cases, faulty management of the soil of an area creates the soil erosion and bank erosion that reduced the infiltration rate and increased the potentiality of water logging and flood (Haghnazari et al. 2015). Soil erosion has been occurred due to higher surface runoff and embankment erosion and bank erosion has been found due to fishing cultivation as a result water logging area is increased in this region.

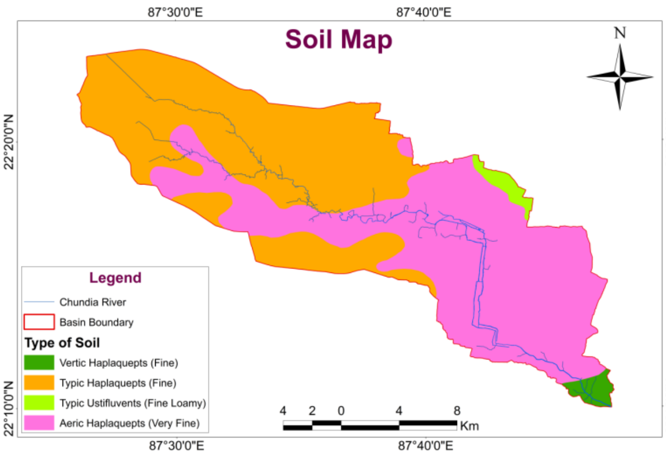


Fig. 9 Map of hydrological soil group

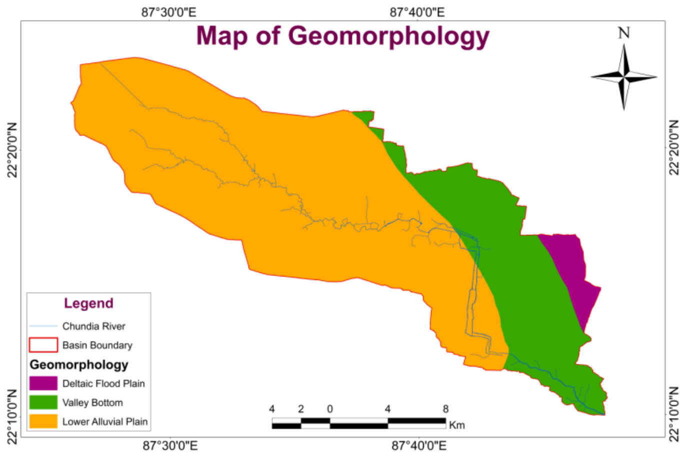


Fig. 10 Geomorphological map

4.6 Land use and land cover change

Large canal irrigation system for agricultural production is responsible for rising of ground water level that leads to water logging during rainy season (Khorasgani and Karimi 2008; Houk et al. 2004; Aslam et al. 2015). As a result, fertility of the soil and agricultural production has been reduced (Ojo et al. 2011; Aslam et al. 2015) and economic activity, agricultural production and livelihood of the local people has been ruined during monsoon period (Hassan and Mahmud-ul-islam 2014; El-Nashar 2013; Singh et al. 2012; Singh 2013; Emergency Capacity Building Project Report 2011). In this situation, the local people take an opportunity of the water logging. They converted their land use pattern from agriculture to fishing cultivation seasonally but with the increasing time, fisheries are developed permanently (Fig. 11 and Fig. 12). Table **1** illustrate that in the year 2005, agricultural land is covered by 26670.80 hectare area in dry season and 26159.17 hectare area in rainy season. But the area of agricultural land is reduced in 2015 by 1049.07 hectare in dry season and 1683.14 hectare in rainy season. On the other hand, shallow water bodies or fisheries is increased their area by 971.93 hectare in dry season and 1606.00 hectare in rainy season during this period. Area of other types of land use and land cover such as Betel vine, river, canal, deep water bodies, vegetation, road ways, settlement, railway line, platform, brick field and fallow land have not significant change from 2005 to 2015 in both seasons.

Impact of land use and land cover changes on hydrological component is more important in source region of a basin, because water availability and management of the lower portion of the basin is mostly depended on human activities of the upper catchment (Woldesenbet et al. 2016). But, transformation of the land use and land cover is mostly occurred in lower portion of the study area mainly Moyna Block region. Infiltration rate and water holding capacity of soil is became smaller and peak flow of discharge and direct surface run off is increased due to clearing of the forest (Zhang et al. 2013) and increased the rice cultivation (Shi et al. 2013; Calder et al. 1995; Woldesenbet et al. 2016). Increasing percentage of surface run-off in large catchment area depends on the percentage of the land use change from forest land to grass or cropland (Siriwardena et al. 2006) and increasing rate of population and their activity (Lorup et al. 1998). Mean stream flow of a river basin is very low in forest covered area than agricultural field; even stream flow in agricultural ecosystem is 100% higher than natural ecosystem in small catchment area (Dias et al. 2015). At present scenario, infiltration rate is decreased and surface runoff is increased due to population growth and enhancement of the built up area (Hundecha and Bardossy 2004; Tang et al. 2005). Sometimes, Surface run-off or water flow of the main stream has been decreased because of harvesting of rain water for intensive irrigation in the agricultural field linked with population growth in a particular area (Hao et al. 2008).

Generally, agricultural production such as paddy, jute and vegetable cultivation plays a dominant role as a primary economic activity in the study area. Most of the conversion of land use and land cover from agricultural land to fishery that leads to decreasing the infiltration rate and increasing the surface runoff. Fisheries of the Moyna block is totally fill up by water with 3.5-4 ft depth which produces 100% surface runoff and 0% infiltration during rainy season. Ground water level of the surrounding area is increased temporally due to storing of the water and canal irrigation for fishing cultivation to maintain the certain depth of the water. In this process, area of the water logging is gradually increased toward the surrounding region and forced to the conversion of land use and land cover.

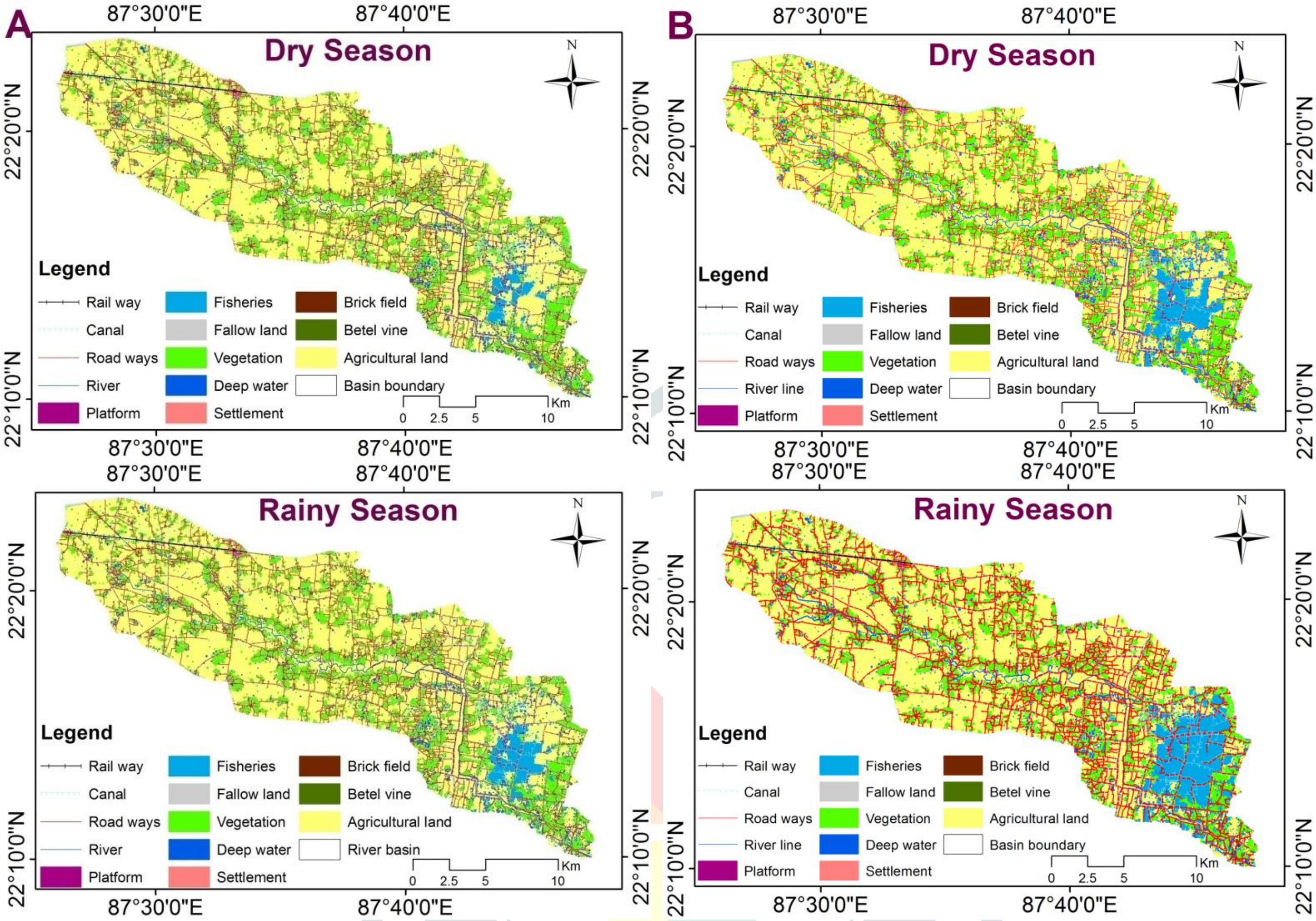


Fig. 11 A. Landuse land cover map of 2005 B. Landuse land cover map of 2015

Table 1 Land use land cover change

Land use/land cover type	2005		2015	
	Area (ha) in dry season	Area (ha) in rainy season	Area (ha) in dry season	Area (ha) in rainy season
Agricultural land	26670.8	26159.17	25621.73	24476.03
Betel vine	86.88	86.88	108.19	108.19
River	276.44	276.44	274.29	274.29
Canal	685.11	685.11	675.98	675.98
Deep water	1550.35	1550.35	1452.87	1452.87
Shallow water	447.61	959.24	1419.54	2565.24
Vegetation	4999.49	4999.49	4993.89	4993.89
Road ways	325.94	325.94	338.8	338.8
Settlement	1939.54	1939.54	2067.88	2067.88
Rail way	31.94	31.94	31.94	31.94
Platform	8.04	8.04	8.04	8.04
Brick field	0.53	0.53	21.78	21.78
Fallow land	88.08	88.08	95.81	95.81
Total	37110.75	37110.75	37110.75	37110.75

Fig. 12 Seasonal landuse land covers change

4.7 Drainage and embankment

Natural surface runoff has been restricted by unplanned and haphazard development of the embankment that creates the water logging condition in low lying area during rainy season (Rahman and Debnath 2015). According to previous statement moderate to higher drainage density is found in lower right portion of the river bank and upper portion of the basin. Length of embankment is too much at lower portion due to excessive drainage network and low lying plain land from past to onwards. In the year 2005 and 2015, length of embankment is 524.76 km and 549.68 km and density is 1.41 and 1.48 respectively. Fig. 13, the embankment density map of both years, shows that concentration of embankment is so high in lower right part of the river. Construction of mud dams or embankments on the river or canal bed is higher for the transport and communication of the local people. For the development of permanent and temporary fisheries, huge amount of mud dams and embankment has been established over the agricultural land to store the water for fishing cultivation. Sometimes, the mud dams have been constructed in canal or river valley to reserve the water. That totally choked the flow of water through the river or canal (Fig. 14 A) and interrupted the surface water flow (Fig. 14 B) from the higher elevated area to river or canal.

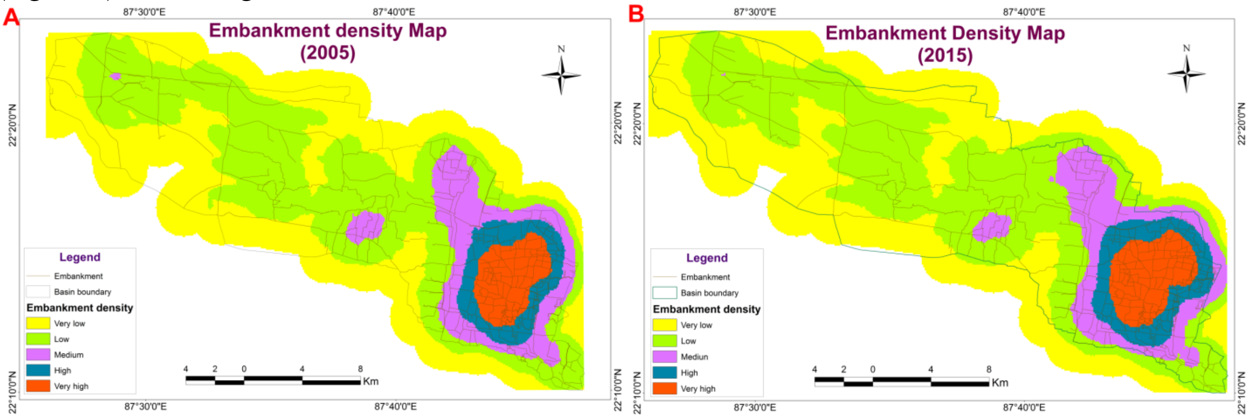


Fig. 13 Embankment density map A) 2005 and B) 2015

Fig 14 (A) River flow interrupted by local road (B) Surface flow restricted by mud embankment or road

4.8 Fisheries and embankment

Mud dams and embankments of my study area have been built up to reserved the rainy water for the temporary and permanent fisheries. Fisheries perform as a cementing layer over soil surface and produces 100% run-off that promotes the water logging rainy season. Surface run-off and over land flow is totally restricted by high embankment around the fishery. So, area of water logging is gradually enlarged day to day in rainy season due to embankment. To recognize the relationship between area of the fisheries and length of the embankment, a regression analysis (Fig. 15) has been done. Area of the fishery of a mouza added as an independent variable while length of the embankment of the same mouzas used as a dependent variable in the statistical analysis. A positive relationship between area of fisheries and length of embankment has been recorded in the scatter diagram in the year 2005 and 2015. Length of the embankment is depended on the area of fisheries and embankment length is gradually increased with fishing area. The weight of relationship is 0.455 and 0.342 at 95% confidence level in the year 2005 and 2015, respectively. It's indicated that embankment has been increased because of fishing cultivation and as a result water logging has been prolonged.

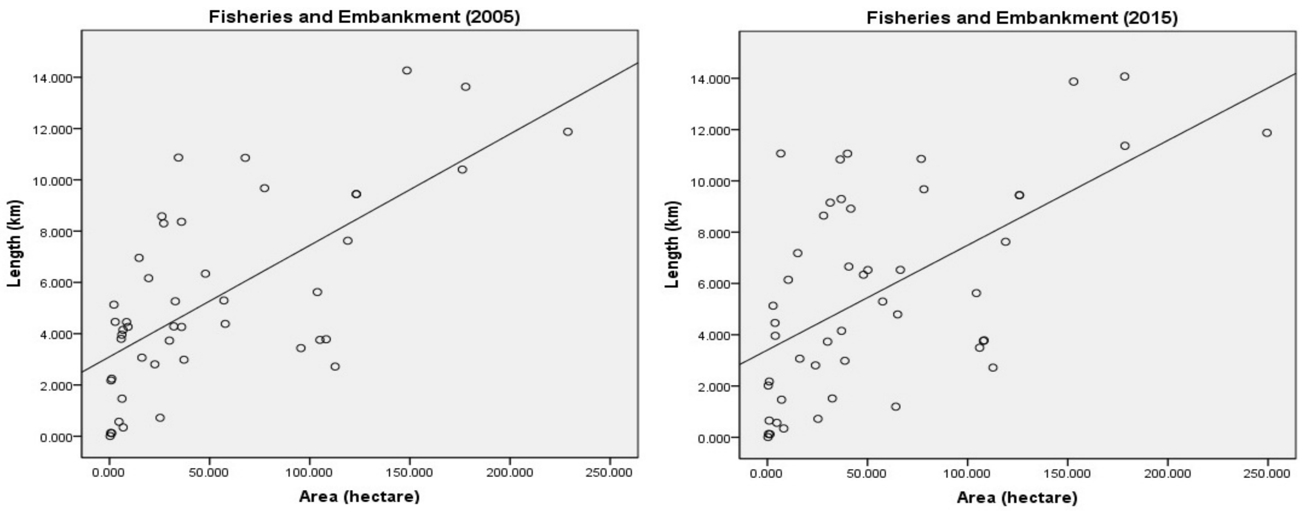


Fig. 15 Scatter diagram: showing the relationship between area of fisheries and length of embankments

4.9 Human activities on river bed

Water logging of an area can be consolidated through proper management of drainage system and improvement of sustainable drainage condition (Valipour 2014). But lack of natural drainage, inadequate surface drainage, worst drainage condition and retrenchment of the water holding capacity due to siltation (Papry and Ahmed 2015) and solid waste disposal (Rahman and Debnath 2015) developed a friendly background for water logging and flood in monsoon period. Chundia river valley is greatly affected by major constructional network and economic activity that creates a barrier of surface water flow and reduced the carrying capacity of the canals. Many village level roads are developed on the valley without any bridge or with very small bamboo or concreted bridge (Fig. 16 A). Concrete bridge of some main communication roads of the area constructed over the river is very small in respect to the valley that leads to stagnation of water in Rainy season. In present time, intensive agriculture (mainly paddy) is found on the river valley (Fig. 16 B) in dry season and river channel is closed by mud bank for the harvesting or storing of the surface water for irrigation during dry season. Many sluices (Fig. 16 C) are set up on the river valley or canal for gathering of water for fishing cultivation in dry season. Different types of culvert are found (Fig. 16 D) in this area which is too small respect to canal area. They cannot afford to drain out the total canal water during rainy season. So, in the rainy season, water of the river cannot drain easily through the channel and gradually lost their carrying capacity that developed water logging and flood. This leads to seasonal and permanent land use conversion from crop cultivation to fishery

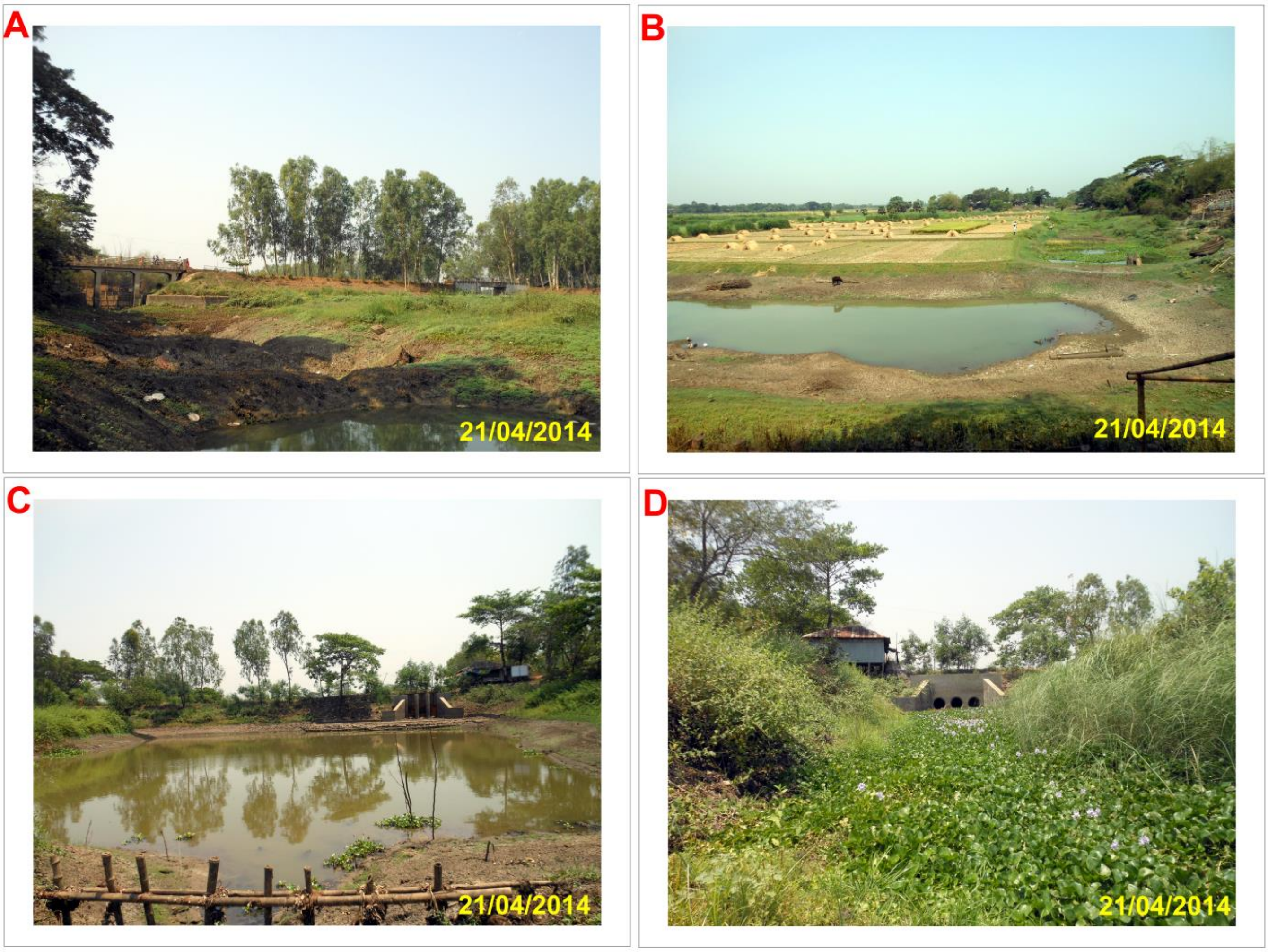


Fig. 16 Flow interrupted by different human activities (A) Small concrete bridge respect to valley (B) Agricultural activity on river bed (C) Small sluice on river valley (D) Small culvert on river valley

5 Conclusion

After the analysis of land use data and maps, find that central part of the Moyna block faced heavy water logging problem in rainy season. Low elevation, shape of the area like a trough, fine clayey soil, and haphazard construction of embankment, low depth of ground water and negative slope of drainage network are developed a favourable condition for water logging. At past, agricultural productions of the logging area face a challenged and damaged in rainy season that leads to transformation of land to fisheries in seasonally. The seasonal land use changed was a good decision for the people of logging area in land use purpose. When farmers are feels that fishing cultivation is more profitable than agriculture, they converted their land to permanent fisheries. Huge amount of embankment is constructed over agricultural land and sluice and mud dam on canal for fishing cultivation in dry season for the storing of water at present situation. Water of the upper portion of basin area cannot easily drain over the agricultural land and through the canal due this type of embankment or mud dam. So, water logging is increase due to this type of human activities that leads to further land use change in the study area.

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