2.1 Location and extension of the study area

Assam part of the Belsiri River basin is taken-up as the study area. The Belsiri River, a right bank tributary of the Brahmaputra River in India, is located in the north-eastern part of India and its basin extends from 26°36'N lat. to 27°05'N lat. and 92°20'E long. to 92°40'E long (Fig. 2.1). Belsiri River flows through the territories of the west Kameng District of the state of Arunachal Pradesh and the western part of the Sonitpur District of the state of Assam, India. The Belsiri basin occupies a total area of 496 km$^2$ consisting 154 km$^2$ (31%) and 342 km$^2$ (69%) in the territories of the states of Arunachal Pradesh and Assam in India.

The Belsiri River basin is too small if compared with the other river basins of India like the Ganges, the Brahmaputra, the Godavari, the Krishna Rivers. The Belsiri River is a middle category river of the Brahmaputra systems of rivers. The similar tributary rivers in the central part of the northern bank of the Brahmaputra system of rivers are Tangani River, Gelabil River, Panchnoi River, Ghiladhari River. However, the overall basin morphological characteristics of the Belsiri River basin are similar in a scale down perspective with all other tributaries of the Brahmaputra River. The basin exhibits an elongated shape with wider extent in the plains than that in the hills. The basin perimeter measures 158 km with a maximum length and width of 57 km and 15 km respectively.
Figure 2.1: Location of the study area
2.2 Geology and Geomorphology

2.2.1 Geology and Tectonics: An overview

There is no systematic work found on the geology and tectonic of the Belsiri river basin. But, several authors have done some generalised work on eastern Himalayas and particularly in the Brahmaputra basin. Evan (1932) for the first time surveyed the stratigraphy of Assam. His survey has laid the foundation of the stratigraphic classification of the Tertiary formations in difficult and inhospitable geologic terrain (Wadia, 1981). Evan’s (1932) account on lower Siwalik which in part belongs to the study area describes the rocks are consisting of thick, coarse, ferrogenous sandstones, molted sandy clays, shales, fossil wood and lignite (Sarmah, 2002). Detailed and systematic geo-hydrological information are available on the Assam section of the study area along with the Sonitpur district in the works of Kumar (1997) and Talukdar (2011). Some information on geology and structure of eastern hill catchment of the river are found in the works of Nandy et al. (1971) and Das et al. (1971).

The geological history of the North-Eastern Region of India is directly or indirectly involves almost all the major geological ages from the Achaean to the Recent (Nandy, 1975). Being the part of Brahmaputra valley, the Belsiri River is also experiencing the very similar characteristics of the geology as well as the tectonic settings. The present configuration of the Brahmaputra Valley evolved during two million years of Pleistocene and recent time (Murthy, 1968; Rao, 1979). In Assam it is a techno sedimentary basin 720 km long and 80-90 km wide, underlain by Recent
alluvium, approximately 200-300 m thick (GSI, 1974). The rocks are everywhere of fluviatile and sub-aerial formation—massive beds of clay, either sandy or calcareous, corresponding to the silt, mud and sand of the modern rivers (Sarmah, 2002). During the Pliocene times (about 10 million years ago) the rapid upliftment of the Himalaya had resulted in the deposition of pebbles, cobbles boulders and coarse sands on the foothills of the Himalaya (Bhattacharjee, 2008). They have got exposed that are actually the outer expression of hard and massive Pre-Cambrian rocks of Gondwana origin (Taher, 1974). Geologically, the Belsiri basin which is a part of the whole region was built up mostly of recent alluvium deposited continuously for millions of years on the tectonically developed sag below the Bhutan Himalaya called the fore-deep (Krishnan, 1982) or the Rift valley (Burrad, 1912). This fore-deep or the rift valley rested on the pre-Cambrian rocks base. About 250 million years ago, the process of sedimentation took place in the area now occupied by the Bhutan-Himalaya (Bhattacharjee, 2008). After the formation of this part of the Himalayan region including the Belsiri basin came under subsequent geomorphic processes and the geological composition along with structural development (Bhattacharjee, 2008). All this had variously influenced to modify continually the surface of the region (Directorate of Geology and Mining, 1982.)

Belsiri River basin forms a part of Sonitpur district in Assam. It is dominantly characterized by quaternary sediments with isolated hillocks of Precambrian period. Viswanathan and Chakrabarti, (1977) have delineated nine geological formations which corresponds with nine geomorphic surfaces. This includes both floodplain and piedmont plain (GSI 1998). They can be arranged in a chronological order as follows-
Table 2.1 Stratigraphic succession of Older Alluvium of the study area (after Viswanathan and Chakrabarti, 1977)

A. Quaternary

<table>
<thead>
<tr>
<th>Flood plain</th>
<th>Piedmont plain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuruwai Formation</td>
<td>Recent gravel bar deposits</td>
</tr>
<tr>
<td>Solabari Formation</td>
<td>Seijosa Formation</td>
</tr>
<tr>
<td>Itakhola Formation</td>
<td>---</td>
</tr>
<tr>
<td>Rangapara Formation</td>
<td>Balipara Formation</td>
</tr>
<tr>
<td>Siwalik Group</td>
<td>Siwalik group</td>
</tr>
</tbody>
</table>

B. Precambrian

<table>
<thead>
<tr>
<th>Flood plain</th>
<th>Piedmont plain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granitold-Gneiss</td>
<td>---</td>
</tr>
</tbody>
</table>

Gneissic complexes are observed in the study area and they are believed to be the basement of the tertiary and quaternary deposits. The tertiary brownish sandstones are observed in the foothills of the river basin. The quaternary sediments are mainly of piedmont terrace deposits. Older valley floor deposits are deposits of Pleistocene to Sub-Recent period; and the flood plain deposits are deposits of Sub-Recent to Recent times (Bora, 1991 and Sarmah, 2002).

Larger part of the Belsiri River basin is part of Sonitpur district which falls under the domain of same geological framework. Some of the geological formation within the basin area as follows:
**Quaternary Formation:** The sediments of the piedmont zone comprises very coarse material such as boulders, cobbles, pebbles and sands of various grades and a very little clay and the formations of the zone are highly permeable (Bora, 1991). The piedmont zone deposits grade through a transition zone where traction load component gradually diminishes and ultimately merges with valley flat deposits, constituted mainly of suspension load like various loads of sands (Bora, 1991). However, there seems to be some substantial variation of sedimentary formation in the region of study. On the other hand the plain region of the southern part of the basin constitutes mostly of the sub-recent to recent deposits and can be observed in the higher grounds of the older alluvial surfaces from the north to south of the Belsiri River basin.

**Dedja Formation:** This Formation is also called Menga Formation or as Chillipam formation is nothing but a thick succession of dominantly carbonate rock, which are unconformably overlying the Tenga Formation occurs in Tenga valley in West Kameng district of Arunachal Pradesh. This Formation has been divided into two distinct members (Kumar, 1997). The lower member broadly corresponds to the Kobak formation and referred as kobak member (GSI, 2010). This Kobak member consist of a basal oligomictic conglomerate with pebbles and cobbles of quartzite in phyllite matrix, impersistent bands of dolomite, massive grey to white dolomite/limestone and black dark grey phyllite (Bhusan et al. 1991). Kumar and Bora (1984-85) have referred the upper member as Niumi Member that comprises mainly carbonates with alternations of greenish grey, purple and dark grey carbonaceous phyllites (GSI, 2010).

**Tenga Formation:** Das et al. (1975) mentioned that the low grade meta sediments consisting of green phylite, meta volcanics seicite-quartz phyllite and quartzite of Tenga valley as Tenga formation. They further added that the exposed section lying between
Bame and Pangin, consisting of metavolcanics, quartzite, and carbonate rocks are also as equivalent as of Tenga formation (GSI, 2010). Dhoundial et al. (1989) have divided the Tenga Formation into two members on the basis of comparison with similar rocks in the Darjeeling-Sikkim Himalaya (GSI, 2010). They have classified these two group as i) the lower Garubhutan Member which comprises schistose quartzite, silty shale and phylite and ii) the upper member as Reyang Member which consists of basic metavolcanics, green chlorite phylite and chlorite-biotic-garnet schist and thin beds of marble (GSI, 2010).

**Bichom Formation:** It is represented by a thick succession of diamictite, dark grey shale/slate and minor quartzite overlying the Miri formation conformably in the Bame-Igo-Basar section (GSI, 2010). These rocks were also mapped in the lower reaches of Bichom valley as Bichom formation (Anon, 1974; Das et al., 1975).

**Bhareli Formation:** The Bichom formation is overlain by thick sequence of grey to dark feldspathic sandstone and grey shale with lenticular coal beds yielding rich Lower Gondowana floral assemblage which represents the continental facies of the Lower Permian sequence which have been referred to as the Bhareli formation (GSI, 2010). Bhusan et al., (1989) have sub-divided the Bhareli formation into two types: a) Upper Member: Feldspathic sandstone, carbonaceous shale with impersistant lenticular coal, b) Lower Member: Arkosic silicified sandstone, siltstone, carbonaceous shale with thin impersistant lenticular coal.

**Middle Siwalik:** The middle Siwalik is also known as Subansiri formation which belongs to Tertiary rocks which composed of conglomerates, sandstones and silt and clays.
Figure 2.2: Geological map of the Belsiri River basin (prepared based on GSI map 1977 and Kumar, 1997)
**Tectonic settings**

The complex tectonic setting of the north eastern region of India is due to north-eastward movement of India along the Himalayan arc and east west convergence along the Indo-Burma fold thrust schuppen belt (Duarah, 2008). Geologically Himalaya is the example of continental collision with diversity in lithology, stratigraphy, tectonic and metamorphic history (Pande, 1975). These mighty mountain ranges spread along 2400 km and across 240-325 km (Gansser, 1974) spread into the south East Asian landmass. It has been divided into the western, central and eastern Himalaya along strike length and outer, lesser and higher Himalayan zone from south to north across the Himalayan trend (Talukdar, 2011). The present tectonic settings of the region give it a unique geological realm. The Geological history of the region directly or indirectly involves almost all the major geological ages from the Archean to the Recent (Nandy, 1975). The major tectonic discontinuities of the Himalaya are the Tsangpo Suture (TS), Main Central Thrust (MCT), Main Boundary Fault (MBT).

The present configuration of the geomorphology and different orographic features of the province evolved in chronological order and were synchronised by the geo-tectonic processes. In fact, present structural configuration of the province is the cumulative effect of diatrophism (Directorate of Geology and Mining, 1982).

The major tectonic lineaments which play dominant role in geological evolution of the state and also active now are (Directorate of Geology and mining 1982) :

a) E-W Basement fault along the mergin of Shillong plateau , Extending upto Halflong, in the North Cachar Hills. The EW Jorhat fault bordering north of Karbi Anglong district along the Brahmaputra.
b) N-S faults along the Jhinijram, west of Singimari.

c) The E-W great boundary fault of on the north.

d) NE-SW Naga thrust passing through the eastern border of sibsagar and Dibrugarh district along upper Assam Coal Belt.

Figure 2.3: Regional tectonic elements of NE India and adjoining region including the Belsiri basin draped on SRTM DEM (after Nandy, 2001, Murthy et al., 1969, Talukdar, 2011)
2.2.2 Geomorphology: A brief description

The study area is located in a region of diverse physiographic settings, high variation climatic characteristics, and variation in soil, flora and fauna. The topography of the study area is not even and appears to be undulating in its hills catchment and fairly even in piedmont zone and even in plain catchments. The study region including the Belsiri River basin is a minor part of the Brahmaputra River basin that mostly builds up by alluvium deposition through fluvial processes across recent geological periods. Study made by observation and analysis of topographical maps, Satellite Imageries for the period 2000-2015, and Google Images for the period 2011-2015 reveal that there are some uniformity of geomorphological characteristics in area/region basis in the study area and thus delineated into six geomorphological units. These are (i) High Hills and Mountain zone, (ii) Denudational Hills and Foot Hills zone (iii) Piedmont zone, (iv) Older alluvial surfaces, (v) Younger Alluvial Plain, and (vi) Floodplain zone. Geomorphological units and area under them along with the percentage proportions are presented in table 2.2 shown in fig. 2.4.

<table>
<thead>
<tr>
<th>Geomorphological units</th>
<th>Area (km²)</th>
<th>Per cent of basin area</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Hills and Mountain zone</td>
<td>134</td>
<td>27</td>
</tr>
<tr>
<td>Denudational Hills and Foot Hills zone</td>
<td>24</td>
<td>5</td>
</tr>
<tr>
<td>Piedmont zone</td>
<td>119</td>
<td>24</td>
</tr>
<tr>
<td>Older Alluvial Surfaces</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Younger Alluvial Plain</td>
<td>188</td>
<td>38</td>
</tr>
<tr>
<td>Active floodplain zone</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td><strong>Basin area</strong></td>
<td><strong>495</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: Estimated in GIS platform using the map presented in fig.2.4
High hills and mountain zone: This geomorphic unit (Fig.2.4) covers an area of 134 km² (27%) and is located in the upstream part of the basin. It includes hills and mountains of lower Himalayas with elevation ranging from about 500 m to 2400 m comprising hill ranges of rocky, narrow and broad crests and sharp conical and rounded summits. The general surface gradient is 1:9 and it roughly dips towards south. Rocks in this unit generally consist of shale, sandstone, conglomerates, mica and slate. Ground water is mostly confined to fractures and joints of slopes and bends including in valley floors. In general, parallel to sub-parallel hill ranges with high slopes, stream divides and forest clad V-shaped valleys are the aerial topographic view of this unit. Cliffs and escarpments are common in this unit and are devoid of soil cover. The scarp zone is predominant in the valley sides. The debris slope is not very prominent due to high speed surface runoff through the scarp which washes away the accumulated debris. Narrow V-shaped valleys in this unit are subjected to excessive runoff of high velocity and are often the spots of accretion of sandy soils. Gravitational transfers, especially the landslides in the form of slumping, debris slide, rockslide and rock fall are significant geomorphic processes here. In this zone, significant headward erosion, down cutting of streams, excessive gully development and erosion are predominant. The drainage network conforms dendritic to trellis pattern. Important drainage lines here are the head streams of the Bichrikho River. This geomorphological unit is interruptedly covered by sub-alpine meadows with coniferous and tropical evergreen trees particularly in windward slopes.
Denudational hills and foot hills zone: This geomorphological unit (Fig.2.4) is the zone of maximum vertical erosion and it covers an area of 25 km$^2$ (5%) of the Belsiri basin. It comprises the severely eroded hills of lower Himalayas in which elevation
ranges between 240 m to 500 m with scattered narrow and broad crests of conical and rounded summits. The surface generally dips towards south with the gradient 1:111. Areas ahead of vertical stream banks one finds the parallel elongated narrow deep valleys which indicate maximum vertical erosion. Downstream part of this zone is marked by frequent landslide prone worn down hills. Numerous forest clad deep gullies, vertical side walls and conical summits are the common fluvial features of this unit. Debris slopes are moderately to severely erode with high accretion of finer soils in the valleys. Commonly occurring rocks are moderately hard to soft, medium grained, sandstone and shale. Surface runoff is extremely high during wet season. Partial recharge commonly takes place along joints, fractures in weathered friable sandstone and shale. In general, ground water prospect is poor, though it may be tapped from the fractures and weathered areas. Drainage pattern is parallel in general being dendritic in the upper part of the zone. Most of the hills are devoid of forest cover due to occurrence of frequent landslides.

**Piedmont zone:** The piedmont zone (Fig.2.4), covering an area of 119 km$^2$ (24%), exhibits a peculiar hydro-geomorphological characteristics (Landsat 8, 21 January, 2015) which is reflected in the satellite imageries. This is a zone of high porosity, permeability and absorption capacity in regard to precipitation and surface runoff. It is also characterised by fairly high degree of slope, relief, and drainage density. The surface generally dips towards south at an average gradient of 1:400. The soil and sub soil layer is consists of coarse, clastic materials viz. boulders, cobbles, pebbles, gravels and sands (Fig.2.5, Field Photo) of varying sizes and therefore this represents a zone of high water seepage. The northern part of this zone shows severely dissected small low height hillocks with boulder beds (Field Photo) in the
valley floors. Water seepage is found to be the most significant geomorphic process here. Middle part is highly dissected by the distributaries of Belsiri River and her tributaries (Satellite Photo). The important drainage lines here are the Belsiri River, Mejangjuli River, Dhekiajuli River, and Dighaljuli River (Fig.2.1). The bed of the Belsiri River channel exhibits to be braided probably due to intensive seepage of water leading to frequent appearance of new and disappearance of old distributaries. Sarmah (2005-2006) in a study on the Jia Dhansiri River basin, a river located 10 km west of the Belsiri River, reveal that significant fluvial processes/activities in the piedmont zone of that river basin are water seepage, distributaries formation/channel bifurcation leading to appearance of new distributaries and disappearance of old tributaries, activation of palaeochannels, boulder bed formation, sand bar formation, gravel bar formation, etc.

Figure (Photo plate) 2.5: A part of the piedmont zone of the study area
**Older alluvial surfaces:** The older alluvial surfaces occur in some scattered blocks of relatively higher elevation compared to the younger alluvial plain. Presence of these surfaces in the Brahmaputra Valley are mentioned in the works of Bora (1990), Goswami (1985, 1998), Sarmah (2001, 2005-2006, 2012), Nath (2012). This geomorphological unit of the basin covers an area of 21 km$^2$. The topography of these surfaces is relatively even (Field Photo). However, the relative relief varies from 2-3 meters. The surface gradient generally dips towards south and east indicating the dominant base flow to the Brahmaputra river. These surfaces are characterized by the presence of ferruginous, reddish brown silt or clay on the top and underlain by a granular zone comprising fine to coarse sand with some gravel and pebble (ARSAC, 1993). Field observation reveals that chemical weathering mostly oxidation is a dominant denudational process here. Gravitational transfer like soil creep of various types is predominant during dry season. Fluvial processes such as rill erosion, sheet wash, etc are active in these surfaces during rainy season. The older alluvial surfaces in the basin mostly support tea gardens which form prominent vegetation cover of the basin, probably owing to the acidic character of the soil.

**Younger alluvial plain:** The younger alluvial plain (Fig.2.6) is the largest geomorphological unit of the Belsiri River basin in terms of area. It covers an area of 188 km$^2$ (38%). The elevation ranges between 60 m to 100 m. from msl. The topography is mostly even with little variation at places where drainage lines are encountered and dips very gently from north to south. This plain is a part of the greater Brahmaputra valley which is 200–300 m thick deposits of alluvium (GSI, 1974) of the Brahmaputra valley consisting mainly of silt and clay and built-up during recent periods. It is
observed during field work that the plain is dissected by many floodplain gullies near
the Belsiri River. It takes an intermediate position in terms of height between the older
alluvial surfaces and the floodplain zone. The plain is composed of clay, silt and sand
which are overlain by a pebble horizon (ARSAC, 1993). Ground water availability is
moderately good and is more prominent near the river and streams. The dominant
fluvial processes of this plain are sheet wash, gully erosion, rill wash, flood and
inundation, overbank deposition, sedimentation from flood water, and river bank
erosion. Old river terraces, remnants of few natural levees, gullies, eroded river banks
are the significant fluvial landforms of the younger alluvial plain. This
geomorphological unit supports highest population compared to any other units of the
basin. Species of deciduous forests located mainly in the inhabited areas form the major
part of the vegetative cover in this zone. Major part of this plain is used for rice
cultivation while other areas are mostly devoted to oil seeds, vegetables and inhabitation
purposes.

Figure (Photo plate) 2.6: A part of younger alluvial plain of the study area (Field
photograph)
**Active floodplain zone:** The geomorphological unit of the Belsiri River basin which is delineated as Active floodplain zone (Fig. 2.7) covers a total area of 9 km² (2%). It is delineated interruptedly in a very irregular shape along in both sides of the Belsiri River channel. The topography of this zone is fairly level except areas where floodplain gullies, river terraces and river banks are present. The average elevation varies between 70 to 60 m from m.s.l. The average surface gradient is calculated at 1: 2700 and generally dips towards south. Genetically, this is a depositional landform which mainly consists of clay, silt and sand especially fine sand. The ground water table is encountered at a relatively lower depth and therefore, the availability is good in general and very good in the areas occurring river channels, palaeochannels, ox-bow lakes, swampy areas, etc. Numerous wetlands are observed in this zone during field survey and in the satellite imageries. Presence of these surfaces in the Brahmaputra Valley are mentioned in the works of Bora (1990), Goswami (1985, 1998), Sarmah (2001, 2005-2006, 2012), Nath (2012). The floodplain is dissected by the Belsiri River and its palaeochannels and gullies. The drainage density of this area is calculated to be 511 m/km² which can be said to be moderately high. The Belsiri River basin too comprises wetlands of different sizes. The remarkable fluvial features/landforms as noticed during field observation and on the satellite imageries are natural levees, ox-bow lakes, back swamp deposits, palaeochannels, abandoned channels, river terraces, sand bars, gravel bars, point bars, channel cut-offs, channel fill deposits, and many others. The dominating fluvial processes or events of this zone are flood with extensive inundation and over bank deposition, bank erosion and bankline migration, gully erosion, sheet wash, channel widening, sedimentation from flood water, channel aggradation, braiding of river channel, etc. This geomorphological unit also supports a considerable
percentage of the total population of the basin. Several species of deciduous trees in the inhabited areas such as household plantation, grasslands and scrublands in the riverine areas can be termed as the prominent vegetation cover of this zone. Rabi crops specially vegetables and oil seeds are extensively grown in this geomorphological unit.

Figure (Photo plate) 2.7: A part of the floodplain zone of the study area

2.3 Climate

The climate of the region is not much different than that of the rest of the Brahmaputra valley. The regional climate is basically controlled by the monsoon winds regulated by the diverse physiographic settings. Powerful south-west monsoon sets in the middle of June and continued till October with strong influence during July and August. Frequent thunderstorm activity with bright powerful lightening is a regular
feature particularly in the evening time. Rainfall occurs for two three days during July and August and sometime continues for a week. The study area experiences cool-dry winter and warm-humid summer. As suggestive in the name itself (in Sanskrit) ‘Arunachal Pradesh’ is the “land of the dawn lit mountains” (Sharma, 2005), with very pleasant climate where a significant part of the study area falls. So far as season is concerned, June to September are wet/rainy season, October to November are cool-humid season, December to February is cold-dry season, March to April is dry season and May to June is hot-humid season.

2.3.1 Temperature

The annual temperature of the plain part of the basin varies from 8ºC to 39ºC. The maximum temperature varies from 30ºC to 39ºC in the months of May, June and July. Temperature remains in the higher side during April to August recording highest between 1 p.m. to 3 p.m. The temperature of the high hills catchment area falls below freezing point in winter months.

2.3.2 Relative humidity

The relative humidity of the study area is recorded with the hygrometer in convenient days especially during field work. It is found that in most of the days of humidity record, it ranges from 98% to 100%. However, humidity at any station of the study area was not recorded during the months from October to June. In general from November to February humidity is very low and weather is dry.
2.3.3 Average annual rainfall

The average annual rainfall of the study area is 200 cm. The rainfall pattern in the study area is not much different from that of the greater Brahmaputra valley. However, in regional perspectives, the average annual rainfall increases toward north east of the Brahmaputra valley. In this study, average annual rainfall of 25 stations located in and outside the study area for 1981-2007 and 2009-11 are calculated following general statistical method and three isohyetal maps are prepared in Arc Info platform. These two maps are presented in Fig.2.8, Fig.2.9 and Fig. 2.10. It is evident in Fig.2.8 and Fig.2.9

Figure 2.8: Average annual rainfall of the study area with adjacent region
that rainfall pattern during 1981-2007 and 2009-11 are more or less similar. Annual average rainfall varies from 134 cm to 207 cm (Fig.2.8) during 1981-2007 and 2009-11. On the other hand May to October months average rainfall varies from 159 cm to 411 cm (Fig.2.9) during 1981-2007 and 2009-11. Rainfall data are presented in Appendix-I.

2.4 Natural Vegetation

The basin possesses bountiful floral resources. Upper part of the basin is covered by coniferous tree species and mostly tropical evergreen trees in the windward slopes. The lower part of the hill catchments including the foothills and the Reserve Forest is covered by sub-tropical semi-evergreen trees and mixed deciduous trees. It is observed in the satellite imageries of IRS P-6 LISS III (Fig.2.11) that there are two Reserve
Forests viz. Charduar Reserve Forest and Sonai Rupai Game Sanctuary. Some parts of it, interruptedly the older alluvial lands of relatively high altitude, are covered by tea gardens. Valley parts of the basin are interruptedly exhibits deciduous plants mostly confined in the built-up lands particularly in habituated areas. Seasonal agricultural lands are also possesses green cover mostly during wet season. The riverine and swampy areas are dominated by vegetative cover of reeds and grasses.

Figure 2.11 IRS P-6 LISS III image showing Charduar Reserve forest and Sonai Rupai Game Sanctuary in the Belsiri basin
Major species of trees are Sam (*Artocarp chaplasha*), Gonsoroi (*Cinnamemum ceeicedaphne*), Khoir (*Acacia catechu*), Titosopa (*Michelia champaka*), Gomari (*Gmelina arborea*), Amari (*Amoora rohituka spectabilis*), Hollock (*Terminalia myriocarpa*), Nahar (*Mesuaferrea*), etc. The alluvial plain of the basin covers mixed deciduous trees and tea crops (Tea Estates). Common trees of this part are Choir (*Bridelia resturasprang*), Outenga (*Dillenia indicum*), Mango (*Mangifora indica*), Peepal tree (*Ficus religosa*), etc. The riverine areas support tall grasses. Common grasses include Birina (*Phragmites species*), Kher (*Imperata cylindria*), Cane (*Calamus viminalis*), Reed (*Saccharum spontaneum*) etc.

The Belsiri River basin is endowed with faunal resources. It supports countless species of fauna ranging from micro-organisms to large animals like elephants. Several species of fish, reptiles, flies, birds, herbivores and carnivores of domestic and wild varieties are found in the whole basin in general and in the Charduar Reserve Forest and Sonai Rupai Game Sanctuary in particular. Many endangered and rare species are also found in the reserve forests. Besides, several bird species including migratory birds are seen in the area, notably among them are Grey horn, large and lesser whistling teal, samorant, king fisher, Myna, Jungle Crow, stork etc. And in the dense mixed jungle areas containing leopard, wolves, elephant, wild cat, monkeys etc.

### 2.5 Soil

A technical bulletin on soil series of Assam published by the National Bureau of Soil Survey and Land use Planning (ICAR) in co-operation with the Department of Agriculture, Government of Assam reveal that the Belsiri River basin in Assam has six distinct soil groups. These are classified as AS13, AS14, AS18, AS20, AS 23 and
AS31. As 13 soil group is known as Coarse-loamy, Typic Fluvaquents. This is deep, well drained, coarse-loamy soils occurring in the very gently sloping piedmont plain having loamy surface with moderate erosion and slight flood hazard.

Figure 2.12: Soil types of the study area
(Source: Prepared using soil map collected from Department of Agriculture, Government of Assam)
The As 14 soil type is associated with Fine-loamy Aeric Haplaquepts, which is very deep, imperfectly drained, fine loamy soils occurring on gently sloping depressed piedmont plain with slight erosion and moderate flood hazard. AS 18, Typic paleudalfs is very deep well drained fine loamy soils occurring on gently sloping to undulating upland having loamy surface with moderate erosion. It is associated with deep moderately drained coarse loamy soils occurring on gently sloping plain with moderate erosion. AS 20, dystric eutrochrepts is well drained fine loamy soil occurring on gently sloping plain with slight erosion; it is associated with imperfectly drained coarse loamy soil with slight flooding. AS 23 typic haplaquepts are very deep, poorly drained, fine silty soils occurring on nearly level depressed plain having clayey surface with very slight erosion, ground water table between one to two metres below the surface and slight flooding. It is generally associated with deep well drained coarse loamy soils occurring on nearly level plain with slight erosion. AS31, typichaplaquepts is very deep imperfectly drained fine silty soils occurring on level plain to nearly level active flood plain having loamy surface with slight erosion and moderate flooding, associated with deep moderately well drained fine loamy soils occurring on level flood plain with moderate erosion and severe flooding.

2.6 Land use pattern

Land is a vital element that supports life on the surface of the earth, but human pressure on land has arised several environmental problems. Therefore it is a need of an hour to check the land resources in a scientific way. The present study keeps to through some light on the aspect of land use pattern of the Assam part of the study area based on Landsat 8 OLI, 2015 and Landsat 5, 2008 imageries in GIS environment.
Here, seven land use and land cover categories have been identified for which the study is conducted. The areas under different land use categories are shown in the fig.2.13a and fig.2.13b. The areal coverage and land use change is presented in the table 2.3. It is observed in table-2.3 that 33.39 per cent and 25.68 per cent of agricultural and Settlement area is increased during a time span of seven years. The increase of agricultural land have primarily because of the clearing of mixed forest areas located in the northern part of the study area. Because of clearing of mixed forest area construction of settlement and transportation lines are also attributable to decrease of forest area during 2008-'15. Illega felling of trees and collection of forest resources for business is another reason of decrease of forest area in the study area. It is evident that many patches of mixed forest area are also scatterdly existed in the study area.
2.7 Population

The study area has 95 villages in 2011 (Town and Village Directory, Census of India, 2011). Besides some institutions and other establishments are also found to exist in the study area. Total population is calculated to be 1,12,003 persons and 53,807 persons in 2011 and 1971 respectively with increase of 58,196 persons in 20 years. The male and female population of the study area is 56,363 persons and 54,635 respectively in 2011. The same is 28,199 persons and 25,608 persons in 1971. The high increase of
population during 40 years (1971-2011) exerted a great pressure in the natural resources including land, water, and forest. Construction of settlements, transportation lines, increases of agricultural land, intensive cropping are some of the activities which directly or indirectly impacted the fluvial processes like flood and erosion. Bank erosion has been accelerated due to human impact such as destruction of bank vegetation, sand quarrying as a result of increase of population pressure during recent years.