CHAPTER II

REVIEW OF LITERATURE

The present investigation has been undertaken for identification, genesis, characterization and classification of older alluvium and their present status and use for better management of land and its resources. The literatures relevant to the present investigation are reviewed under the following heads:-

2.1. Geo-environmental Study

2.2 Older alluvium

2.3 Soil Characteristics

2.4 Classification and mapping of the soil

2.5 Geo-environmental factors and processes of Soil formation

2.6 Paleohistory, Land use/land cover

2.7 Land evaluation for land use planning

2.1 GEO-ENVIRONMENTAL STUDY

The geo-environment on one hand affords the human community to take advantages of mineral and ground water resources and other favourable geologic phenomena necessary for its existence and evolution; on the other hand, it endangers the mankind by harmful
geologic processes and brings about unfavourable condition for the development of the Society (Hrasna, 2002).

Sarma, S (2006) conducted a geo-environmental study of Kulsi watershed, Assam covering geology, soil, land use, water resources and socioeconomic aspects for sustainable development of the area. A number of suggestions were made for use of land like gap afforestation, economic plantation, fuelwood and fodder plantation etc. ARSAC (1997) made a detailed study of the Puthimari watershed of kamrup district, Assam using remote sensing technique for sustainable development. Site specific action plans suitable for the existing terrain conditions were suggested for agricultural/horticultural development, soil management and flood management. For effective implementation and monitoring specific suggestions were also made.

The most critical problem engulfing the whole of the N.E. India is the problem of soil erosion and land degradation. The easily erodible alluvial soils are severely eroded by rain as well as flowing water. The eroded lands are mostly found in hills, although some areas in plains have also been damaged by river bank erosion, gully erosion and siltation in the flood plains of Brahmaputra, considerable areas of productive rice lands are eroded away due to formation of gullies (Sharma, N.N, 2003).

Majumdar et al (2001) placed on record a few evidences of neotechtonic activity in the Brahmaputra valley by geological/geomorphological mapping for identifying the hazards due to landslides, floods, erosion etc. to provide basic inputs for various developmental projects.
GSI (2002-03) took geo-environmental appraisal studies in the Tista Basin; upstream of Singtam, Sikkim and found that land use pattern of Nanching town is primarily governed by altitude, drainage and communication facilities. Landslide hazard zonation mapping was also carried out by GSI in parts of Aizawl and Kolasib districts, Mizoram and landslide inventory along NH-54 between north of Sairang and north of Kolasib has been completed.

Singh, T (2003) studied the geo-environmental hazard of the Arunachal Pradesh and found that under the active geodynamic condition of the region, geoenvironmental threat is quite active and there is a need to take extraordinary care while undertaking the developmental activities to minimize the adverse impact on the geo-environment.

Reddy et al (1997) made a geo-environmental appraisal in Morigaon and Nagaon districts of Brahmaputra valley and in parts of Barak valley of Assam. Regional geo-environmental appraisal involving preparation of multi-thematic maps depicting the geomorphology, channel migration pattern, land use/land cover and collection of meteorological data has been carried out.

Do Van QUY et al (2001) conducted geo-environmental research for environmental monitoring of Bau Trang Lake area of Binh Thuan Province, Vietnam and suggested for monitoring land use management, prohibiting cutting down trees and improving impoverished soil by adding more cattle manure and clay to the soil.
2.2 ALLUVIUMS-OLDER AND NEWER

Alluvium is soil or sediments deposited by a river or other running water. These are typically made up of variety materials including fine particles of silt and clay and large particles of sand and gravel. Flowing water associated with glaciers may also deposit alluvium. Alluvium formed on deposition during the Pleistocene age is known as older alluvium.

The alluvial soils are extensively distributed over the Brahmaputra and Barak plain. These soils are very fertile as they were formed from the alluvium, deposited by the rivers Brahmaputra, Barak and their tributaries. The alluvial soils of Assam can be further divided into two sub-types based on some micro differences in character such as – younger alluvium and old alluvium. The younger alluvial soil occurs in an extensive belt of the north-bank and south-bank plains including the active floodplains of the Brahmaputra and the Barak rivers. This soil is characterized by recent deposition of alluvium, moderately deep to very deep with grey to molted grey colour. It is mostly composed of sandy to silty loams and slightly acidic in nature. On the riverbanks it is less acidic and sometimes neutral or slightly alkaline. The soil lacks in profile development and is deficient in phosphoric acid, nitrogen and humus. The old alluvial soil occurs in some patches of Kokrajhar, Barpeta, Nalbari, Kamrup, Darrang, Sonitpur, Lakhimpur and dhemaji districts between the northern piedmont soil belt and the southern new alluvial soils of the Brahmaputra valley. In the south bank districts of the valley it occurs in a narrow belt bounded between the southern hill soils and northern new alluvial soils. In the Kopili plain covering Nagaon district the old alluvium finds wider extension (ASTEC, 2005).
The older alluvial plains of Brahmaputra valley of Assam are at a slightly higher elevation than the younger alluvial plains. The valley is mostly fracture controlled. The material consists mostly of highly weathered rocks comprising gravels, pebbles and sands of various grades forming the aquifer system with variable thickness of occasional clays. It represents a recharge zone with shallow ground water table (ARSAC, 1990). The Brahmaputra valley is made up of alluvial soils formed on recent river deposits called 'new alluvium'. There are few isolated pockets of Pleistocene deposits called 'old alluvium' within the valley, along the foothills and in parts of Bangladesh (Goswami and Das, 2003).

The archaeological sites of Mahasthangars and Paharpur stand on Barind tract of Bangladesh. Here the soil formed on older alluvium is well drained by numerous small entrenched meandering streams and rivers. The greater part of Barind tract is undissected and has poorly drained grey soils. The sloping soils of Madhupur tract on upland edges are vulnerable to erosion (Banglapedia, 2006).

The older alluvial plains of Victoria in Australia are extensive and generally flat with minor level differences where intense soil and regolith investigation is required to differentiate behaviour changes in the landscape to water movement and other characteristics. Drainage systems are very sparse apart from the major streams but are more evident radiating off occasional gentle low rises. Local variations in drainage reflect spatial variation of soil and regolith types (Victoria Resources online statewide, 2008).
2.3 SOIL CHARACTERISTICS OF OLDER ALLUVIUM

Morphological and physico-chemical characteristics of older alluvium derived soils in the Brahmaputra valley differ from other types of soil. The dominant hue of the soil colour of Brahmaputra basin is 10YR. Soils of uplands are dark brown to yellowish brown with value ranging from 4 to 6 and chroma 3 to 8. These colours of the soils indicate their better drainage conditions. Some of these soils also contain mottles with high chroma at variable depth of the profile. The fluctuation in the depth of water table in the profile causes the variation in the depth of mottles as the soil remains saturated temporarily during rainy season and subsequently oxidized during dry period (Chakravarty et al., 1978; Dutta and Karmakar, 1995; Chamuah et al., 1996; Talukdar et al., 2004). The recent and old flood plain soils, the channel soils and low lying soils have characteristics of gleyed colour associated with wetness (Chakravarty et al., 1978; Chakravarty et al., 1996; Das et al., 1997; Dey and Sehgal, 1997; Bhattacharya, 1998; Talukdar et al., 2004).

The structure of recent and old flood plain soil is weak and granular to subangular blocky in surface horizons and massive to subangular blocky in subsurface horizons. The structure of upland soils is moderate to strong subangular to angular blocky at lower horizons due to alternate wet and dry condition prevailing in the basin with considerable illuviation of clay in sub-surface horizons. The soils of the valley have wide textural variation ranging from sand to clay. The flood plain soils are predominantly silty loam to sand. The upland soils are loam to clay loam at the surface horizons and clay loam to clay at lower horizons. The upland (older alluvium) soils are stable and heavy textured, contains higher clays and clay rich argillic horizons are formed below the surface horizons. Flood plain soils
of the Brahmaputra basin contain a higher percentage of sand at lower depths. Sand content of upland soil is less than 28 per cent at the surface and it decreases further at lower depths. Soils near the Brahmaputra River are coarser in texture and those away from the river are finer in texture (Chakraborty et al, 1978; Dutta and Karmakar, 1995; Das et al, 1997; Gangopadhyay et al, 1998; Talukdar et al, 2004, Jain et al, 2007).

In the alluvium-derived soils of Assam, the soil pH value decreases with the increase in age and degree of development of soil (these values were 7.6 to 8.0 in the recent flood plain soil, 4.4 to 7.5 in the old flood plain soils and 4.8 to 6.4 in the two upland soils). The pH values also decreases with the increase in the intensity of the rainfall in the area (Chakravarty et al, 1978). The bulk density of the soils of the Brahmaputra basin ranges from 1.36 to 2.10 g/cm³. Relatively more developed upland soils of the basin have a higher bulk density than other soils. The bulk densities of the soil chiefly depend on the clay content. The Cation exchange capacity (CEC) of the soils of the basin varies from 3.0 to 23.3 me/100g. The CEC of the soils is found mainly controlled by the clay content of the soil. The base saturation of the soils varies between 25.7 to 54.7 per cent. The organic matter content of the surface horizons of the soils of Brahmaputra basin varies from 0.60 to 2.90 per cent and its distribution decreases with depth (Chakravarty et al, 1978; Dey and Sehgal, 1997; Bhattacharya, 1998; Talukdar et al, 2004; Jain et al, 2007).

The tea soils of the Brahmaputra valley which occupy an area of 196173 ha are mainly alluvial and vary widely in texture. Some of the soils on the north bank are usually very sandy and poor in plant nutrients. Most of the tea soils of the Brahmaputra valley have
low to medium organic matter status. There are small areas of old red soils which are mostly loamy in texture and suitable for tea (Talukdar et al, 2004).

NBSS and LUP(2002) found that the soils occurring on old alluvial plains of Assam are very deep, brownish to yellow brown, moderately well drained to well drained, fine loamy to coarse loamy, slightly to moderately acidic with low CEC and poor base saturation. The south bank old alluvium show structural and/or coloured B horizon while argillic horizon is also noticed at some places; these soils are very deep, pale brown to reddish brown, moderately well drained to well drained, light textured, strongly to moderately acidic, rich in organic matter with low CEC and base saturation.

Sen et al (2003) found that soils of Central Assam range are generally well developed, moderately to strongly acidic with varying degree of Al saturation in subsoils, high in organic matter and low in cation exchange capacity (CEC). The soils of Brahmaputra valley exhibit great spatial variability. The soil in general are very deep, poorly drained to well drained, slightly acidic to neutral, low in CEC, high in organic carbon and have moderate to high base saturation.

Goswami and Karmakar (2002) reported that the old flood plain soils of the Citrus Research Station, Tinsukia, Assam are dark grey brown to yellow in colour and coarser in texture. The structure of the soil is mainly subangular blocky. The soils are acidic in nature (pH 4.5-5.9) and varied considerably in organic matter (0.13 to 2.46%), clay content (4.5 to 23.6%) and CEC (2.9 to 8.5 cmol (p+) kg⁻¹). Calcium is the dominant cation in the soil followed by magnesium.
Bhaskar et al (2008) found that the newer alluvium flood plain soils of Majuli are coarse loamy, having low organic matter (1.5 to 5.2 g kg\(^{-1}\)) content, have dark grey and olive grey matrix with coarse loamy particle size in the control section and slightly acidic to neutral in reaction.

The soils in the Barind and Madhupur jungles of Bangladesh formed on older alluvium are hard dark brown to reddish clays and loams. The major soils of the Barind track are Clay-Clayey loam and loam soils. Clay-Clayey loam-Loam soil (98%) dominates the area with a small portion of Sandy loam (2%) soils. The top and sub soil is generally Clay to loam and substratum is dominantly Clay soil. They are sticky during rainy season and hard during the dry period (Encyclopedia Britannica on line, 2007).

2.4 CLASSIFICATION AND MAPPING OF THE SOIL

The recent system of Soil classification which is being used in India has been developed in U.S.A after it was passed through various stages and the last one is 7th approximation (Soil Survey Staff, 1960). Later this system of soil classification was published as USDA soil Taxonomy which has been modified a number of times and recently it has been further modified and improved in 1998 (Soil Survey staff, 1998).

The alluvium derived Soils of Brahmaputra valley have been grouped into new and old alluvial and forest soils according to the conventional system of soil classification. These ill defined groups include widely divergent soils which are placed together simply because of common mode of formation of parent material or other existing land use. However, at
present these soils are classified according to Soil Taxonomy. The major groups of alluvium-derived soils are Entisols, Inceptisols and Alfisols (Chakravarty et al, 1981; Karmakar, 1985; Bhattacharya et al, 1998; Talukdar et al, 2004).

Talukdar et al (2009) studied the Char areas of Nalbari district, Assam to identify and delineate different sub-agroecosystems using remote sensing and GIS techniques for effective crop diversification. Based on soil-site characteristics, hydrology, ground truth and socioeconomic parameters, three agro-economic subdivisions viz- Occassionally flood effected area (OFAA), annually flood effected area (AFAA) and frequently flood effected area were delineated.

Goswami and Karmakar (2002) classified the old flood plain soils of the Citrus Research Station, Tinsukia, Assam as Inceptisols (Oxyaquic Dystrudepts and Aquic Dystrudepts). Soil correlation was carried out to identify the soil series and to delineate their extent on map and three tentative soil series were identified in the study area.

Dey and Sehgal (1997) classified few paddy and nonpaddy soils of Assam on the basis of morphological, physical and chemical characteristics and placed soils of North Lakhimpur, Titabor and Kaki under the order Inceptisols due to presence of Cambic horizon, where as soils of Cachar were placed under order Alfisols due to the presence of argillic horizon.

Sen et al (2003) presented an account of the nature, classification, distribution, land use limitation, potential and management of the major soils of Assam based on soil resource inventory undertaken on 1:250000 scales and other database vailable. These soils
have been developed on sedimentary, metamorphic rocks and alluvium under the predominant influence of climate, vegetation and topography and classified into 4 orders, 9 suborders, 15 greatgroups and 26 subgroups. Inceptisols are dominant soils (41%) followed by Entisols (34%), Alfisols (11%) and Ultisols (4%).

Goswami and Duarah (1996) conducted geomorphological mapping of Assam using satellite remote sensing and identified different geomorphic units and delineate their boundaries in the map. The geomorphic units identified were alluvial plain (flood plain, younger alluvial plain, older alluvial plain, lower piedmont plain, upper piedmont plain and valley fill) structural hill, denudational hill, water body etc.

The Soil Resources Development Institute (SRDI) identified about 500 soil series in Bangladesh. All of these soil series have been mapped as soil association by the SRDI through reconnaissance soil survey carried out during 1965 and 1975. These soil series have been correlated with the FAO-UNESCO soil units of Fluvisols, Gleysols, Histosols, Planosols, Luvisols, Cambisols and Arenosols. According to the USDA soil taxonomy, these soil series falls under the order Entisols, Inceptisols, Histosols, Mollisols, Ultisols and Alfisols (FAO, 1988).

Sen et al (1992) employed remote sensing techniques to identify and delineate soils in a part of Dibrugarh district of Assam. Landsat-4 MSS data in the form of FCC (4, 5, and 7) were interpreted visually for physiographic analysis in conjunction with Survey of India topographic maps. Ground data were translated in terms of soils using composite interpretation map as base. The abstraction level attained was Families of Soil Taxonomy.
Four major physiographic units were delineated, viz. active flood plain, recent alluvial plain, gently undulating old alluvial plain and gently sloping to undulating piedmont plain. Dominant soils identified were: coarse loamy Aeric Fluvaquents and fine loamy Typic Udifluvents in active flood plain; fine Typic Haplaquepts and fine loamy Aquic Dystrochrepts in recent alluvial plain; fine loamy Umbric Dystrochrepts and fine Ultic Hapludalfs in old alluvial plain; coarse loamy Typic Udorthents and fine Mollic Hapludalfs in piedmont plain.

NBSS & LUP (2002) in collaboration with the State Department of Agriculture, Assam classified the soils of Assam according to US soil Taxonomy and found that major Soil orders of Assam are Alfisols, Entisols, Inceptisols and Ultisols. They identified 10 sub-orders, 17 great groups, 35 sub-groups, 86 families including 84 mapping units covering the whole state. It also prepared a soil map of Assam depicting soil group according to US soil taxonomy.

The old alluvial soils of Indo-Gangatic plains are locally known as bhangar which is more clayey, dark in colour and full of Kankar. In the US soil Taxonomy such soils fit in the order Alfisols and in great group level it falls under Haplustalfs and Natrustalfs (Sehgal, 1996). Sharma and Mandal (2006) mapped salt affected soils in irrigation command of the western Jamuna canal using digital image analysis and GIS. The final map showed five salinity classes with an overall accuracy level of 85.6 per cent.

ASTEC (2005) in its State of Environment report, Assam placed the older alluvium soils of Assam under the order Alfisols and in great group level as Paleaustalfs and Haplaquants. The soils are distributed between the upper limit of the Brahmaputra flood plain
and Piedmont zone of Arunachal Himalaya to the north and north east, Nagaland in the south and fringe area between Karbi Anglong and the Kopili and Dhansiri valley.

2.5 GEO-ENVIRONMENTAL FACTORS AND PROCESSES OF SOIL FORMATION

Soil formation is a process of two consecutive but overlapping stages. The sequence processes involved in the formation of soils are the formation of regolith by the breaking down of bedrock through weathering and addition of organic matter through the decomposition of plant and animal tissues and reorganization of these components by soil forming processes to form soil. The older alluvium soils are upland soils that are developed in areas unaffected by stream activities in recent geologic time and ordinarily lying at higher elevations on rolling and convex position.

2.5.1 FACTORS

Soils are natural expression of the environment in which they were formed. There are many factors which influence geologic processes that produce weathered rock materials that is regolith. The genetic factors set the stage of soil development process. The main factors that influence geological weathering are:

- Climatic conditions
- Physical characteristics of rocks and minerals and
- Chemical and structural characteristics of rocks and minerals.

Soils are derived from regolith that has been subjected to wide spectrum of climatic conditions. Soil development is influenced by the topography on which soil occur, the plant
and animal life which they support and amount of time which they have been exposed to these conditions. The combined influence of these factors determines the properties of a soil. Soil scientists recognize five major factors that influence soil formation: -

- Parent material (regolith) and geology
- Climate
- Living organisms/vegetation
- Topography and
- Time

Chakravarty et al (1980) studied the role of soil forming factors in the pedogenesis of alluvium derived Soils of southern bank of the river Brahmaputra and found that climate plays a dominant role in the genesis of these soils. The difference in soil development in the uplands of the eastern vis-à-vis middle region is due to rainfall and that between eastern and western region is due to the temperature variations. The high rainfall results in increasing the organic matter, Fe and Al oxides and in decreasing soil $p^H$ and silica/sesqui oxides ratio. The enrichment of clay in the upper horizons of low lying areas and occurrence of kaolinite and montmorillonite minerals in old flood plains are manifestation of influence of topography. Influence of parent material is evident on the soils near the river which gets modified gradually with distance from the river. The soil development also shows the effect of increasing age of the alluvium. The upland soils are more developed due to origin of the alluvium of the Pleistocene age but the old flood plain is less developed due to origin of younger alluvium.
Chakravarty and Baruah (1983) found that vegetation influenced the genesis of the soil through accumulation of high organic matter and exchangeable calcium throughout the soil profiles. Plant canopy and grasses might have contributed to the addition of high organic matter in the soils of citrus growing belts of hill districts of Assam.

Dutta et al (1999) reported the influence of plantation crops viz-Tea, Coffee and Rubber on soil characteristics of Brahmaputra alluvium. The report indicates that soils under non plantation fallow contain higher amount of basic cations as compared to under plantation crops. The difference in organic matter content of the surface horizons are evidently due to differences in vegetation. In case of bulk density, besides organic matter content the rooting system of crops also influences it as higher bulk density of soils under tea was found compared to Coffee and rubber due to different rooting patterns.

Sen et al (2003) reported that the soils of Brahmaputra valley have been developed on sedimentary, metamorphic rocks and alluvium under the predominant influence of Climate, Vegetation and Topography. The diverse climate, physography, geology and vegetation have led to considerable variation in soils of the valley.

Bockheim et al (1999) studied the factors and processes of soil formation on uplifted marine terraces in south western Oregon, USA and found that the time is an important soil forming factor because as soils age, many original minerals are destroyed and many new ones are formed. Soils become more leached, more acidic and more clayey. In many well drained soils, B horizon tends to become reddish with time.
Sarkar, D et al (2001) carried out pedologic investigation on a soil toposequence of chotanagpur plateau developed in old alluvium underlain by granite gneiss. The soils in the upper slope of the toposequence are very deep; yellowish red to dark red in colour whereas soils in the lower slopes are very deep; light brownish grey to grey in colour. All the soils are well developed, however the profile development was least at the toe end of the toposequence.

### 2.5.2 PROCESSES

The processes of formation of regolith from the hard rock can be divided into two parts:

- Geochemical weathering and
- Pedochemical weathering.

Geochemical weathering is that taking place below the soil solum and that which would take place where the soil solum is not there. Pedochemical weathering is the disintegration and chemical modification of mineral taking place within the soil solum with all the associated biologic and other soil forming processes. The various reactions that take place as part of geochemical weathering are oxidation, reduction, oxidation-reduction, hydration, solution and hydrolysis. Important reactions that take place under pedochemical weathering are Oxidation-Reduction cycles, Shuttling of Al from clay lattices to hydrous oxides via exchange sites and Al inter layering of clay minerals.

Important soil forming (Pedogenic) processes that take place on regolith formed after weathering is:
- Eluviation: movement of material out of a portion of a soil profile.
- Illuviation: movement of material into a portion of a soil profile.
- Leaching: washing out of eluviating soluble materials from the soil solum.
- Erosion, surficial: removal of material from surface layer of soil.
- Laterization: chemical migration of silica out of the soil solum and concentration of sesquioxides.
- Podzolization: chemical migration of sesquioxides and concentration of silica.

In the upland soils of Brahmaputra valley of Assam, illuviation of clay is a dominant soil forming process which is the reason for formation of argillic horizon in the soil profile. The soils towards the Assam ranges are older in age and finer in texture even in lower horizons and this has been ascribed to the advanced stage in weathering and translocation of clay to the lower depths. The chemical processes associated with reduction and mobilization of Fe and Mn, results in low chromas under saturated conditions and high chroma colours with subsequent oxidation and precipitation under unsaturated conditions (Chakravarty et al, 1978; Das et al, 1997, Bhattacharya et al, 1998).

Dey and Sehgal (1997) reported that all studied paddy soils of Assam showed marked eluviations of both free iron and manganese from surface horizons with corresponding zone of illuviation in the B horizon. The zone of illuviation of free Mn was below that of free Fe.

Reddy et al (1997) found that older alluvial plains of Morigaon district of Assam designated as Amsoi surface is an erosional plain developed due to coalescing of alluvial fans.
of rivers, located at higher elevation and characterized by high degree of oxidation and
dissection.

The Barind tract of Bangladesh, unlike other floodplain terraces was uplifted and
formed above the sea level probably before the late Pleistocene. Since then it has been
subjected to the action of soil forming processes. Soils have been developed in the two kinds
of Madhupur clay- deeply weathered pervious clay and little altered impervious clay. They
vary considerably in drainage, depth of solum and degree of profile development depending
on the extent of weathering of parent material and topography (FAO, 1988).

Alexander L. Alexandrovskiy (2007) studied the rates of the soil forming processes in
three main models of pedogenesis and found that the rate of most soil forming processes are
much higher under humid climatic condition than under arid climatic conditions.

Dahlgren (1998) studied the soil forming processes in vernal pools of northern
California and found that dominant soil forming processes are ferrolysis, organic matter
accumulation, clay formation and translocation, duripan formation and calcium carbonate
accumulation.

The older alluvial plains of Victoria of Australia are older and generally higher in
landscape. All of the soils on these plains are derived from sediments deposited mainly
during the Pleistocene (Late Neogene) which is collectively known as the Shepparton
Formation. The age of the regolith, its constituent, particle size distribution and climatic
factors have influenced the land forming processes and pedological development of today’s
soil (Victoria Resources online statewide, 2008).
2.6 PALEOHISTORY, LAND USE/LAND COVER

2.6.1. PALEOHISTORY

Paleohistory is the study of physical remains that societies of humans and animals have left long after their own demise. These remains usually include bones, fossils, tools or implements and rock art.

The older alluvium is formed on deposits made during the Pleistocene age. The Barind tract of Bangladesh is floored by the characteristics of Pleistocene sediments known as the Madhupur (Barind) clay. They were deposited in the late Pleistocene time towards the end of the glacial period. Nearly 18000 years ago the last glacial period reached the peak of activities. During that time the sea level dropped to 100m to 130m below the present day level and dry and cold climate prevailed. Later 12000 years ago the south west monsoon climate started dominating the region and brought heavy rainfall over the Bengal basin. The rivers spilled over the banks and deposited sediments over the large Bengal plains. After the deposition, due to the neotectonic movement, these regions got uplifted and formed high terraces (Banglapedia, 2006).

The older alluvial plain designated as Amsoi surface of Morigaon district of Brahmaputra valley of Assam is an erosional plain developed due to coalescing of alluvial fans of rivers and is located at a higher elevation. It rests uncomfortably over pre-cambrian basement rocks that are gneiss and granite. The soils are presently utilized for tea plantation. Radiometric dating of 17920± 575 B.P. of the entrapped wood fixes the age of this surface as upper Pleistocene (Reddy et al, 1997).
Alam, Shafiqul et al (1997) used oxygen and carbon isotope composition of pedogenic carbonates from Pleistocene paleosols in North West Bangladesh as paleoclimatic indicators and found that variations in the oxygen isotopic composition are much smaller and these smaller differences could have been induced by temperature changes.

Frye, John C. and Leonard, A. Byron (2008) reported that Kansas possesses representative deposits of each Pleistocene stage with glacial deposits of Nebraskan and Kansan ages. All Pleistocene stages in Kansas contain abundant fauna of fossil mollusks and more than 100 species are listed from more than 200 localities. The existing landscape of Kansas is a result primarily of geologic processes operating during Pleistocene time.

### 2.6.2. LAND USE/LAND COVER

Land use is a series of operations on land, carried out by man, with the intention to obtain products and/or benefits using land resources (Huizing, 1994). Land use is carried out in different ways but can be divided in two categories: -

- Rural land use; including agriculture, forestry and wildlife.
- Urban and industrial land use including towns, villages and industrial complexes.

A kind of land use described or defined in a degree of detail is known as Land Utilization type. Mishra, A.K. and Satapathy K.K. (2003) reported the land use classification of Assam as follows: -
Out of these actual land use/land cover area covered by Forest land is 1726.387 ('000ha) and Agricultural land is 4248.638 ('000ha).

NBSS&LUP (2002) showed the land utilization of Assam (Area in '000ha) in table 2.1:

**TABLE 2.1: Land Utilisation in Assam**

<table>
<thead>
<tr>
<th>Category</th>
<th>Area (000ha)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forests</td>
<td>1984</td>
<td>25.3</td>
</tr>
<tr>
<td>Barren and non-cultivable land</td>
<td>1541</td>
<td>19.6</td>
</tr>
<tr>
<td>Land put on non-agricultural purposes</td>
<td>914</td>
<td>11.6</td>
</tr>
<tr>
<td>Others</td>
<td>707</td>
<td>9</td>
</tr>
<tr>
<td>Net sown area</td>
<td>2706</td>
<td>34.5</td>
</tr>
</tbody>
</table>

Net shown area-2706 (34.5%), Forests-1984 (25.3%), Barren and non-cultivable land-1541 (19.6%), land put to non-agricultural use-914 (11.6%) and others-707 (9%).

Vadivelu et al (2003) prepared a land use plan for Jorhat district of Assam and found that the soils near foot hills covering an area of 40571 ha are presently under tea cultivation with limitation of organic carbon, coarse texture and strong acidity. The Tiru and Disoi soil are under natural forest covering 12286 ha and mostly occurs on moderately steep to strong hill slopes.
The well drained, humus reach hill and upland soils of the Brahmaputra valley are suitable for tea, coffee, pineapple, rubber and other crops tolerant to high level of aluminium saturation. The Alfisols and Ultisols of similar characteristics of the adjoining north eastern region show that tea, native spices and horticultural crops could be meaningful land use options in Assam (Sen et al, 2003).

The older alluvium soils of upper Brahmaputra valley are mostly utilized for tea plantation where as in central and lower Brahmaputra valley. These areas either utilized for growing upland/horticultural crops or covered by forest and timber. The older alluvium soils of Kamrup district of Assam are found to be suitable for growing plantation crops like arecanut, mango, jackfruit etc. (ARSAC, 1990).

Rahman et al (2007) found that the changes in vegetation cover in response to the rainfall amount show a higher sensitivity of the Barind tract areas in comparison to flood plain areas of Bangladesh. Land cover information as derived from multidate Landsat data demonstrates a relatively high change (about 68%) in the aerial extent of vegetation cover in the Barind tract and a small change (about 8%) in the flood plain areas between summer and rainy season though both sites receive an almost similar amount of seasonal and annual rainfall. The flood plain areas are found to be moderately vegetated across different seasons, which is in contrast to the semi-arid Barind tract area that remains either mostly bare or highly vegetated depending on the season.

Ramesh kumar et al (2007) studied soil quality changes in relation to change in land use in Rajankunte watershed, Karnataka between 1980 to 2002 and found that cultivable land area reduced at 4.1 ha annually. The area under food crops, agro-forestry and grazing lands has been diverted to horticultural fruit crop like grape, guava and banana. Nitrogen and
phosphorous application increased. The change in land use and management resulted in increase in area under acid soils, decline in base saturation and organic carbon.

2.7. LAND EVALUATION FOR LAND USE PLANNING

Land suitability evaluation is the process of assessing the suitability (or potential) of land for a specific use. Land evaluation is concerned with assessment of land performance when used for specific purposes. It involves execution and interpretation of basic surveys of climate, soils, vegetation, and other aspects of land in terms of requirements of alternative forms of land use.

Land evaluation is the assessment or prediction of land quality for a specific use, in terms of its productivity, degradation hazards and management requirements (Austin and Basinki, 1978). The essence of land evaluation is to compare or match the requirements of each potential land use with the characteristics of each kind of land. The result is a measure of the suitability of each kind of land use for each kind of land. These suitability assessments are then examined in the light of economic, social and environmental considerations in order to develop an actual plan for the use of land in the area. When this is done, development can begin. Land evaluation is done for land use planning for both agricultural and non-agricultural uses. Non-agricultural uses include construction of building, highways, laying of pipelines, disposal of sewage, pollution etc. whereas for agricultural purpose it is mainly done for use of soil for growing, crops livestock, forestry etc.

A typical approach of land evaluation is the Capability System of the USDA Soil Conservation Service, published by Klingebiel and Montgomery (1973). This evaluation
method lists a number of criteria like depth of soil, texture and structure, permeability, relief, erosion, flooding, depth of ground water table, climate etc. that are essentially related to permanent physical or other characteristics that either limit land use or impose risk to yields or management potentials.

Land is also evaluated for suitability for sustained use under irrigation by grouping soils in to irrigability classes. For making such a kind of interpretation (of soil and land conditions) one is concerned with predicting the behavior of soils under greatly altered water regimes brought about by introducing irrigation (Sehgal, 1996).

The FAO Panel for Land Evaluation (1976) defined the concept of land utilization types and suggested the classification of land for specific use. The classification itself is presented in different categories: Order, Classes, Sub-classes and units known as Land suitability classification. According to FAO (1993), Land use planning is the systematic assessment of land and water potential, alternative patterns of land use and other physical, social and economic conditions, for the purpose of selecting and adopting land use options which are most beneficial to land users without degrading the resources or the environment. Land use planning may be at international, national, district or local levels. It includes participation of land users, planners and decision-makers and covers educational, legal and financial measures.

Soil-site suitability evaluation for crops forms an essential part of every land use planning programme. Several soil and site characteristics are used as parameters for assessing the suitability of land for crops in every land evaluation exercise. Another rule of land evaluation states that more the number of limiting properties lesser is the suitability
rating. Hence, it becomes all the more essential to exercise caution in identifying the soil-site characteristics for use as parameters in land evaluation. In the Brahmaputra Valley, soil texture, pH, organic carbon and inundation decide the suitability of the land for growing rice, potato, cabbage, tomato, french bean, peas and cowpea (Vadivelu et al, 2004).

Walia and Chamuah (1991) evaluated soil and land suitability for plantation crops in Karbi Anglong and North Cachar hills of Assam utilising different topographical and climatic conditions. Soil pH appeared to be the key factor determining the suitability of Citrus and Banana as both the crops can be planted on fine textured soil provided drainage is satisfactory. Ultisols characterized by low pH and low base saturation were categorized as marginally suitable for banana. The soils occupying piedmont plains placed in Inceptisols and Alfisols were found to be suitable for Banana plantation because of favourable soil pH, texture and drainage. Soil and topography are the major factors that will determine the suitability of plantation crops since climate in the region is optimum.

Sen et al (2001) evaluated the soil erodibility of Jorhat and Sibsagar districts in the Brahmaputra valley of Assam with respect to their inherent soil properties. It was found that the percentage of total geographical area under high erodibility ratings were 63 and 68% for Jorhat and Sibsagar districts respectively. Presence of high silt fraction renders these soils susceptible to erosion under high rainfall. It was found that the soils with higher content of intermediate size fractions (silt+very fine sand) are more erodible than the soils with higher clay (clayey soils) and higher sand content (sandy soils).

Baruah et al (2005) conducted land evaluation for rapeseed/mustard in Nagaon district, Assam and found that in general soils are deep to very deep, coarse loamy to fine
loamy and slightly acidic to neutral in reaction. The valley soils have severe limitation of flooding and poor drainage during and immediately after rainy season and therefore most of them are associated with aquic moisture regime. The suitability evaluation for rapeseed and mustard indicates that 12.8% of area in the upland parts of the valley is suitable, 20.85% moderately suitable and 21% marginally suitable. The major soil limitations are poor drainage, acidity and poor base saturation.

Karmakar (1995) evaluated the soils of the Brahmaputra basin for their suitability for agriculture by using the index of soil productivity. In this approach the productivity index was calculated by considering eight factors viz- soil moisture content($H$), Drainage($D$), effective depth of soil($P$), texture and structure($T$), nutrient content of A horizon($N$), organic matter of $A_2$ horizon($O$), nature of clay($A$) and nutrient reserve($M$).

\[
\text{Productivity (P)} = H \times D \times P \times T \times N \times O \times A \times M
\]

Based on these indices of soil productivity, the upland soil (piedmont) of the basin are rated as better than alluvium soils for achieving higher crop yield. However for improvement of productivity of these soils, it will require adoption of measures such as drainage, timely irrigation and application of nutrient inputs.

Bhattacharya, T. et al (1998) surveyed the state of Tripura in 1:250000 scale to have the basic information of the natural resources with a view to finding out the soil suitability for rubber under the overall rubber expansion project of World Bank. On the basis of soil-site characteristics and the optimum requirement of rubber for soils and sites, all the soil units on the soil map were rated for overall suitability for rubber. The study indicates that
most of the soils of the Tripura state are moderately suitable for rubber which was estimated to be about 91,000 hectares forming 8.3 per cent of the total area of the state.

Giri, J.D. et al (2000) accessed the suitability of soils under Narmada Command in Gujrat state for irrigation using soil resource information. The information generated during the soil resource mapping of Gujrat state has been utilized to assess the extent of feasibility of using this information to delineate potential risk areas for productivity of soils under irrigation. The risks identified were water logging, rise in water table, secondary salination and erosion. Beneficiary farmers need to be trained to prevent the potential risks.

Patel et al (2001) conducted land capability assessment for land use planning using remote sensing and GIS in part of Solani watershed of Haridwar and Saharanpur district in Uttaranchal and U.P and present composite land use and land capability maps were integrated and suitable criteria were framed to prepare land use adjustment plan for appropriate soil conservation needs and proper land utilization.

Vaidelu, S. et al (2003) evaluated the land of Jorhat district of Assam considering the compatibility of land uses with regard to landscape ecological factors in evaluation and planning for growing crops such as rice, wheat, mustard, ground nut, potato, tea, banana etc. and found that soil PH and coarse texture are major limitation for crop growth. Several crops were recommended depending on their suitability for the post-rainy months in the soils which are kept fallow in the present land use system. Potato and mustard were found to be suitable for almost all the soils in the post-rainy season. The soils near foot hills
covering an area of 40571 hectares were under tea cultivation with limitation of organic carbon, coarse texture and strong acidity.

Satisha et al (2008) assessed the erodibility of rubber growing soils of Kerala and found that soils of lateritic origin showed relatively higher erodibility than soil developed over other parent materials. The soils with higher content of intermediate particle-size showed more erodibility risk than the soils with higher clay and sand content. In general, all the soils have moderate to high risk of erosion and hence needs suitable soil conservation measures to reduce soil loss and increase productivity.