"Mapping of suitable areas for expansion of Mulberry Sericulture in Jaintia Hills district of Meghalaya using Geospatial technology"

Dissertation submitted to North Orissa University

In partial fulfillment for the award of Master of Science In Remote Sensing & Geographic Information System

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CERTIFICATE

This is to certify that the Dissertation regarding the project entitled "**Mapping of suitable areas for expansion of Mulberry Sericulture in Jaintia Hills district of Meghalaya using Geospatial Technology**" is submitted by Gautam Borah, Registration No. - of 2014, in partial fulfillment of the requirements for the accomplishment of the final year project work for the award of the degree of Master of Science in Remote Sensing & Geographic Information System, Department of Remote Sensing & Geographic Information System at North Orissa University.

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DECLARATION

I, Gautam Borah a bona fide student of M.Sc. in Remote Sensing & GIS in North Orissa University, Odisha would like to declare that the dissertation entitled " **Mapping of suitable areas for expansion of Mulberry Sericulture in Jaintia Hills district of Meghalaya using Geospatial Technology**" submitted by me in partial fulfillment of the requirements for the award of the Degree of Master of Science in Remote Sensing & Geographic Information System is my original work. I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources.

Date: .....

Place: Gautam Borah

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1. INTRODUCTION

1.1 Background

Sericulture is one of the significant sectors of economy in India and plays a vital role in agenda of poverty improvement. Compared to agricultural crops, sericulture provides more employment all round the year and fetches higher income for rural farm families. Sericulture allows commercialization and diversification of farm enterprises. It is also an environmental friendly farm activity because the silkworm food plants like mulberry, som,tasar, eri and muga. etc.are perennial crops protecting the soil from erosion. Sericulture is an art and science of rearing of silkworm to produce cocoons and silk. Silk is the natural textile fiber and accounts for 0.2% of the textiles in the world though accounting for a meager quantity in textile sector, silk attract the user by its glamour, elegance, richness& beauty.

Indian sericulture is an ancient practice, producing all four types of natural silk namely Mulberry, Tasar, Eri and Muga. Our country is the second largest producer of mulberry silk accounting for about 15 percent of the of the global raw silk production. Mulberry sericulture is practiced in almost all states in the country but Karnataka, Andhra Pradesh, West Bengal and Tamil Nadu together account for about 98 percent of the total mulberry silk production in the country.

Non-mulberry sericulture, also known as forest sericulture, mainly consists of tropical and temperate Tasar, Eri and Muga. Nearly 95 percent of the global production of non-mulberry silks is Tasar. This sericulture provides livelihood for large number of indigenous and tribal communities.

Sericulture production is still limited to a few pockets in our country and there was sharp decline in mulberry area in some states (Andhra Pradesh, Tamil Nadu) during mid-1990s. The current production (about 17 thousands tones) is not adequate to meet the demand for silk in the country. There is tremendous scope for improving the

production and quality of silk through improved method of information collection, processing and dissemination, in addition to use of biotechnology.

The technology of remote sensing has further improved with launch of RESOURCESAT-1 (October 17, 2003) and CARTOSAT –1 (May 05, 2005) and CARTOSAT-2 on January 10, 2007 with improved spatial and temporal resolutions. The sensors on board these satellites allow us to detect and map sericulture activities over areas of size 50 to 300 sq. meters. Dhyani et al (1996) have reported that the sericulture-based agro-forestry systems (AFS) have great potential for higher returns in the north-eastern region with sloping and valley-land conditions. Based on a field investigation, initiated in November, 1992 at Research Farm, Barapani (980 m above msl, 26°N and 92°E and average rainfall 2428 mm/year) on acid Alfisol, they had evaluated seven mulberry (Morus alba L.) varieties, seven silkworm breeds and rearing performance of a bivoltine breed, NB-18. They tried three sericulture-based AFS viz. i) sericulture with fruit trees and fodder grasses, ii) field (upland) crops, and iii) lowland rice. Mulberry varieties TR-4, S-1635 and TR-10, and NB-18 — a bivoltine silkworm breed were found better suited for this region. Sericulture with field crops (French bean-groundnut-mustard/vegetables) for valley land, with fruit plants (guava, pineapple) and grasses for mid-hill situations, and with rice for low lands were found suitable at the farm and for possible adoption in the north-eastern hill region of India. Although many organizations are involved at various stages of silk production in different NER States, reliable information on the potential area suitable for silkworm food plants is not available at the district level and the extension machinery is not able to reach the far-flung places in the region. Host plant protectsthe soils from degradation, to raise surplus income in the hands of farmers and to attain ecological/economic security of the traditionally wheat-rice ecosystem of our country. It is in this context, sericulture has to be seen as an alternative to agriculture.

Developments in the geospatial technologies have allowed us in the past to mount many applications of relevance to sericulture development at grass-root level. Adoption of sericulture as an alternative to agriculture is possible under suitable agro-climatic

conditions all over India and especially NER. But the potential varies from place to place and needs scientific evaluation of an area before venturing into the practice. It is here that the satellite technology has an important role to play.

In enhancing and replenishing the decaying natural recourses and thus, improve the living conditions land-use/land-cover change have important role in it. The changing land use and land cover pattern in the world has a consequential impact on the natural systems of the earth. There are various forces involved in driving the changes throughout the world. A clear understanding of the changing dynamics and global factors can be understood through LULC mapping. Thus LULC mapping helps in future planning perspective. Changes for this we need to know kinds, distribution, extent, quality and quantity of unit area of land. Combination of RS and GIS is an effective tool to know these parameters and has used to analyze the land used land cover changes for Jaintia hills district. Knowledge of extent of land utilization is essential for any land use planning to provide any adverse consequences in future. Such planning also requires the knowledge of land diversion over a period of time to judge the priority of the area.

Although the mainstay of the district is agriculture, sericulture is an important cottage based eco friendly industry in the rural areas. Sericulture is widely practiced in the rural region but there has not been much development in this sector. Hence, there is a scope for expanding the area under host plantation for silkworm to increase production of silks and thereby improve the economy of rural people. Therefore Jaintia hills district is selected for this study.

1.2 GIS & REMOTE SENSING

Geographic Information System or simply GIS is an advanced map based analysis system. According to Rhind (1989) GIS is “the system of hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modeling and display of spatially referenced data for solving complex planning and management problems”. GIS is designed to managing spatial data and solve spatial

problems (C.P. Lo et al., 2007). The GIS system transforms the data into information through computational process and delivers the final output which can be used directly in the field to solve the spatial problems.

Data collection is an imperative stage for any research activity. Data can be collected in situ and by remote sensing means without being in any physical contact with the object under study. According to the American Society of Photogrammetric and Remote Sensing, remote sensing is "the measurement or the acquisition of information of some property of some object or phenomena by a recording device that is not in physical or intimate contact with the object or phenomena under study (Colwell, 1997). In remote sensing systems red, green and near-infrared dataset are used in many applications, there are many spectral bands located in the optimal locations of the EMR spectrum which will be useful for specific applications. The engineers have developed sensors sensitive to hundreds of bands in the EMR spectrum (John R. Jensen, 2005).The remote sensing can be used to characterize the natural resources on the earth by measuring the physical, chemical and biological aspects of the subject under study.

1.3 OBJECTIVES

The following objective are taken identification for study area

- Preparation of land use land cover maps of the Jaintia hills district
- Integration of required parameter in GIS domain for site suitability of silkworm host plant
- Identification of Potential areas for sericulture host plant

2. LITERATURE REVIEW

A variety of studies and research has been taken place on finding the suitability area of silkworm host plant using GIS and Remote sensing techniques. A considerable amount of study has also been done in India by government agencies and individuals. India keep on to be the second largest producer of silk in the world, India is the abode to an enormous diversity of silk secreting fauna which also includes an astonishing multiplicity of silk moths. This has enabled India to achieve the unique distinction of being a producer of all the five commercially traded varieties of natural silks namely, Mulberry, Tropical Tasar, Oak Tasar, Eri and Muga (Dr. S. Sudhakar, NESAC et al.). Silk obtained from sources other than mulberry are generally termed as non-mulberry or Vanya silks. Sericulture is one of the important sector of economy in India. Compared to agricultural crops, sericulture provides more employment all round the year and fetches higher income for rural farm families. In India, Sericulture is essentially a village based industry (Divya Uniyal et al., 2014). The production of sericulture is limited in some small pockets of area in the country. Their production is limited to certain agro-climatic conditions. Therefore there are only a few states in India which produces silk and still rare to find the state which produces all the five varieties of the silk. The states of Maharashtra, Karnataka, Tamilnadu, Orissa, West Bengal, Uttarakhand etc. Are the major producers of silk in the country, Total area under mulberry plantation in the country is 170,000 ha Meghalaya in which the current study area is situated is one among a few states in India which produces all the five varieties of silk. The current output of the industry is thought as inadequate considering the large possibility of extending the growth capacity in the country. However, total annual consumption of silk in the country is 29300 MT. By the year 2025, domestic demand is expected to increase to 45,000 MT/year showing tremendous growth potential in sericulture which could provide additional employment opportunities for up to four million rural families(Dr N K Sharma et al.,2012). The advancement of technology, particularly space

3. STUDY AREA

3.1 Location of study area

The study area is Jaintia hills district of Meghalaya with the geographical area of approximately 3819 sq. km. Agriculture is the major land use activity in the study area. Jaintia Hills District of Meghalaya is one of the seven administrative districts with its headquarters at Jowai. The area is located above the Mean Sea Level between 1050m-1350m. The Geographical location of the District is between 25^{o} 45'06.42" N to25^{o}

01'16.11" N Latitude and 91^{o} 58'29.24" E to 92^{o} 48'35.09" E Longitude. The prevailing climate in the state is characterized by heavy rainfall. The district is bounded by on the east and north, East Khasi Hills district on the west and has an international border with Bangladesh on the south.

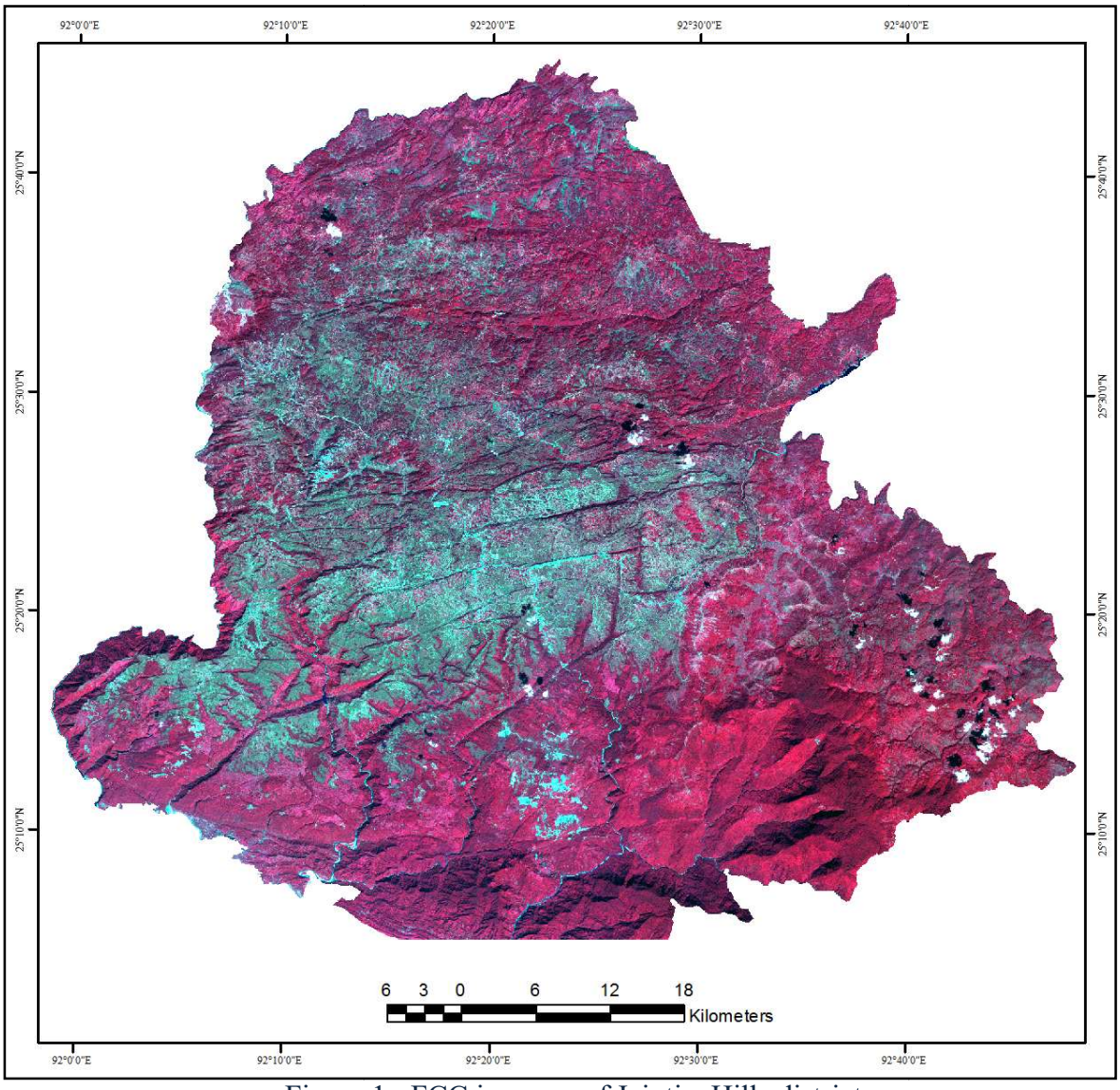

Figure 1 : FCC imagery of Jaintia Hills district

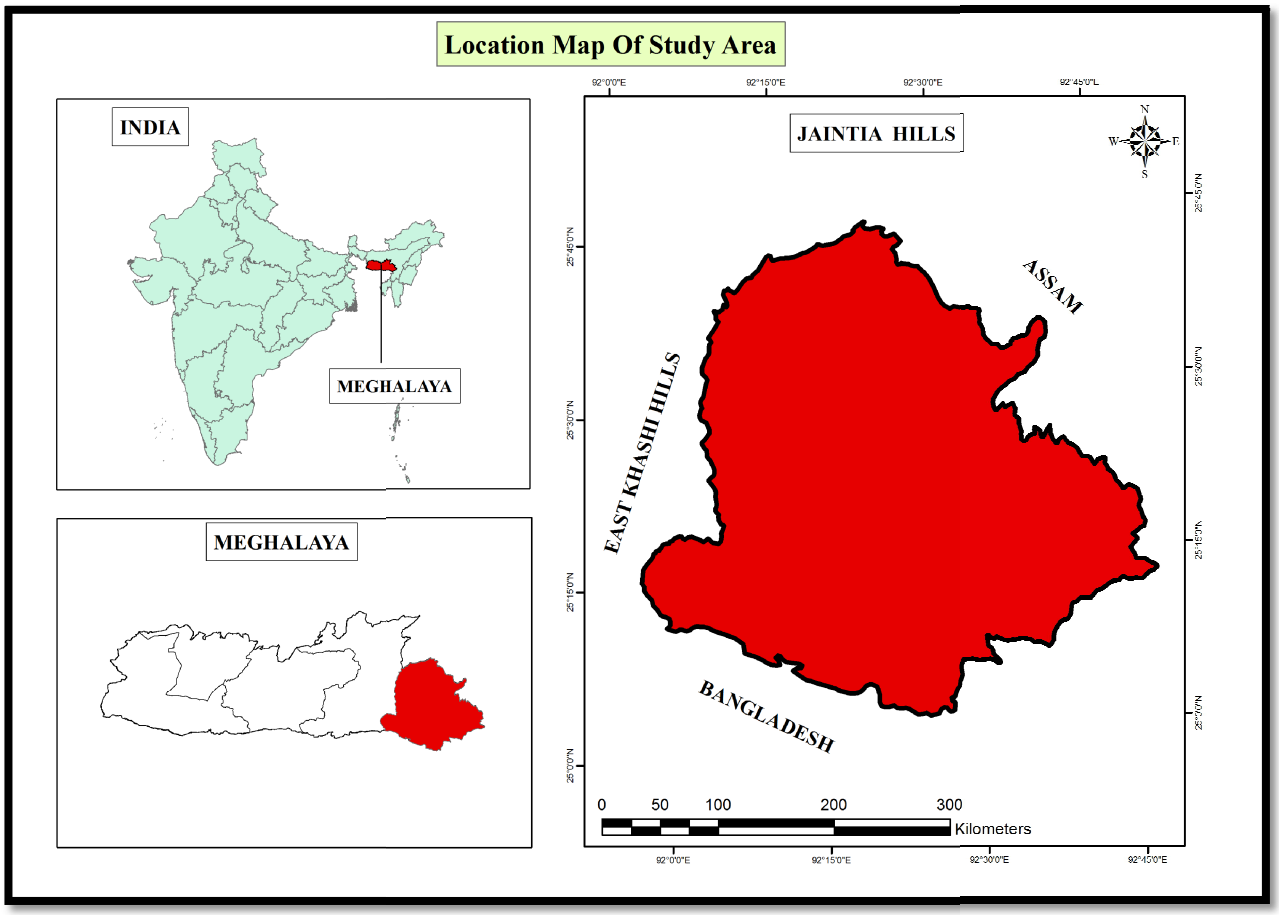

Figure 2: Location of study area

3.2 Geology

The plateau is mainly composed of pre-cambrian archaean gneissic complex with acid and basic intrusive, Shillong Group of rocks, Lower Gondwana rocks, Sylhet Traps and Cretaceous-tertiary sedimentary rocks.the Cretaceous-Tertiary sediments is divisible into three major group,viz. Jaintia Group, khasi and garo groups. The Jaintia group is one of shelf facies of Bengal basin of tertiary deposition mainly of calcareouse origine. this group is divisible into three formations viz. the Longpar, the Shella and the kopili formations. The rocks of langpar formation consist of calcareous shale,sandstone, limestone and fine calcareous sandstone.

3.3 Natural Vegetation

The upper part of the northern slope of Jaintia hills has shrubby vegetation and lower part of it has tropical evergreen type. Further the northern part of the Jaintia hills has moist deciduous type of vegetation with Sal as the principal tree.

3.4 Mineral Resource

A very large extensive limestone deposited is found in Jaintia hillsdistrictwhere it extends the eastern Jaintia hills. The limestone deposite are Lumshnong-Mynkre deposites,Sutnga deposite, Nongkhlieh deposites, Lakadong deposites,syndai deposites, Nongtalang deposites.

4. MATERIALS AND METHODS

4.1. DATA SOURCE

4.1.1. Archive data

- IRS P6 LISS III Image
- Land use/Land Cover map of year 2011-12
- Cartosat Image
- Cartosat DEM

4.1.2. Ancillary Data

- Soil data
- Meteorological Data
- Administrative Atlas

4.1.3. Software

- ArcGIS 10.2
- ERDAS imagine 2015
- Microsoft Word, Excel 2007

4.2. METHODOLOGY

4.2.1. Mapping of land use land cover (LULC)

Land use and land cover map is prepared from the IRS-P6 LISS-III images of 2015-2016. The map was prepared by following visual interpretation techniques using various scene elements like shape, size, tone, shadow, pattern, texture, site and association. A variety of land use/land cover categories were identified and mapped for the study area. Total areas for each categories of land use/land cover were calculated. Change analysis has been carried out using LULC map of 2011-12 and 2015-2016. Brief description of land use classes is given below:

A. Agricultural Land

This are the land primarily used for farming and for production of goods, fiber, and other commercial and horticultural crops. It includes land under crops (irrigated and un-irrigated, fallow, plantation etc.).

i. Agricultural Land-crop land- Kharif crop

These are the areas synonymous with the cropping session extending between June/July to September/ October1`.This class represent those areas, which are crop only during Kharif if crop is observed in this area during one or more other season, they are included under two crops area or more than two crops areas.

ii. Agricultural Land-crop land-two crop area

These are the area that area crop during either Kharif and rabbi or rabbi summer season that area often seen associated with irrigated area.

iii. Agricultural Land- and plantation and Horticultural plantation

These are the area that refers to cultivation of citrus fruits, orchards, other areca nut, and other horticultural herbs shrubs, fruits ornamental shrubs and trees, vegetable garden mostly under irrigated condition.

B. Forests

These are the areas bearing an association predominantly of trees and other vegetable types capable of producing timber and other forest products.

i. Forest -evergreen/Semi evergreen

These are areas that compresses of thick and dense canopy of tall tree which predominately remain green throughout year. It includes both coniferous and tropical broadly leaves trees. Semi evergreen is a forest type that includes combination of evergreen and deciduous spices with former dominating the canopy cover

ii. Forest -evergreen/Semi evergreen dense/closed

This category includes all the areas where they can canopy cover of density are more than 40%.

iii. Forest -evergreen/Semi evergreen open/ degraded

This category includes all the areas where the canopy cover/density ranges between 10-40%.

iv. Forest-Forest Plantation

These are the forest areas crown density is less than 10%.generally fever at the

C. Built up land

It is an area of human habitation developed due to nonagricultural use and that has a cover of building, transport and communication, utilities in association with water, vegetation and vacant lands

D. Wasteland

Wasteland is described as degraded land which can be brought vegetation cover with reasonable effort and which is currently underutilized and which is deteriorating for lack of appropriate water and soil management or account of natural causes.

E. water bodies

Water bodies: this category comprise areas with surface water either impounded in the form of pond, lakes and reservoir or flowing as streams, river, canals etc.

4.3. Identification of potential areas for mulberry silkworm host plant

The methodology for identification of potential areas for sericulture development involves evaluation of land and water resources requirements for growing silkworm food plants as well as rearing of silk worms. Mulberry *(Morus spp*.) is the only food plant for silk worm *Bombyx mori.* The assessment of suitability of land for sericulture involves evaluating the land qualities for the requirements of the silkworm food plants (FAO, 1976; Sys, 1985, Sys *et al*., 1993) and silkworm rearing. It needs interpretation and integration of climatic parameters, physiographic conditions, soil parameters and land use/ land cover etc. using GIS.

4.3.1. Evaluation of site suitability based on landscape and soil characteristics

Soil map at 1:50K prepared at NESAC under Soil Resource Mapping (SRM) project was used for evaluation of soil site suitability for mulberry plant. Different thematic maps like soil pH, texture, drainage, depth and stoniness were prepared by using soil map and soil reports. The Slope map was derived from DEM prepared from Cartosat images at NESAC under SISDIP project. The slope map was reclassified based on plant requirements. Information on ground water availability was obtained from ground water prospect map prepared at NESAC under Rajive Gandhi National Drinking Water Mission. Different thematic layers were generated in GIS environment for each of the land characteristics (Table 1) and compared with the requirements of silkworm food plants (Table 2). Degree of limitation ranging from 1 (suggesting no or slight limitation) to 4 (suggesting very severe limitation) is assigned.

Table 1 Soil site parameters considered for land evaluation

Soil site characteristics	Related land quality
Climate (c) during crop growing period -Total rainfall (mm) - Mean maximum temperature (ºC) - Mean minimum temperature (ºC) - Mean relative humidity (%) - Length of growing period (days)	-Available moisture
Topography and landscape (t) -Slope -Erosion	-Landscape position -Resistance to erosion
Wetness (w) conditions -Drainage -Ground water availability	-Available moisture/ soil aeration -Landscape position -Deficiency and toxicity of nutrients
Physical condition (s) of soil -Texture -Depth	-Water availability/ soil aeration/ soil structure -Available space for root development
Soil fertility (f) -pH	-Availability of plant nutrients

Table 2 Criteria or limitation rating for evaluation of soil site suitability for Mulberry

Soil-site characteristics		Degree of limitation & Suitability class			
Limitation	Unit	0-1 None to slight	2 Moderate	3 Severe	4 Very severe
Suitability		S1 (Highly suitable)	S2 (Moderately suitable)	S3 (Marginally suitable)	N (Not suitable)
Topography and landscape					
Slope	(%)	1-8	8-15	15-30	>30
Erosion		e_1	e_2	e_3	e_4
Soil characteristics					
Drainage	Class	Well	Moderately well	Imperfect	Poor/Excessive
Ground water	Availability	Good	Fair	Fair to moderate	Poor
Texture	Class	Clay loam–gravelly clay	Fine loamy	Coarse loamy	Sandy fragmental
Depth	Cm	>100	75-100	50-75	<50
pH		6.5-7.5	5.5-6.5	4.5-5.5	<4.5

4.2.2. Evaluation of site suitability based on climatic parameters for silkworm food plants

Climate is an important parameter which determines the growth of plant species, as the extreme climatic conditions are detrimental for plant growth. The suitability of climate for a given crop can be described in terms of: (i) minimal length of growing period, (ii) temperature, (iii) water supply (rainfall). The weather data, collected from the class-I observatories of IMD or the automatic weather stations (AWS) has to be analyzed for rainfall, maximum and minimum temperature, Potential Evapotranspiration (PET) and length of growing period (LGP) for the silkworm food plants.

Length of growing period (LGP) or moisture availability period for crop growth is the period (in days) when precipitation (P) exceeds 50 percent of the PET. Shorter LGP (less than 120 days for mulberry and 90-120 days for castor, as examples) may not suitable for cultivation of silkworm food plants.

Monthly potential evapotranspiration (mm) are computed by Thornthwaite method (1948) as illustrated below:

$$PET = 16 \times C \times (10 \times T/I)a \quad \text{for } T \leq 26.5^0C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

$$PET = C \times (-0.43253 \times T^2 + 32.244 - 415.85 \times T) \text{ for } T > 26.5^0C \quad \ldots\ldots\ldots (4.2)$$

Where,

PET = Potential evapotranspiration (mm/month)

T = Mean monthly temperature (^{0}C)

I = annual heat index for 12 months in a year ($I = \sum i$)

i = Monthly heat index $\{i = (T/5)^{1.514}\}$

$a = 6.75 \times 10^{-7} \times I^3 - 7.71 \times 10^{-5} \times I^2 \times 1.792 \times 10^{-2} \times I \times 0.49239$

C = Correction factor for each month

$C = (m/30) \times (d/12)$

m = No of days in a month, d = Monthly mean daily sunshine duration in hour

Based on climatic characteristics , limiting levels such as highly suitable, moderately suitable, marginally suitable and unsuitable have been decided by matching the requirements of silkworms food plants (Table 3) and assigned suitability class (limitation) to each polygons. Thus a climatic limitation map was generated. This map is superimposed on the soil limitation map, to finally arrive at a site suitability map.

Table 3: Suitability for Mulberry Host plant for Jaintia Hills district

Climatic characteristics	Suitability classes			
	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Mean temperature in growing season(^{0}C)	20-30	30-37	30-37	<15, >37
Total rainfall (mm)	500-750	750-2000	2000-3400	<500, >3400
LGP(days)	>120			

4.3.3. Evaluation of suitability for silkworm rearing

Silkworms are delicate and very sensitive to environmental conditions. Among the various environmental factors, the most important are atmospheric temperature and humidity prevailing at the time of rearing. Temperature has indirect correlation to the growth of the silkworms and excessive fluctuations in temperature are harmful and should be avoided. The combined effect of both temperature and humidity largely determines the satisfactory growth of the silkworms. The growth of the worm is better under higher temperature and higher humidity condition followed by lower temperature and lower humidity condition during their life cycle. Humidity also influences directly the physiological functions of the silkworm (Table 4).

Table 4: Suitability of mulberry silkworm rearing based on limiting condition of climatic parameters

Season/Crop	Limiting Temperature(^{0}C)			Limiting Average Relative Humidity (RH%)
	Max Temp	Min temp	Average	
Jan-Feb	23	15	20	55
March-April	28	22	25	55
may-Jun	30	25	28	70
Jun-July	29	24	28	85
Aug-Sept	28	24	27	85
Oct	29	23	26	85

The optimum temperature and relative humidity ranges are 20-28°C and 70-85%. The temperature above 30°C directly affects the health of the worm. The temperature below 20°C worm becomes too weak and susceptible to disease. But in hilly region (Limiting condition derived taking Mizoram condition as model) the minimum temperature and relative humidity it can withstand up to 15°C and 55% respectively.

4.3.4. Integrated evaluation of soil and climatic suitability for silkworm food plants and sericulture development

The limitation maps generated for climate (i.e. temperature, rainfall and length of growing period), landscape and soil characteristics (i.e. slope, soil drainage, texture, depth and pH) have been spatially overlaid in GIS environment to produce a composite layer. Each polygon of the resultant layer has 8 values (climate & soil characteristics) of degree of limitation. Based on number and the intensity of limitations suitability classes have been decided and graded as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N) as given in Table 5. The entire sequence of steps in this method is illustrated in figure 2.

Table 5 : Criteria for determination of land suitability classes

Land classes	Criteria
S1: Highly suitable	Land units with no or only 4 slight limitations
S2: Moderately suitable	Land units with more than 4 slight limitations and/or not more than 3 moderate limitations
S3: Marginally suitable	Land units with more than 3 moderate limitations and/ or one or more severe limitation
N: Not suitable	Land units with very severe limitation

5. RESULTS AND DISCUSSION

5.1. Land use land cover map

Seven major land use classes have been identified from the LISS III images of year 2015-16. From the study it is observed that tree clad area covers highest area (57.63%) followed by wastelands and forest that covers 25.13% and 8.52% respectively. The wastelands mostly open scrubland that covers 24.5% area and 0.5% area is under stony land. In the forest area mainly evergreen/semi evergreen plant species are available. Though agriculture is the mainstay of the district, the area under agriculture is only 3.29% of the study area. Built up and water body areas occupy only 3.02% and 0.95% area respectively. Very negligible area is under shifting cultivation (0.09ha).

5.2. Land use land covers change detection

For change detection study LULC maps of 2011-2012 and 2015-16 were used. From the study it is observed that during the period of 2011-12 to 2015-16, the area under agriculture, rural built-up and forest is increased where as wastelands has been decreased. The area under agriculture increased from 11276ha to 12608 ha. The net increase in the rural population of the study area has resulted in a corresponding increase in the agricultural land in the region. Wasteland area decreases 96482 ha to 96114 ha. Area under evergreen forest is increased from 27905 ha to 28745 ha. Scrubland is converted to built-up and agricultural land. It is also observed that in spite of merging the peripheral rural area with, the net increase in peripheral rural area is 222.88 ha.

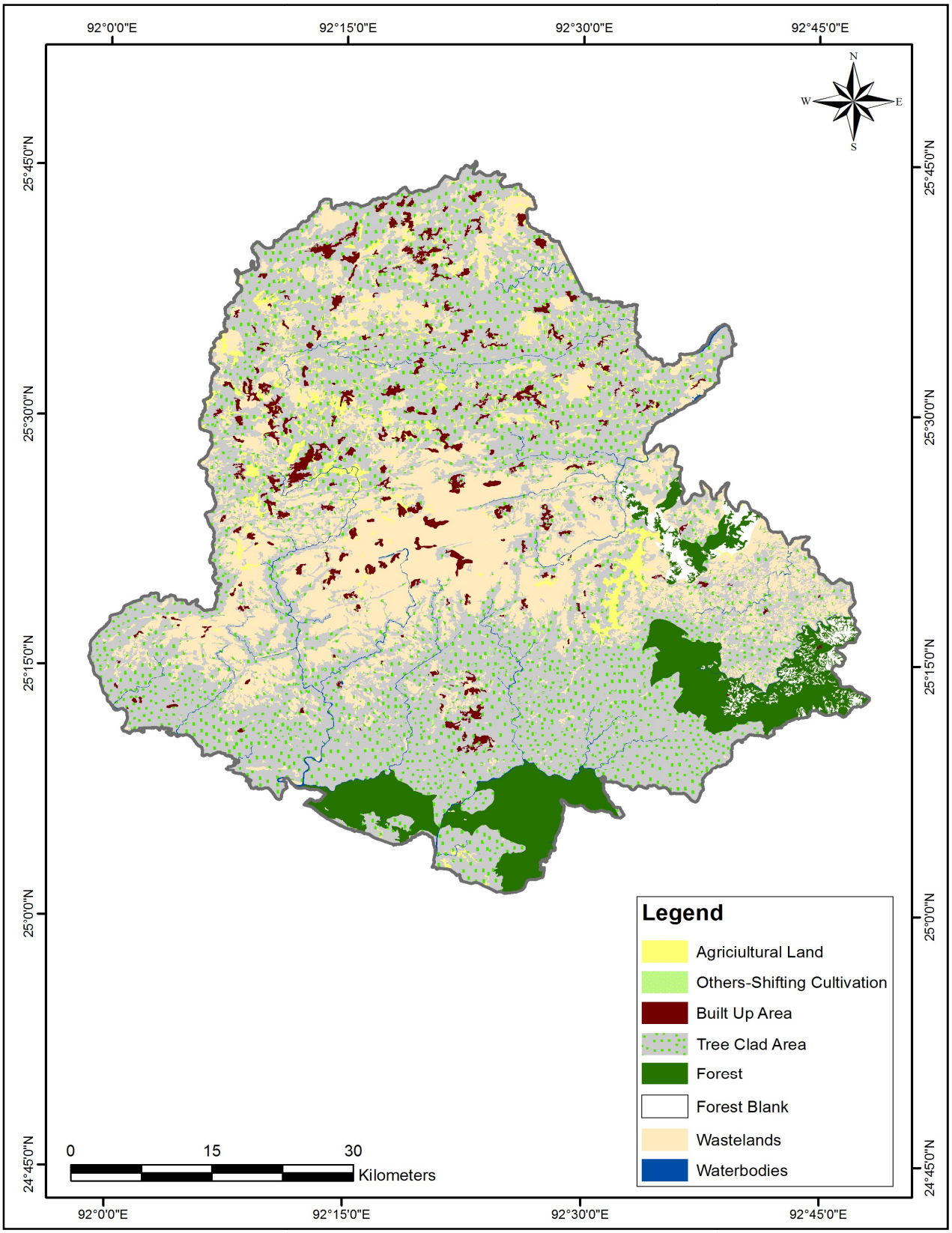

Figure 3: LULC Map of Jaintia hills district 2016

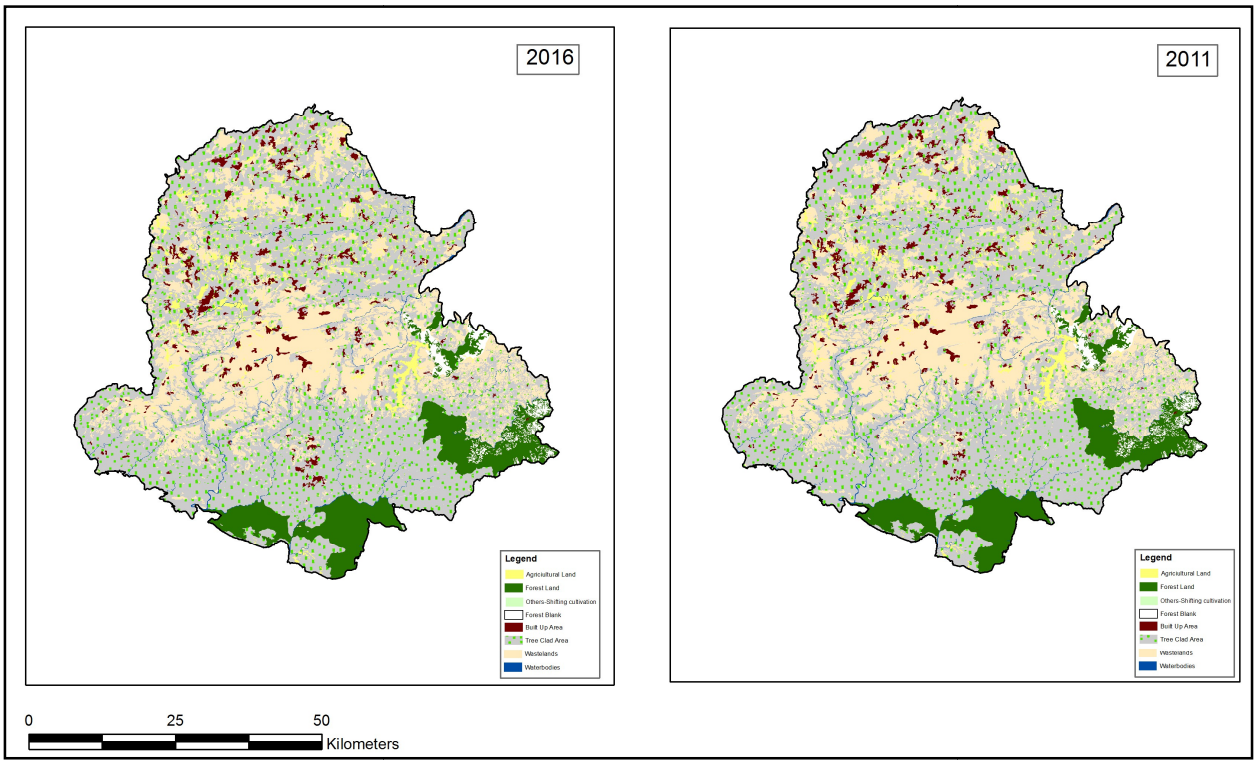

Figure 4: LULC Change detection map of Jaintia hills 2011-2016

5.3. Identification of potential areas for mulberry plantation:

For the study soil and slope map was used for soil and landscape parameters. Maps on climatic parameters were derived from data collected from IMD stations. Different thematic maps like soil pH, soil texture, soil depth, soil drainage, slope, rainfall and temperature were prepared for the study area. From the study following observations have been found out.

5.3.1. Soil pH

From the soil pH map it is observed that pH varies from very strongly acidic to slightly acidic in nature. Slightly acidic soil is highly suitable for mulberry plantation that covers 67% area of total geographical area (TGA). Moderately acidic soils cover about 17% area of TGA which are moderately suitable with moderate limitation for mulberry plantation (Fig.5.1). Strongly acidic and very strongly acidic soil covers about 12% and 0.5% area respectively. Very strongly acidic soil (pH<4.5) is not suitable for mulberry plantation where as strongly acidic soils (pH4.5-5.0) are marginally suitable with severe limitation for mulberry plant.

5.3.2. Texture

The soil texture varies from clayey to coarse loamy to loamy skeletal. Fine loamy soils are found in about 41% area where as clayey soils covers about 29% of TGA. Clayey skeletal and loamy skeletal soils are found in 9.5% and 0.4% area respectively. Coarse loamy and fine soils cover about 11.6% and 3.9% area respectively. The heavy textured soils are highly suitable for growth of mulberry plant. From the study area it is found that clayey to fine texture soils covers about 43% area which is highly suitable for mulberry plantation. Fine loamy soils are moderately suitable that covers 41% area. Coarse loamy soils are light textured soil which has severe limitation for supporting mulberry plantation. About 12% area of the district is marginally suitable for mulberry plantation which is coarse loamy soil (Fig.7).

5.3.3. Depth

From the soil map it is found that the soils of the district are very deep to shallow in depth. In the study area it has been found that about 60% area is very deep to deep in depth which is highly suitable for the growth mulberry plant. About 34%area is moderately suitable because the soil depth is moderate. Shallow soils are marginally suitable for mulberry plantation because the soil cannot support optimum root growth. In the study area it is found that about2%area is marginally suitable for mulberry plantation because of severe limitation of soil depth (Fig.8).

5.3.4. Soil drainage

From the study it is observed that the soils of the study area are well drained. The well drained soils are highly suitable for mulberry plantation. Therefore there is no limitation of soil drainage for mulberry plantation in jaintia hills district.

5.3.5. Slope

The slope map derived from CartoDEM showed that the slope varies from very gentle slope to very steep slope. From the study it is observed that about 21% area of the district is highly suitable for mulberry plantation because the slope is very gentle to gentle. Moderately sloppy areas cover about 23% area which is moderately suitable for

mulberry plantation. About 32% area is marginally suitable for mulberry plant because of severe limitation of slope. The areas with very steep slope is not suitable for mulberry plantation because of its very severe limitation for growing of mulberry plant that covers 22% area of the district.

5.3.6 Climate

From the study of different climatic variables the suitable seasons for silk worm growth has been find out. It observed that the months from January to April are not suitable for the silk worm growth considering different climatic variables. And the months between May to October is found to be suitable from the study (Table 6).

Table 6 Suitability of Mulberry Rearing in Jantia Hills

Season	Existing Temperature			limiting Temperature			Relative humidity%		
	Max	Min	Avg	Max	Min	Avg	Existing	Required	Suitability
Jan-Feb	18.8	9.5	14.2	23	15	20	77.34361	55	Not suitable, Low max and min temperature
March-April	22.8	16.0	19.4	28	22	25	81.21486	55	Not suitable, Low max and min temperature
May-June	24.7	18.7	21.7	30	25	28	89.20861	70	Suitable
June-July	23.9	19.6	21.8	29	24	28	92.87736	85	Suitable
Aug-sept	25.1	20.0	22.5	28	24	27	91.55778	85	Suitable
Oct	24.3	18.6	21.4	29	29	26	82.84167	85	Suitable

The suitability analysis of climatic parameters for mulberry silkworm host plant was done by using rainfall and temperature data collected from IMD stations. From the study it is found that the mean annual temperature is moderately suitable for growth of mulberry plant. Annual rainfall for the region is recorded as 3294 cm which is marginally suitable for the mulberry plant. Length of Growing Period (LGP) of mulberry plant is found as 300, which is highly suitable for silkworm food plant (Table-7). In the present study, the overall suitability of climate for mulberry plantation is found to be moderately suitable.

Table 7: Suitability for mulberry host plant for Jaintia Hills

Climatic characteristics	Existing	Suitability	Overall suitability
Annual rainfall	3294	Marginally	Moderately
Annual mean temperature	18.89	moderate	
LGP	300	Highly	

5.3.7. Suitable area for Mulberry silkworm food plant

The suitable areas for expansion of mulberry sericulture was done by combining all thematic maps (i.e. soil pH, soil depth, soil texture, soil drainage, slope, rainfall, temperature and LGP) in ArcGIS software. All these layers were overlaid in GIS environment and a composite layer is generated. Degree of limitations of all layers was given by comparing the requirement of mulberry silkworm and host plant. Then suitability classes were assigned by following number and intensity method. The final suitability map is given in Figure 5. From the study it is observed that 74% area of the district is suitable for expansion of mulberry sericulture. Rest of the area is not suitable for mulberry sericulture because of very severe limitations from slope (very steep slope) and strongly acidic soil pH. The soils are marginally suitable because of severe limitation of slope; pH and soil texture (40%). Highly suitable areas covers about 6% area of the district and found in very deep to deep soil with slightly acidic pH on very gentle slope to gentle slope. Moderately suitable areas are found in moderately acidic soil with moderate soil depth on moderately steep slope area which occupies about 28% area of TGA.

6. CONCLUSION

From the study of land use land cover map, it is observed that tree clad is the most dominant land use of the district that covers 57.63% area followed by wastelands and forest that covers 25.13% and 8.52% respectively. The area under agriculture is only 3.29% of the study area followed by built up and water body areas occupy only 3.02% and 0.95% area respectively. The study on change analysis of LULC during 2011-12 to 2015-16 showed that the area under agriculture, rural built-up and forest is increased where as wastelands has been decreased. From the study of soil map at 1:50K it is found that soil pH varies from slightly acidic to strongly acidic. Slightly acidic soils are most dominant in the district that occupy about 67% area followed by moderately acidic soils cover about 17% area. Strongly acidic and very strongly acidic soil covers about 12% and 0.5% area respectively. The soil texture varies from clayey to coarse loamy to loamy skeletal. The most dominant soil texture of the study area is fine loamy that covers about 41% area followed by clayey, coarse loamy and clayey skeletal covers about 29%, 11.6% and 9.5% respectively. The depth of soil varies from very deep to shallow. The soils of the district is mostly deep to very deep that covers 60% area and about 34% area is having moderately. shallow. The soils of the district is mostly well drained. From the study of slope map it is observed that about 21% area of the district is situated on very gentle to gentle slopes. Moderately sloppy areas cover about 23% area and 32% area is with moderately steep slope. From the study of different climatic variables it observed that the months from January to April are not suitable for the silk worm raring . The suitability analysis of climatic parameters for mulberry plant showed that the mean annual temperature is moderately suitable for growth of mulberry plant and annual rainfall is marginally suitable. Length of Growing Period (LGP) of mulberry plant is found as 300, which is highly suitable for silkworm food plant. From the soil site suitability evaluation for mulberry sericulture, it found that 74% area of the district is suitable for expansion of mulberry sericulture. Rest of the area is not suitable for mulberry sericulture because of very severe limitations from slope (very steep slope) and strongly acidic soil pH. The soils are marginally suitable because of severe limitation of slope; pH and soil texture (40%). Highly suitable areas

covers about 6% area of the district and found in very deep to deep soil with slightly acidic pH on very gentle slope to gentle slope. Moderately suitable areas are found in moderately acidic soil with moderate soil depth on moderately steep slope area which occupies about 28% area of the district. From the study it found in the study area about 86813 ha scrubland which are cultivable wastelands is suitable for mulberry plantation can be utilized for expansion of mulberry sericulture as first priority.

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ABBREVIATION

- AWS – Automatic Weather Station
- DEM – Digital Elevation Model
- EMR – Electromagnetic Radiation
- FCC – False Colure Composite
- GIS – Geographical Information System
- IMD – Indian Meteorological Department
- IRS – Indian Remote Sensing Satellite
- LGP – Length of Growing Period
- NESAC – North Eastern Space Application Center
- PET – Potential Evapotranspiration
- RS – Remote Sensing
- SRM – Soil Resource Mapping
- UTM – Universal Transverse Mercator
- WGS84 – World Geodetic System 1984