Mapping of Suitable Areas for Mulberry Plantation Using GIS in Manipur

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1 Introduction

Sericulture is a widely practiced agro-based industry in India and thus is the second largest producer of silk in the world. This sector contributes to the growth of economy in the country and helps to alleviate poverty. It can also provide various types of jobs, especially in rural areas with higher income as compared to other agricultural activities. Mulberry and castor (natural silkworm food plant) plantation help in preventing soil erosion in long term and such activity is eco-friendly. As mulberry and castor plants are perennial crops which have the property to maintain the ecosystem in the surrounding area due to its non-seasonal nature. Mulberry, Muga, Eri and Tasar are the types of silk widely grown in India [1] and becoming 2nd largest producer in the world.

Mulberry plantation prevents soil erosion and therefore study on soil erosion is encouraged. "Soil erosion is a serious problem arising from agricultural intensification, land degradation and other anthropogenic activities" [2–6]. Soil erosion not only lessens the productivity of agriculture, but also lowers the availability of water [7]. "The average amount of soil loss from natural erosion is around 0.1–1 t/ha/year; however, the soil loss becomes 10–1,000 times faster when erosion is exacerbated by human activities" [8]. Use of GIS (Geographic Information System) technology in agriculture and sericulture activities is highly beneficial and several studies conducted a mapping of site suitability for different crops and finding its management strategy with the help of satellite images and GIS tools [9–13].

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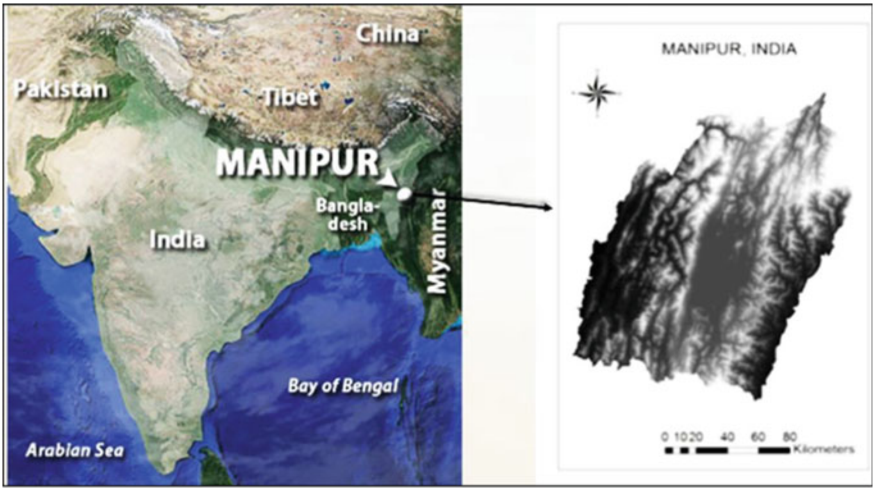

Fig. 1 Study area (Manipur)

In this study, mapping of a cultivable area or site suitability for mulberry plantation in Manipur state (north eastern part of India) is conducted using the soil loss model (Revised Universal Soil Loss Equation, RUSLE) with GIS techniques.

2 Study Area

The selected study area for this study is Manipur (north eastern state of India) which is shown in Fig. 1, having a total geographical area of around 22,437 km^2. Earlier, Manipur has 9 districts, i.e., Ukhrul, Chandel, Bishnupur, Thoubal, Imphal east, Imphal west, Churachandpur, Tamenglong and Senapati. Study area is 90% hilly terrain and remaining 10% is valley plain which is the central part of the state. Hilly part is covered by the red ferruginous soil and the central valley part is by alluvium soil. Climatic condition of the state is moderate and temperature range from few minus degrees in winter to a maximum of 37 °C in hottest summer. The annual average rainfall is in the range of 1200 mm to 1350 mm which is high as compared with other parts of India.

3 Materials and Methods

Different criteria (topographic and landscapes, soil characteristics and climatic parameters) were chosen for deciding the site suitability of the mulberry plantation. Overall methodology for mulberry cultivation is shown in Fig. 2.

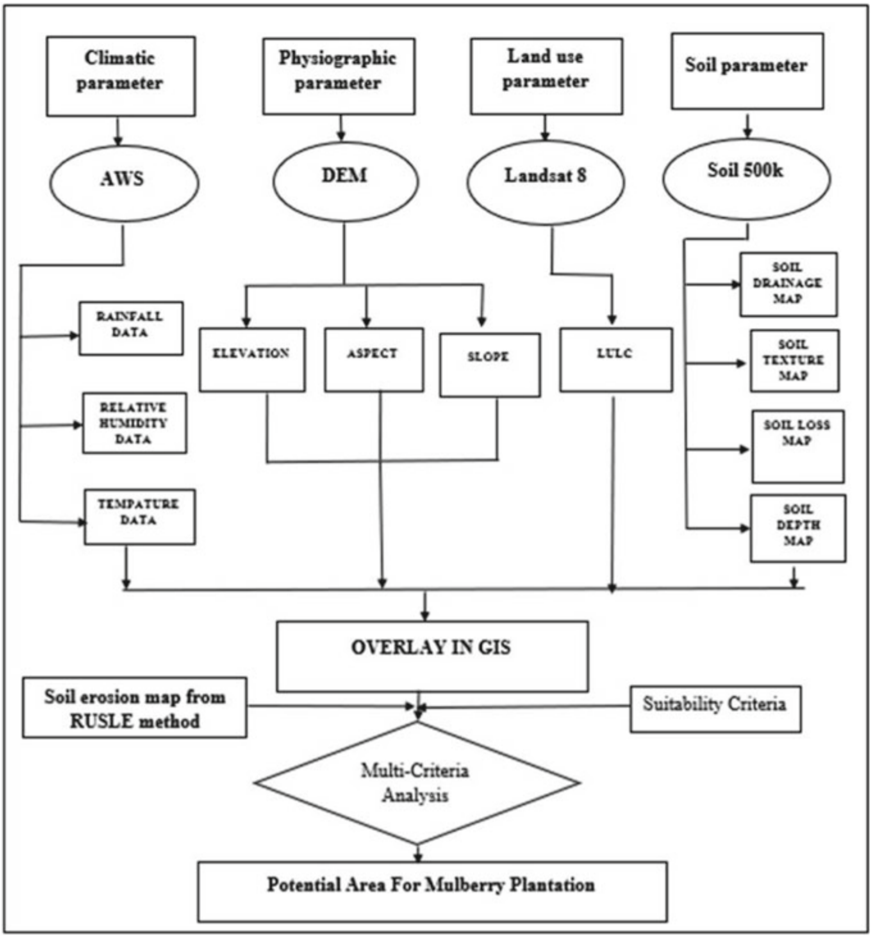

Fig. 2 Flowchart of methodology

The methodology of the RUSLE model adopted for this study is shown in Fig. 3. Assessment of suitability of land for sericulture has been done by different multi-thematic layers viz, climate conditions (temperature, rainfall and humidity), topographic conditions (slope and elevation), soil properties parameters (drainage, depth, erosion and texture) and cultivable land. For the climate condition AWS (automatic weather station) data were used for rainfall map and Land Surface Temperature map obtained by Landsat 8 satellite imagery.

Soil properties parameters were generated by the National Bureau of Soil Survey and Land Use Planning (NBSS-LUP) soil map on a 1:500,000 scale. Landsat 8 satellite imagery of year 2018 was used to compute cultivable land. Topographic maps were generated from Shuttle Radar Topography Mission—Digital Elevation Model (SRTM DEM, 30 m resolution). For quantitative assessment of soil erosion, soil

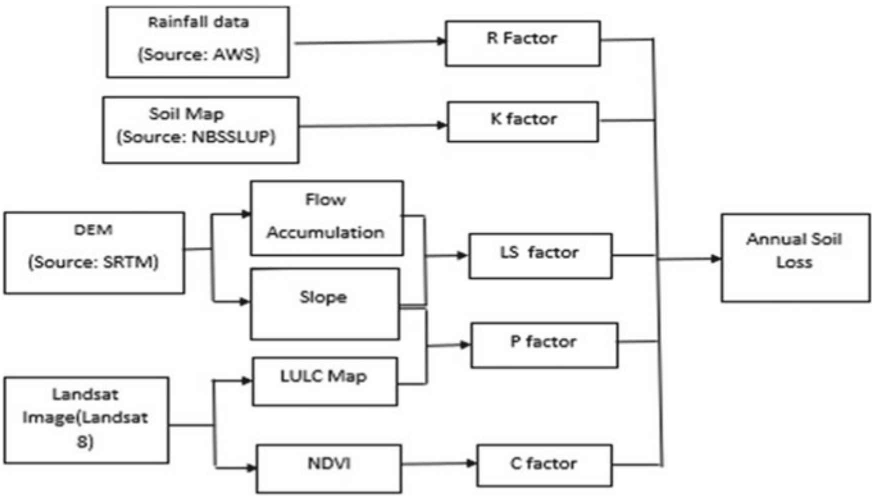

Fig. 3 Concept of RUSLE model

erodibility factor (K factor), rainfall erosivity factor (R factor), cover management factor (C factor), conversation practice factor (P factor) and slope length gradient (LS factor) were calculated by RUSLE [10, 12] model which can be written as:

$$A = R \times K \times L \times S \times C \times P \tag{1}$$

Here, A represents the annual average soil loss in tons/hectare/year. Land use/ land cover was classified into six categories: forest, agriculture, wastelands, shifting cultivation, settlement (built-up) areas, and water bodies.

4 Results and Discussion

4.1 Results

From the landuse/landcover (LULC) analysis shown in Table 1, most of the area in the study location is covered with dense forest i.e. 17,122.74 km^2 (76.19%), settlement area is 1424.71 (6.64%) and water bodies area is 119.11 (0.53%) of total geographical area (TGA). The remaining area can be used for mulberry cultivation including agriculture, wasteland and shifting cultivation area, which is 3983.72 km^2 (16.96%).

Figure 4 shows the different forms of presenting soil textures like soil depth, soil drainage, soil erosion, soil texture; slope and land surface temperature map of the study area respectively. These factors are very important as it adversely affects

Table 1 LULC (2018)

LULC	Area (km^2)	% of TGA
Agriculture land	1250.95	5.57
Settlement area	1424.71	6.64
Forest	17,122.74	76.19
Shifting cultivation	22.47	0.1
Wastelands	253.654	11.29
Waterbody	119.11	0.53

the plantation. The soil textures in the study region are classified as very fine, fine and fine silty. Soil erosion is slight and moderate in 7.85% and 52.34% of the area respectively, which favors the plantation.

The major parts have very poor or excessive drainage which is not suitable for plantation. The depth is greater than 100 cm in 90.51% of the area, which is highly suitable. Slope varies from moderate (valley region) to very steep (hilly region). And

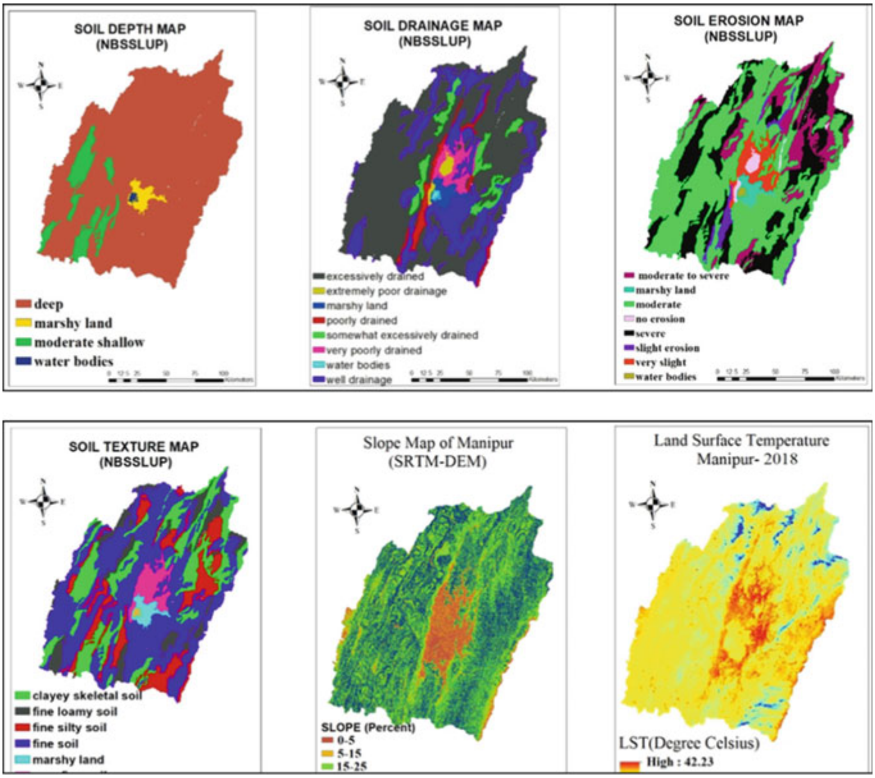

Fig. 4 Soil depth, soil drainage, soil erosion, soil texture, land surface temperature and slope of Manipur

from the land surface temperature map, it is also observed that temperature goes as much as high as around 42 °C and low as much as −7 °C but a majority of the study area is under moderate temperature (25 to 30 °C). It is understood that the temperature above 30 °C directly affects the health of the worm and the temperature below 20 °C worm becomes too weak and susceptible to disease. Study area comes in a heavy rainfall zone which can affect plantations adversely especially small plants.

Figure 5 shows different parameters (C, K, LS, P and R factors) for the assessment of quantitative analysis of soil loss map and soil loss map computed by RUSLE method. Soil erodibility factor (K) depends on soil composition and represents susceptibility to erosion and rate and amount of runoff. Length and degree of slope are indicated by topographic factor (LS) and it is directly proportional to erosion by water. Cover management factor (C) mainly depends on land use or vegetation cover. Area with vegetation cover shows less erosion. Rainfall erosivity factor (R) represents the erosion potential caused by rainfall. Conservation practice factor (P) depends on a slope under cultivable area category [10, 12]. In Fig. 5, including dense forest it has been found that 19,958.87km^2 (i.e. 90.68%) are favorable for mulberry cultivation in Manipur out of which 8458.78km^2 (38.43%) were highly suitable, 6816.071km^2 (30.97%) moderately suitable and 4684.02km^2 (21.28%) marginally suitable, but 1622.79km^2 (7.37%) not suitable. Quantitative assessment of soil loss is done by RUSLE model [10, 12]. Soil loss is categorized from very slight to very severe erosion range, details shown in Table 2 and suitability class in Table 3. It has been noted that the cultivable area also includes dense forests in this study. Using the present approach, soil loss assessment and mulberry suitability analysis can be carried out for all the districts and are presented in Table 4.

Figures 6 and 7 show the Soil Erosion risk by RUSLE model and potential sites for mulberry plantation in Manipur (2018). Very slight to moderate soil loss risk is stable for mulberry cultivation, so the total suitable area is 21,654.29 km^2 (98.05%) where the area of soil loss risk under very slight is 18,807.54 km^2 followed by a slight range of 2025.19 km^2 and under moderate is 821.56 km^2 (Fig. 6). Thus the study area was not found soil erosion hazardous. Suitable areas for mulberry plantations are all three categories of highly, moderately and marginally suitable areas. District wise suitability of mulberry plantation is presented in Table 4. The highest suitable area in whole state is 4116.73 km^2 found in Ukhrul district followed by Tamenglong district i.e. 3899.4 km^2 and the lowest 237.84 km^2 in Imphal west, due to more urbanization. The percentage of suitable area in a total geographical area in the district is highest in Churachandpur district.

4.2 Discussion

The average soil loss rate was estimated as 40.519 t/ha/yr and the maximum value was found as 81.038 t/ha/yr. The predicted soil loss rate and its spatial distribution map can be informative in comprehensive and sustainable land management to mitigate

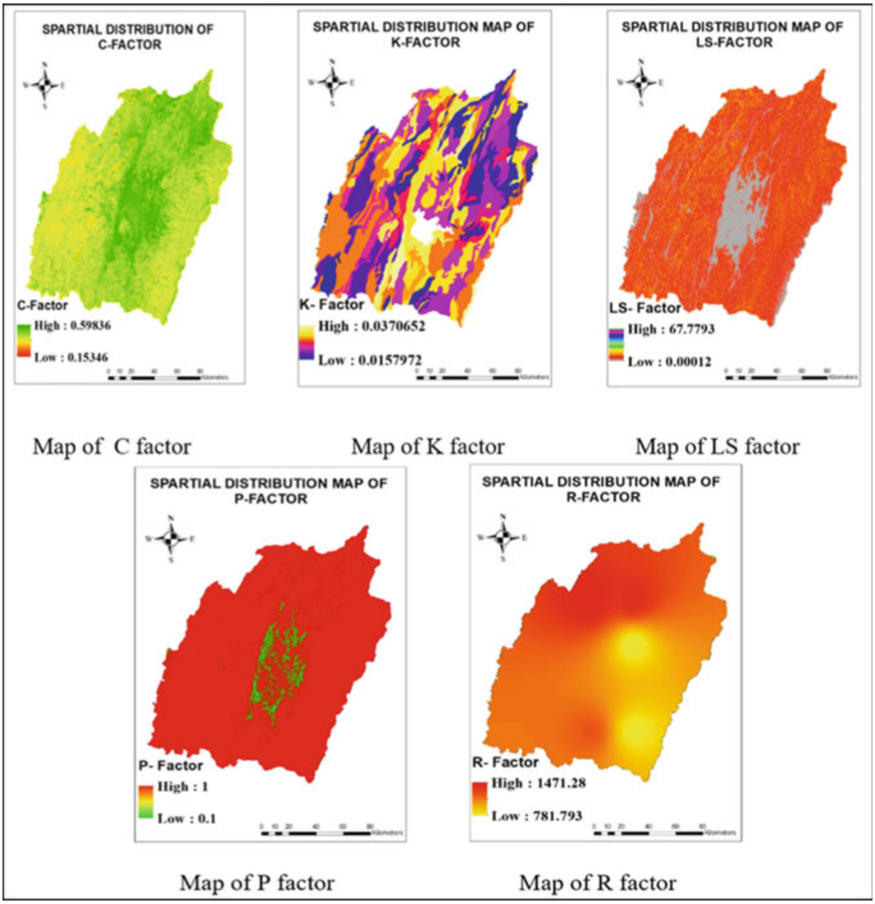

Fig. 5 Parameters assessment for quantitative analysis of soil loss map and soil loss map computed by RUSLE method

Table 2 Percentage of area of soil erosion risk in Manipur

Soil loss (t/ha/year)	Range	Area in km^2	Area in percentage
0–5	Very slight	18,807.54	85.16
5–10	Slight	2025.19	9.17
10–20	Moderate	821.56	3.72
20–40	Severe	46.38	0.21
40–80	Very severe	2.65	0.012

Table 3 Suitable areas for Mulberry cultivation in Manipur

Class	Area in km^2	Area in percentage
Highly suitable	8458.78	38.43
Moderately suitable	6861.07	30.97
Marginally suitable	4684.02	21.28
Not suitable	1622.79	7.37

Table 4 District wise area (km^2) of mulberry plantation in Manipur

Districts	Total area (km^2)	Highly suitable (km^2)	Moderately suitable (km^2)	Marginally suitable (km^2)	Not suitable (km^2)	Total suitable area (km^2)
Ukhrul	4396.11	1083.37	1919.24	1114.11	279.38	4116.73
Chandel	1901.88	1056.06	141.40	609.40	95.023	1806.86
Bishnupur	265.12	81.367	36.99	64.26	82.51	182.614
Thoubal	477.97	163.87	93.89	114.94	105.27	372.7
Imphal east	558.76	202.56	87.057	129.16	139.97	418.785
Imphal west	437.56	42.68	26.74	168.42	199.72	237.84
Churachandpur	4834.81	1767.88	1963.06	862.61	241.26	4593.55
Tamenglong	3964.84	1557.92	1732.04	609.44	65.44	3899.4
Senapati	3398.08	829.03	1168.73	994.046	406.27	2991.81
Total	20,235.13	6784.77	7169.14	4666.38	1614.84	18,620.29

soil erosion hazards. GIS-based RUSLE methodology can be implemented to assess the spatial distribution of erosion risk zone in the study area.

This has been observed that both maps (prepared based on NBSS-LUP and RUSLE method) vary significantly, in soil loss map by NBSSLUP, moderate erosion risk has been observed in maximum percentage of areas in Manipur (i.e. 52.45%) whereas in soil loss by RUSLE model, very slight erosion risk observed maximum percentage of areas in Manipur i.e. 85.16%. However, severe erosion risk was observed minimum percentage of areas in Manipur i.e. 0.21% in soil loss by NBSS-LUP whereas very severe erosion risk was observed minimum percentage of areas in Manipur i.e. 0.012% in soil loss by RUSLE method.

This study has some limitations as RUSLE model use for long term soil loss evaluation but here only one year of losses has been computed. PH data and relative humidity have not been taken as a parameter for soil suitability assessment. And this study has not considered a future expansion of urbanization and development.

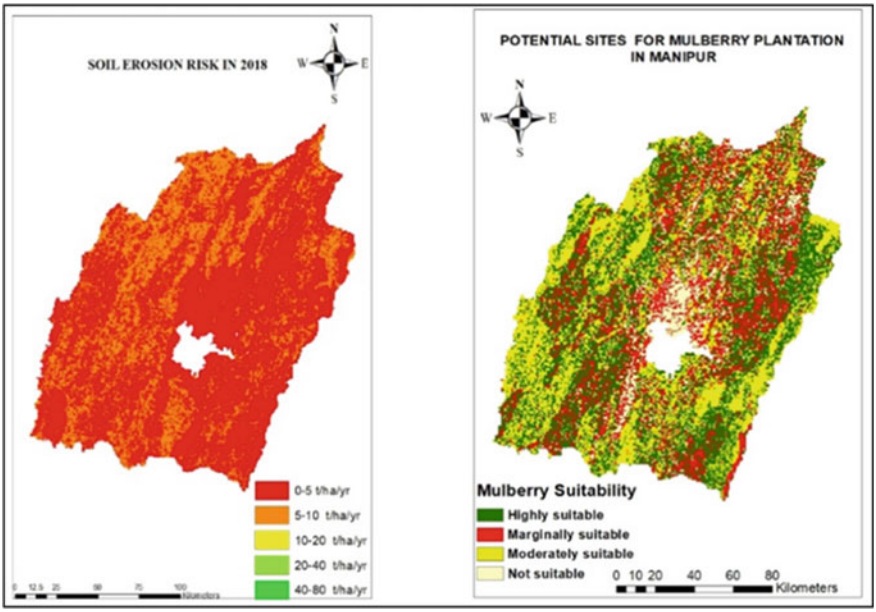

Fig. 6 Soil erosion risk by RUSLE model and potential sites for mulberry plantation in Manipur (2018) map

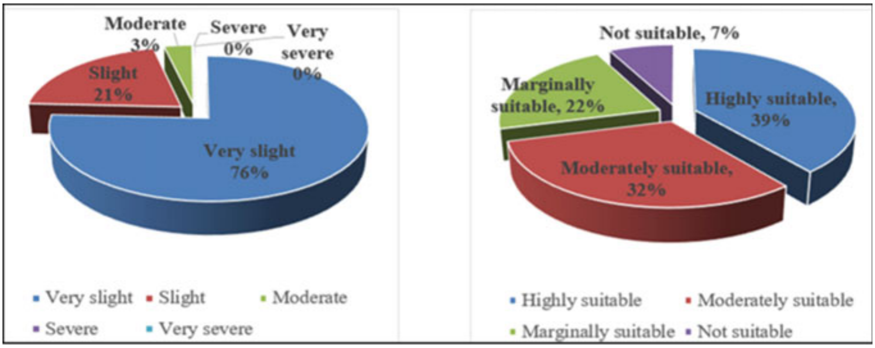

Fig. 7 Pie chart of soil erosion risk by RUSLE model and potential sites for mulberry plantation in Manipur (2018)

5 Conclusions

GIS and remote sensing techniques were utilized for mapping site suitability of mulberry cultivation in Manipur in the present study. By providing the removal or improvement of limiting parameters, the areas mapped under not suitable category can be turned into highly, moderately and marginally suitable areas, which increases the area for mulberry plantation. Mulberry cultivation gives employment opportunities to the farmer throughout the year, which empowers socioeconomic activity for the farmers. Active support of concerned state government authorities can help to achieve this goal.

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