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Mustard crop suitability mapping using analytical hierarchy process in the Imphal-Iril River sub-catchment, Manipur, India

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Abstract

Land suitability analysis is method for obtaining optimum utilization of naturally accessible land resources. The availability of natural resources and the climatic condition of the region have a direct influence on productivity of a specific crop. To produce the optimum production on a sustainable way, it is necessary to identify the requirements of crop. Soil site the suitability criteria can help for improving agricultural inputs and predicting crop yields. The main objective of the present study is to identify the mustard cultivation suitability potential sites in Rabi season using analytical hierarchy process (AHP) in the Imphal-Iril river sub-catchment Manipur, India. Using a combined approach of geographic information systems and remote sensing, the suitability assessment was conducted by using climatic, soil and topography data as the input variables. Using weighted overlay method of spatial analyst tools embedded in ArcGIS, mustard suitability zones were generated. The findings of this study indicate that AHP method of MCDM could potentially use to classify suitable zones for mustard cultivation using GIS and remote sensing techniques. From the model output it was found that highly suitability zones for mustard were observed specially in the valley portion of the catchment having mild slope. Moderately suitable sites were primarily found near the foothill region, which have a gentle sloping topography. It was also observed that few patches of marginally suitable zones were observed near the foothill region of the catchment. Not suitable zone for mustard cultivation were found mostly in the hill regions of the catchment which cannot be cultivated owing to the existence of vast hilly areas, protected reserved forest and natural wildlife habitat regions. The findings of this assessment will helpful for cropping management option for intensification and diversion of crop to the regional growers and helpful to the policy makers in order to achieve high production of mustard in the region.

Keywords: Land suitability, Analytical Hierarchy Process, Land Use Land Cover, Mustard, Geographical Information System.

1. Introduction

Rapseed-Mustard is an important major Rabi season crop cultivated in India and next to ground nut in importance. It belongs to the Cruciferae family and which includes several cultivated related species. Some important distinct types of rapeseed-mustards are Yellow sarson, Brown mustard, Brown Sarson, Taramira and Toria. Toria and Sarson are usually referred to as Rapeseed, while Raya or Rai, or Lahi are referred to as Mustard but both are commonly known as Mustard. The edible leaves are eaten as mustard greens, while the seeds are crushed to generate mustard oil and their by product is used as cattle feed and manure. Mustard oil is generally used in cooking and frying for human consumption. India is one of the major mustard producer countries in the world. Crops are cultivated predominantly in eastern and northern regions of India and are generally grown in Rabi season (Mid-September to March). The main mustard cultivation practice states in India are Uttar Pradesh, Haryana, Rajasthan, Punjab, Orissa, Gujarat, Madhya Pradesh, Bihar, Assam and West Bengal. The crops are mostly grown in temperate climates and at higher altitudes in tropical regions. They need dry weather condition and plenty of sunlight exposure hours for optimal production. They prefer moderate temperature below 25^{o} C for their development and growth. At the temperature less than 3^{o} C and more than 35^{o} C, the plant growth ceases and stunted. A rainfall of 450 to 1000 mm during growing period is desirable. They prefer neutral pH, however excellent results have been observed between the pH level 6 to 7.5, and they are more resistant to acidity than alkalinity. Sandy loam and loam soils are said to be the most favourable for the production of mustard[1].

Mustard is more drought tolerant, thus it may be cultivated in arid and semi-arid environments[2]. Climate change has become a global issue, influencing agricultural productivity and food security worldwide[3]. Because agricultural land is a limited resource, expanding the area cultivated is impossible. To improve agriculture output with available land, land suitability classifications should be identified. Crops must be cultivated in the most suitable location, and site suitability assessment is required for long-term agricultural productivity[4,5]. Sustainable agriculture involves choosing the crop that will grow best in that location, which requires assessing the suitability of the site[6,7]. It is based on evaluating the needs of the crop and the combination of relevant land attributes[8, 9,10]. As a result, suitability analysis evaluates the extent to which the characteristics of a land unit fit the requirements of a certain type of land use[11,12]. Cropland suitability analysis is critical for future growth and planning, as well as providing assistance to planners and decision-makers[13]. Numerous researchers have recently used the multi criteria decision method coupled with GIS to examine whether it could be used to improve agricultural output using sustainable approaches and minimising environmental footprints[14-18]. The integration of AHP and multi-criteria decision approach with GIS is beneficial because different production impacting factors are assessed and weighted in accordance with their relative value in a desirable crop growing state[14,19,20].

The state of Manipur is mostly dependent on agriculture, with rice cultivation accounting for the majority of this sector. A mere 8% of the state's total territory is made up of the valley, where the majority of cultivation occurs. Additionally, the agroclimatic conditions are ideal for traditional rice production methods. Before 1980, rice production was self-sufficient, unless there were unusual monsoon circumstances. However, despite the fact that productivity in the state is greater than the national average, rice output and productivity appear to have stagnated over the last several years. This posses a higher uncertainty and lower sustainability as the Manipur’s economy is higher driven by the production of rice, as rice being the single major crop in the state. In order to overcome this uncertainty associated with rice and achieve sustainability, there is a need to explore in into the potential of other major crop cultivation suitability potential especially in the Rabi season when the land is left fallow after the harvesting of the rice in the Kharif season. Moreover, mustard has also become a valuable rotational crop in a region with continuous rice or rice-fallow based cropping systems as well as a creating alternative weed management strategies. In order overcome this demand, the main research objective of present study is to identify and examine the mustard cultivation suitability sites in the Imphal-Iril river catchment using AHP. This study also assess the potential use of same patch of the agricultural land for cultivation of rice and mustard in the Kharif and Rabi seasons respectively in order to attain sustainability.

2. Materials and methods

2.1 Study area

The present study was conducted in the Imphal-Iril river catchment, which is located in the North-Eastern part of the Indian state of Manipur, and covers a geographical area of 22,327 km^2. The state is located between 23°83'N and 25°68'N in latitude, and 93°03'E and 94°78'E in longitude.The study area consists of hill and valley region. The majority of the study area lies in a mountainous region and received 1467 mm of annual average rainfall[21]. A series of scattered hills could have been found in the eastern and northern regions of the catchment. The study area covers a total area of about 1830 km^2, with elevations ranging from 732 m to 2676 m. Two important river systems in Manipur, namely the Imphal River and the Iril River, flow through this catchment. Figure 1 depicts the geographic location of the present research area. There are several distinct land use types present in this catchment, including settlement vegetation, agricultural, bare soil and water bodies. Figure 2 depicts the present LULC map of the study area and the natural vegetation includes a diverse range of plants, such as bamboos, grasses, and numerous tree varieties. Medium to dense tropical deciduous forest covers the hill terrain. More than 75% of the population in this region engages in agriculture and other allied sectors because it is the main source of state revenue[22]. The region has a humid climate with seasonal shortages of water[23]. Mono-cropping agricultural practice system is observed in most of the agricultural lands within this catchment. By considering this into account, the present study was to evaluate the soil site suitability for mustard crop cultivation in Rabi season.

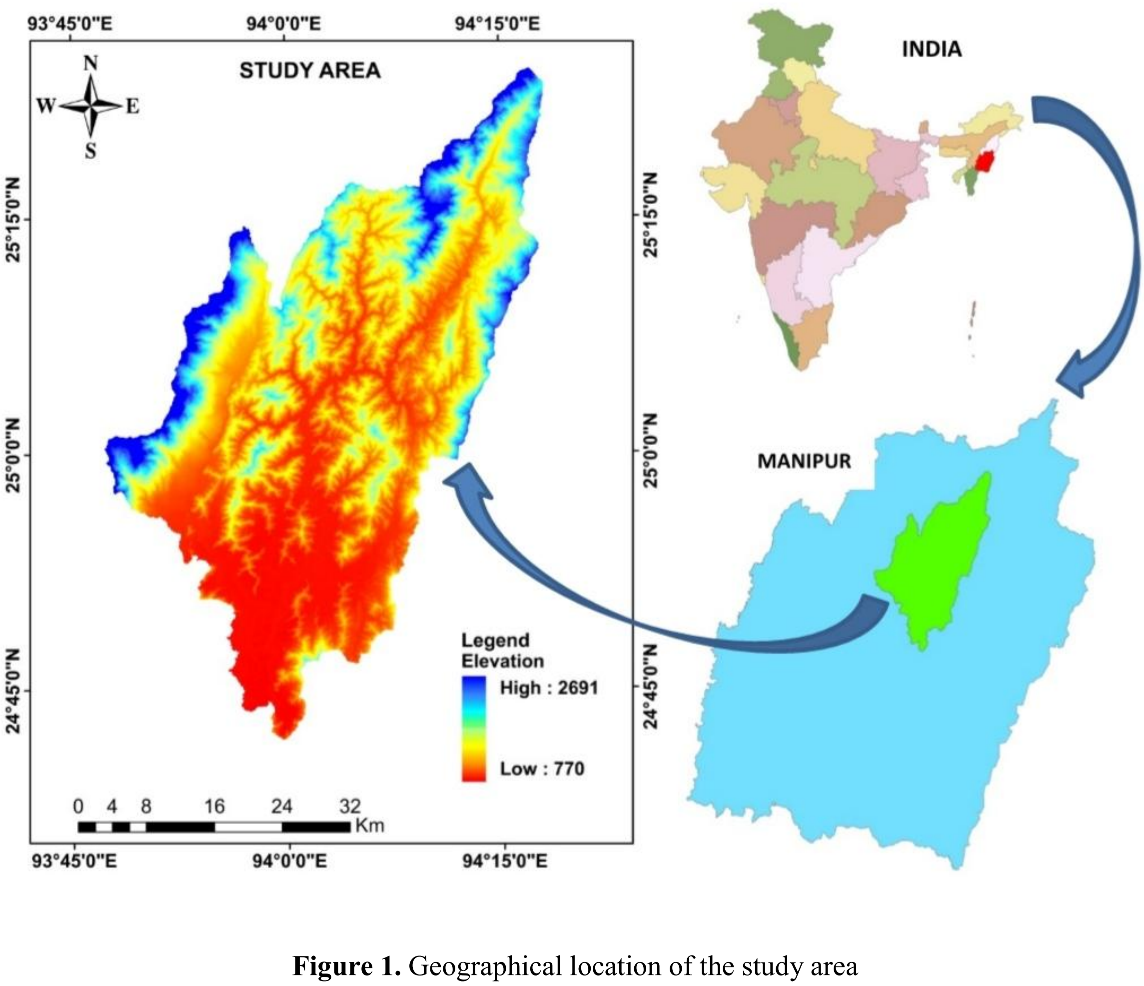


Figure 1. Geographical location of the study area

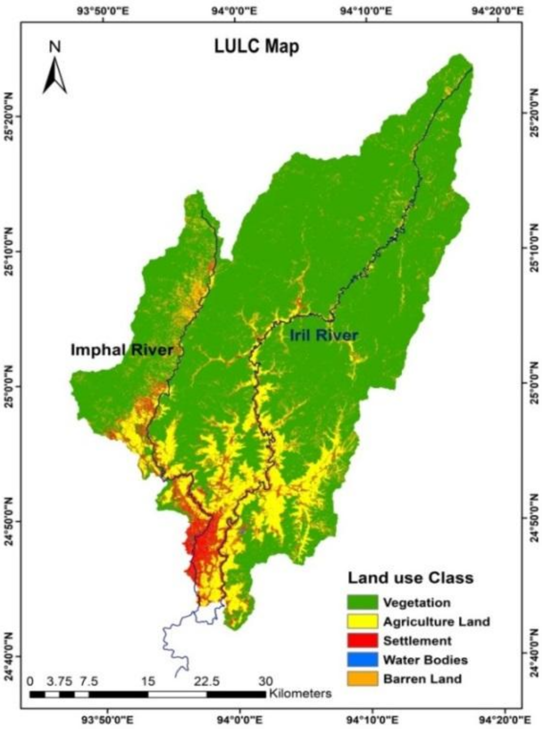


Figure2. LULC map of the study area

2.2 Description of data

In this suitability assessment, seven important parameters are used based on climate, soil and topographical data. Temperature, soil texture, rainfall, pH, drainage, depth and slope are the key parameters use in this study. These characteristics were carefully chosen based on the knowledge of local experts, the accessibility of data, literature reviews, and input from researchers.

2.2.1Climate Data

The growth, development and production of mustard crops are highly influenced by many climatic variables. In this suitability assessment, the weather variables rainfall and temperature are used. Typically, mustard is grown in tropical and subtropical regions where the mean temperature in growing season between 15°C and 26°C, and annual average rainfall between 450 mm and 900 mm. In this study, TRMM daily rainfall and MODIS (MOD11A1) daily surface temperature data from the last 23 years are used. The data information is presented in below Table 1.

2.2.2 Soil Data

Soil is one of the fundamental elements of an agricultural environment. It also helps the plant grow by providing structural support and nutrients. For land suitability assessments, detailed understanding of the physical and chemical property of soil is necessary. Soil texture, soil depth, soil drainage and soil pH are the important soil parameters used in this study. Soil information related data were collected from the National Bureau of Soil Survey and Land Use Planning[24].

2.2.3 Topography

Slope is a significant topographic factor for the application of land suitability studies which may be used to evaluate a site and suitability assessment of the region. Typically, slope is computed using a digital element model (DEM). Applying the spatial analyst tools in ArcGIS 10.3, elevation was computed using the SRTM DEM with a spatial resolution of 30 m. It can be achieved to observe steeper terrain when the slope value is higher and smooth terrain when the slope value is lower. The cultivation of mustard is better useful to terrain with a flat surface and adequate soil drainage.

2.2.4 Multi-spectral Data

Landsat-8 multi-spectral remote sensing data (OLI+TIRS) for the study area was retrieved from the US Geological Survey Earth Explorer site. This multi-spectral data provides a spatial resolution of 30 m and a temporal resolution of 16 days interval. The maximum likelihood classifier algorithm was used to perform LULC classification of the study area using ArcGIS 10.3 and generate the layer in the form of a map. In this LULC assessment five major land use classes have been classified namely settlement, agriculture, vegetation, barren land and water bodies. Agriculture is mostly practised in the valley region and along the foothill with a moderate sloping terrain. The majority of the settlement class is mainly concentrated in the catchment's valley region. The dominant class in the watershed is vegetation, which is found mostly in mountainous areas, and protected reserved forest is also included in this category. Barren land is observed near the foot hill region of the catchment and the classified LULC map is presented in above Figure 2. The specific parameters used in the present study are described in Table 1.

Table 1.Description of Input datasets

Parameter	Source	Description	Resolution
Rainfall	TRMM (https://gpm.nasa.gov)	23 years(2000-2022)	25 km
Temperature	MODIS(https://modis.gsfc.nasa.gov)	23 years(2000-2022)	1 km
Soil data	NBSS and LUP	Texture, Depth, Drainage, pH	-
Slope	SRTM DEM (http://earthexplorer,usgs.gov)	Year -2022	30 m
Multi-spectral data	USGS(http://earthexplorer,usgs.gov)	Year-2022	30 m

The important mustard suitability requirements were collected from the National Bureau of Soil Survey and Land Use Planning (ICAR)[24]. In order to run the suitability model using Arc GIS 10.3, all parameters have been generated in raster data format. All the raster data sets use in this suitability assessment are then resampled to 30m spatial resolution and convert the reference coordinate system to Universal Transverse Mercator (UTM) zone 46 N. Using spatial analyst tool in ArcGIS, reclassified all the parameters into four different suitability class namely highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N) based on suitability requirement provided by NBSS-LUP and ICAR. Table 2 describe how these classified raster layers are rated.

Table 2. Suitability requirement for Mustard crop

Parameter	Unit	Highly Suitable(S1)	Moderately Suitable(S2)	Marginally Suitable(S3)	Not Suitable(N)
Temperature	^{o} C	20 – 26	27 – 32 15 – 19	33 – 34 10 – 14	>35 <10
Soil texture	Class	sil, l,scl, ls, sl	sicl, cl, , sc	c , s	–
Rainfall	mm				
Soil pH	1:2.5	6.5 – 7.5	5.5 – 6.4 7.6 – 8.0	4.5 –5.4 8.2 – 9.0	<4.5 >9.0
Soil drainage	Class	Well drained	Mod. well drained	Imperfectly drained	Poorly drained
Soil depth	cm	>100	50 – 100	25 – 50	<25
Slope	%	<3	3 - 5	5 - 8	>8

Note: c- clay, s- sand, ls- loam sand, scl- sandy clay loam, cl- clay loam, sil- silt laom, l- loam, sc- sandy clay

The degree of the suitability is reflected in the land suitability classifications. According to the classification system for land suitability developed by the Food and Agriculture Organisation[11], four primary categories have been classified for this site suitability: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N). Figure3 depicts an overall methodological approach for Mustard suitability assessment.

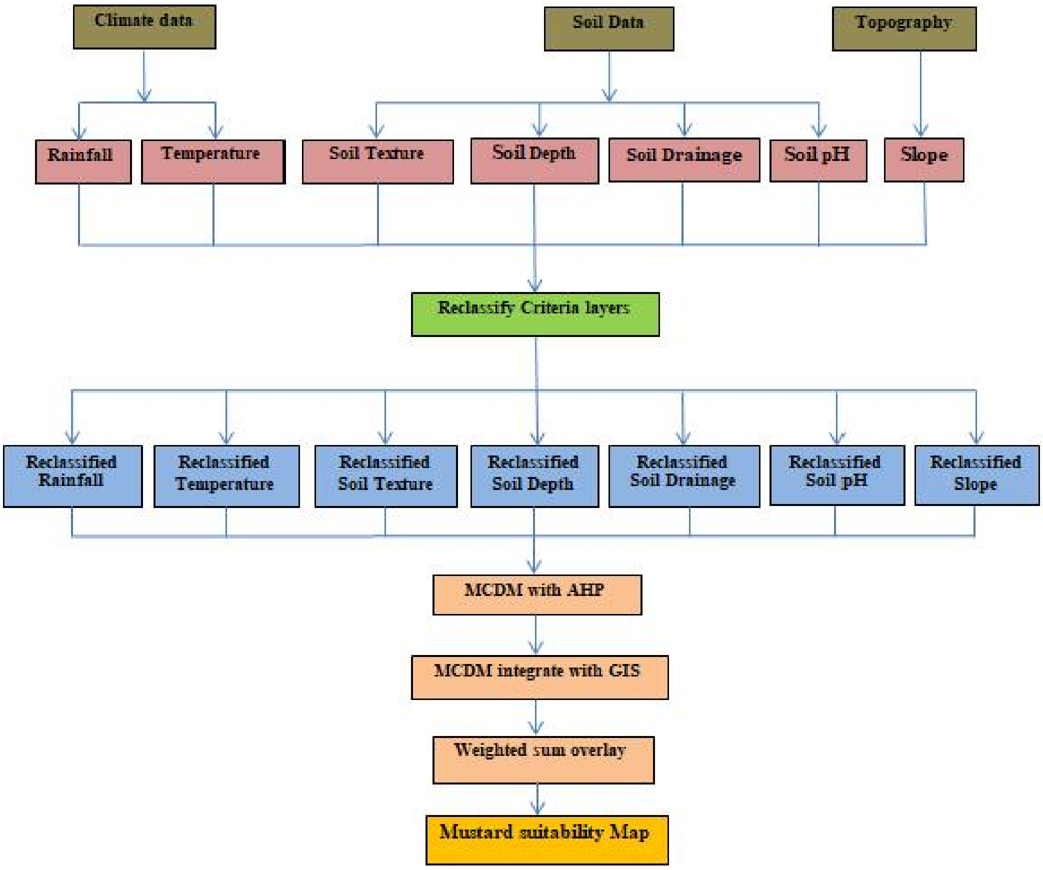


Figure 3. Methodological approach for mustard suitability mapping

2.3Analytical Hierarchy Process (AHP)

The analytical hierarchy process (AHP) is one of the most extensively used multi-criteria decision approaches by numerous scholars for various applications and assessment[25].GIS technology can be integrated with this approach for developing several models based on site suitability[26]. Accurately generating the data needed is one of the most important parts in this assessment. It is necessary to identify the relative importance or weight of each criterion in the decision-making problem[25]. In this study, the pairwise comparison matrix suggested by Saaty (1980) was used as the decision making approach. Concurrently, factor weights were computed by comparing the two distinct parameters using a pairwise comparison matrix. As recommended by Saaty (1980), a scale with values that ranged from 9 to 1/9 has been used in this comparison matrix. A rating number of 9 indicate that the row element is far more essential than the column factor. As a result, a rating scale score of 1/9 implies that the column element is more essential than the row factor. Furthermore, a rating value of 1 implies equal significance[27]. When a criteria element is compared to itself, diagonal elements are given a value of one. Table 3 shows the scale description for the pairwise comparison matrix.

Table 3.Scale description of pairwise comparison matrix

Degree of importance	Description
1	Equal importance
3	Moderately importance
5	Strongly importance
7	Very strongly importance
9	Extremely importance
2, 4, 6, 8	Intermediate importance values
Reciprocals	Values corresponds to inverse comparison

As per AHP model, pairwise and normalised comparison matrix for mustard suitability was constructed as shown in Tables 4 and Table 5. Since the matrix is symmetrical, simply the triangular half of the matrix needs to be filled in with this method. As a result, the remaining components are only another half part reciprocated. For instance, if the score value of soil texture with correspond to slope is 7, then score value of slopewith correspond to soil texture is 1/7.It is necessary to check the consistency of the pairwise comparison matrix. According to the AHP model, matrix should be consistent. To compute consistency ratio, we must first compute the consistency Index (CI) for the above comparison matrix by using the Eqn. 1[27].

$$\text{Consistency index, CI} = (\lambda_{max} - N)/(N - 1) \quad (1)$$

Where, N is the number of parameter used in the comparison matrix and λ_{max} is the maximum Eigen value. The consistency ratio (CR) is then calculated using Eqn. 2 for the corresponding N number of the random index (RI) and thatof RI value is obtained from below Table 6[28].

$$\text{Consistency ratio, CR} = \frac{CI}{RI} \quad (2)$$

Then, the comparison matrix is said to be significant if the CR value obtained is less than 0.1, and the decision is true[28,29]. A CR value of 0.8 was obtained for this comparison matrix. As a result, findings suggest that these factor comparisons are stable, and the resultant matrix is quietly significant.

Table 4. Pairwise comparison matrix

Parameter	Temperature	Soil Texture	Rainfall	Soil pH	Drainage	Soil Depth	Slope
Temperature	1	1/3	3	7	5	7	7
Soil Texture	3	1	3	5	3	5	7
Rainfall	1/3	1/3	1	3	3	7	5
Soil pH	1/7	1/5	1/3	1	1/3	3	3
Drainage	1/5	1/3	1/5	3	1	3	3
Soil Depth	1/7	1/5	1/7	1/3	1/3	1	1/3
Slope	1/7	1/7	1/5	1/3	1/3	3	1

Table 5. Normalized comparison matrix

Parameter	Temp	Soil Texture	Rainfall	Soil pH	Drainage	Soil Depth	Slope	Criteria Weigh	Ranking
Temp	0.20	0.13	0.38	0.36	0.38	0.24	0.27	0.28	2
Soil Texture	0.60	0.39	0.38	0.25	0.23	0.17	0.27	0.33	1
Rainfall	0.07	0.13	0.13	0.15	0.23	0.24	0.19	0.16	3
Soil pH	0.03	0.08	0.04	0.05	0.03	0.10	0.11	0.07	5
Drainage	0.04	0.13	0.03	0.15	0.08	0.10	0.11	0.09	4

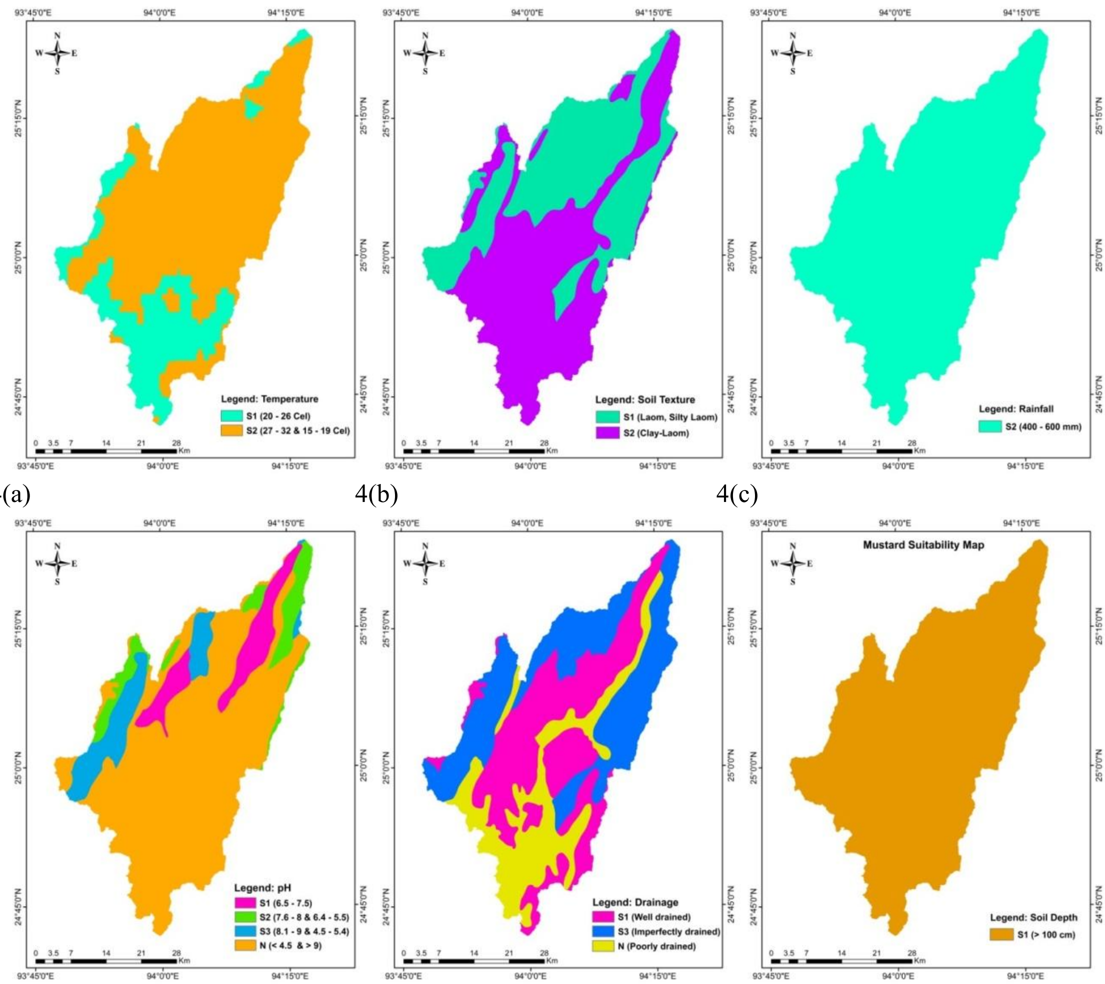
Soil Depth	0.03	0.08	0.02	0.02	0.03	0.03	0.01	0.03	7
Slope	0.03	0.06	0.03	0.02	0.03	0.10	0.04	0.04	6
CR = 0.08				Max Eigen value = 7.68					

Table 6. Random Index table

Order Matrix(n)	1	2	3	4	5	6	7	8	9	10
Random Index (RI)	0.0	0.0	0.58	0.90	0.12	1.24	1.32	1.41	1.45	1.49

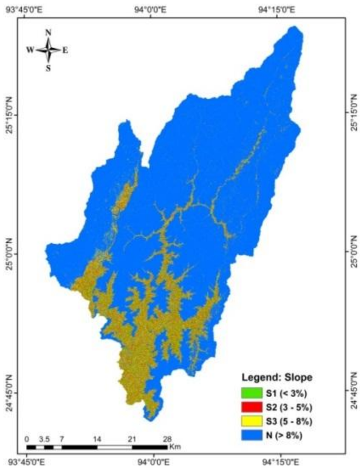
Since the input parameters for this suitability analysis were obtained from various sources, they are standardised to a scale from 1 to 4[30]. Based on the suitability requirements, all criteria are classified into four categories and given a score ranging from 1 to 4. A score of 1 indicates the highest level of suitability, while the lowest suitability is indicated by a score value of 4. Then, as per the suitability model reclassified all parameters based on soil site suitability requirement for mustard introduced by NBSS and LUP (ICAR) publication. A value is assigned on each parameter based on rating and preference. The classified suitability levels for each parameters used in the assessment are shown (Figure 4). To indicate the relative importance of the criteria, the weight for each parameter has been evaluated from the assessment of AHP model. According to the AHP model, soil texture was the most pertinent factor, accounting for 33% of the weightage. In addition to soil drainage, temperature and rainfall are other significant criteria, with the weightage of 33, 28 and 16 % respectively. Soil drainage, pH, slope, and soil depth have been identified as the least important, with weightages of 9%, 7%, 4% and 3% respectively. Table5 provides comprehensive details on the weight of these factors.

The weighted overlay method was applied to generate mustard suitability map using spatial analyst tool of ArcGIS. It is a method for generating an integrated evaluation that utilises the use of a standard scaled rating to represent multiple data inputs[31]. The final mustard suitability map was generated by integrating the required criterion values and has been categorised as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N). The contributing areas for each suitability class are presented in Table 8. As such, spatially distributed mustard crop suitability zones have been generated.



4(a) 4(b) 4(c)

4(d) 4(e) 4(f)



4(g)

Figure4. Suitability levels of the seven parameters (a) Temperature, (b) Soil texture, (c) Rainfall (d) Soil pH,(e) Drainage, (f) Soil depth and (g) Slope

Table 8. Computed areas for different suitability classes

Land suitability class	Area in km^2	Percentage coverage Area
Highly suitable (S1)	203.85	11.13
Moderately suitable (S2)	100.53	5.49
Marginally Suitable (S3)	32.68	1.78
Not suitable (N)	1493.51	81.58
Total	1830.57	

3. Results and Discussions

Mustard crop suitability was assessed for the entire catchment area, comprises of both the hill and valley regions. The output for this assessment will be critical for mustard crop suitability zonation. In particular, the valley region of the catchment with its gentle slope was found to have very suitable mustard cultivation zones. The steep areas, particularly in the mid and higher hills region, are covered with deciduous and evergreen forest. The suitability map of mustard was generated by using weighted overlay technique of spatial analyst tool in ArcGIS 10.3. The mustard suitability map for the Imphal-Iril sub-catchment is depicted (Figure 5). From the result it was found that the highly suitable (S1) class extends around 203 km^2 of area and characterised the soil pH range from 6.5 to 7.5, soil depth more than 100 cm and slope less than 3%. The class has a variety of textures, including loam, silty loam, and sandy loam. The growing season sees an average rainfall of 450 to 600 mm, with mean temperatures ranging from 20 to 26 ^oC. According to the study results, the catchment's existing agricultural land is mainly situated in the lower valley areas, where highly suitable areas may be identified.

As per the model output, moderately suitable (S2) area for mustard cultivation is covered over an area of about 100 km^2. This moderately class were characterised by pH range between 5.5 to 6.4 and 7.6 to 8, depth of soil more than 50 mm, moderately well drained, slope in between 3 to 5% and variety of soil textures, include sandy- clay, silt-clay-loam, clay-loamand annual average temperature between 27 to 32 ^oC and 15 to 19 ^oC. According to the results of the suitability assessment, the majority of the moderately suitable regions are observed near the foot hill portion of sub-catchment, which has a gentle sloping terrain. This zone is indicated by brown colour in the suitability map and majority of this suitability areas were observed in the north-western part of the catchment near Sekmai, Kanglatongbi, Kangpokpi and Saikul regions.

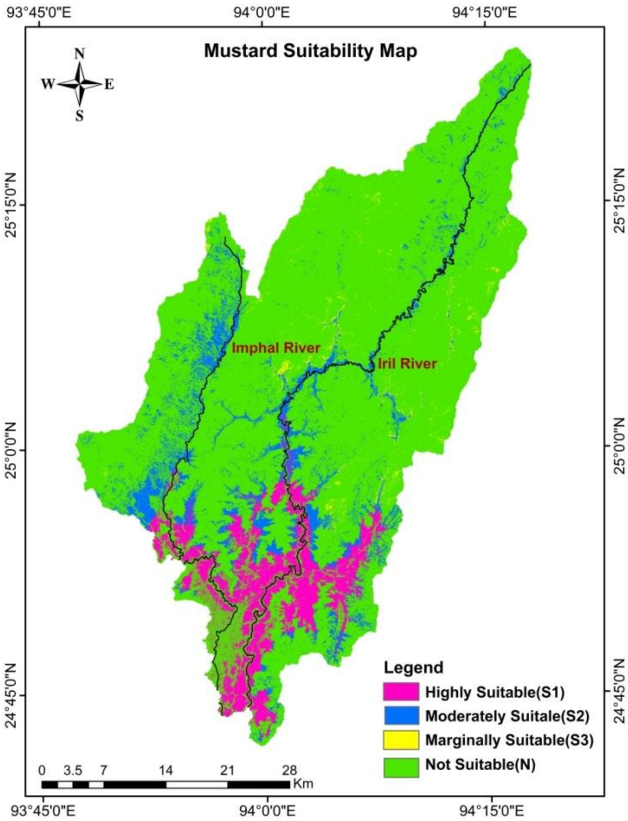


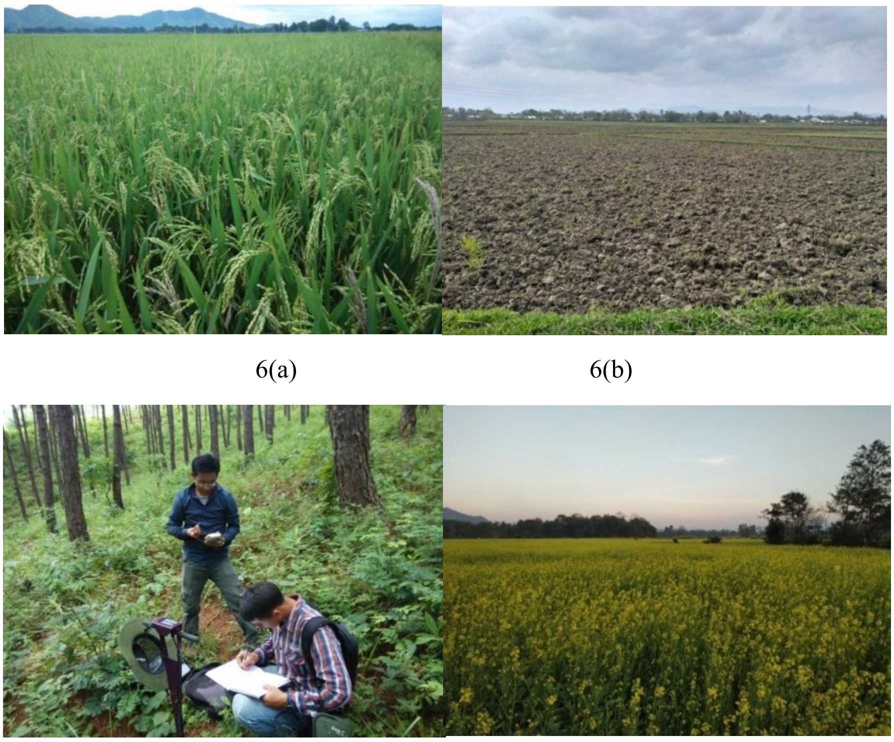
Figure 5. Mustard suitability map in Imphal-Iril catchment

From the model output it was found that a few patches of marginally suitable (S3) zones are observed near the central portion of the catchment and covering an area of about 32 km^2. Interestingly, Not-suitable (N) sites for mustard production were mostly observed in the steep and higher hilly regions of the catchment. In comparison to other suitability classes, a huge substantial area has been observed under the not suitable zone which contributing about 1493 km^2 and this region is part of a huge mountainous region with protected reserved forest and natural wildlife habitat area. Although some hilly regions with higher elevation show marginally suitable class, it is not suitable for mustard cultivation at present because due to the extensive, inaccessible evergreen, deciduous and protected reserved forests that cannot be cut down.

According to the study, mustard should be grown in Rabi season since it requires less water than other crops, which could help agricultural production in the region on sustainable way.

To validate all the suitability classes (highly, moderately, marginally and not-suitable class) obtained from the model performance, ground observation data points have been collected and examined the actual ground condition at the field site using hand held Topcon GPS and camera at different time periods (Kharif and Rabi season) which are shown (Figure 6). The valley portion and foothill region respectively, have been shown to have an extensive prevalence of highly and moderately suitable zones in the catchment. In this catchment, current mustard cultivation is observed in the area along the Imphal River near Awang Potsangbam, Imphal East District during only in Rabi season as shown (Figure 6d). Rice cultivation is observed during Kharif season in the central valley region of the catchment which comes under highly suitability zone for mustard cultivation. In this highly suitability zone, no agriculture activities are observed particularly in most part of agricultural area during Rabi season and field photograph is shown (Figure 6b). So mustard can be cultivated successfully in large area with good productivity. In addition, optimum soil moisture is also observed during Rabi season since rice crop is cultivated in most part of agricultural land in the valley region of the catchment during Kharif season as shown (Figure 6a).

The majority area this suitability assessments fall into the not suitable (N) zone, which is found in higher elevated regions with steeper slopes. Additionally, these areas are found in protected reserved forests, thus rendering them unsuitable for the mustard cultivation (Figure 6c).



6(a) 6(b)

6(c) 6(d)

Figure 6. Validation and cross verification work at field site (a). Agricultural land during kharif season, (b). Agricultural land during Rabi season, (c). Cross verification at reserved forest area, (d). Current mustard cultivation practiced in the flood plain area of Imphal River.

There are large regions of Iril-Imphal River catchment that are known to be marginally suitable for growing mustard but they cannot be cultivated due to the administrative norms as they come under restricted forest cover. High values of suitability were recorded in the case of the valley regions of Imphal-Iril River catchment as consequence of the mild slope and optimum temperature range, which means that mustard could easily be grown in rotation with the other relevant crops of the area. Interestingly, on comparison of Fig. 4(f) and Fig. (5), it indicates the high potential of cultivating mustard in the even in the poorly drained soil unlike the Rice which requires standing water in the sowing period. This indicates the lower dependency of mustard cultivation even in the regions which receives scanty seasonal rainfall or has poor irrigation infrastructure in the region.

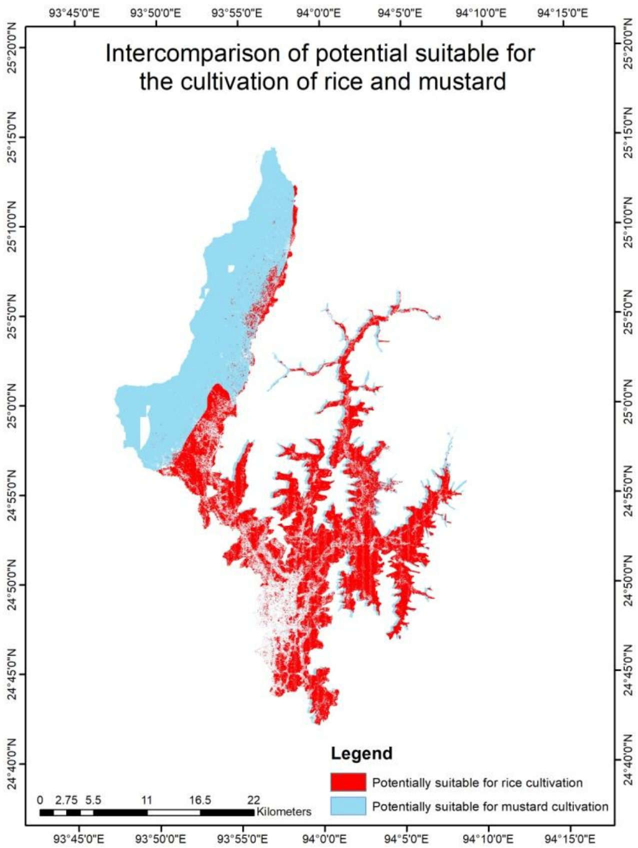


Figure 7. Inter-comparison between the suitability potential of rice and mustard combined.

Since Rice is the predominant crop which is extensively cultivated in the region during during the Kharif season, a inter-comparison was made between the potential suitability of rice with the mustard in order to figure out the coverage and spatial distribution of the area coverage which supports both the rice and mustard cultivation during the Kharif and Rabi season respectively in order to assess the inter rotation of the crop on the same patch of the land to attain sustainability. Figure (7) shows the intercomparison between the suitability potential of rice and mustard combined. The area falling under the high to moderate potential zone for mustard on the extreme western side of the catchment is covered by forest in the upper section of the hills. However, from Figure (7) it was observed that there is 271.64 km^2 area which is potentially suitable for the cultivation of both mustard and rice. It can also be depicted from Figure (7) that mustard has a comparatively high potential area coverage for cultivation as compared to rice especially in the foothills with comparatively greater slopes owing to its better cultivation potential in the comparatively steeper slopes compared to the rice[1].

There are certain limitations and uncertainties associated with such type data and decision driven techniques. Certain types of land that may be either highly suitable or unsuitable for farming may not have any recorded yield due to farmers' decisions not to cultivate them, possibly because of their remote locations or economic factors or the lack of information. Consequently, there will be more uncertainty surrounding the expected suitability in areas where farmers do not normally cultivate crops. Nevertheless, since even expert knowledge is influenced by data, similar drawbacks would exist for any land suitability model, data-driven or not. However, the outcomes of this study clearly signifies the high potential of mustard cultivation in the Rabi season in rotation with rice in the Kharif season in order to attain sustainability and over dependency on the production of rice.

4. Conclusion

Assessment of the soil site suitability for a particular crop is crucial for overall development in agriculture, planning and management for a region. Mustard cultivation suitability assessment was carried out using soil, topography and climatic data. The findings of the present study indicate that AHP method of MCDA could potentially use to classify suitable zones for mustard cultivation using GIS and remote sensing techniques. The suitability results obtained from this model approach was validated with ground data and information with local people using GPS and field survey. As per the model output, the major portions of highly suitability zone for mustard cultivation are observed particularly in the valley region of the catchment where rice crop is cultivating currently. The moderately suitable zones have been found near the foothill area of the catchment with mild sloping terrain. A few patches of moderately suitable (S3) zones can be found near the foothill portion of the catchment. Not-suitable (N) zones are found in steep and higher elevated hilly regions of the catchment and majority portion of the catchment comes under this suitable category. Although the model's performance output suggests that mustard might be grown in a certain portion of land in not-suitable zone (N), this is practically impossible due to higher elevation, extensive protected-reserved forest land, and wildlife habitat area. The findings of this assessment clearly represent the spatial distribution of mustard suitability zones in Imphal-Iril river catchment and which will give important ideas, information and guidance to the regional growers for choosing their cropping pattern which will increase the agricultural production as well as the state economy. The results of this suitability assessment will be helpful to the policy makers in order to achieve high production of mustard in the region. Such type of land suitability assessment is extremely important in states like Manipur where agriculture plays a significant role, especially for crops grown during the Rabi season. This is because the majority of the agricultural lands in this catchment are not currently under cultivation. This assessment will helpful for cropping management option for intensification and diversion of crop. The sustainable use of the agricultural land can be influenced by socioeconomic factors and irrigation infrastructure, which might be taken into account in future research.

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