CHAPTER V
RESULTS AND DISCUSSION

5 General

This chapter discussed about the results of selection of cropping area using remote sensing images, AHP weightage distribution, suitability area distribution mapping for various crop and best crop selection in GIS software environment.

5.1 Primary Data Analysis

5.1.1 Selection of the site

The study area is one of the leading agricultural area in West Bengal growing various crops such as: rice, potato and jute etc. In the study area, farmers generally go for rice and jute cultivation in *kharif* season and mainly potato crop in *rabi* season. Primary survey was carried out around 5 rice- potato cultivated villages in *Tarakeswar* block, Hooghly district, West Bengal. The selected study area is located in the bank of Damodar Hooghly River covering the five revenue villages, such as: *Aligori, Basudebpur, Bajitpur, Jothsombhu and Kolaikundu* of *Tarakeswar* block, Hooghly district, West Bengal, India. The owners of the farmlands are from the mentioned surrounding villages. The study area is situated between 2528500 to 2530600 Northing (latitude) and 604500 to 606500 Easting (longitude) in terms of UTM projection system for Zone 45 in WGS 1984 Datum system. The total study area is around 291 hectares. Most of the study area is under canal irrigation system.

5.1.2 Cropping area selection

Cropping area selection is very important for land suitability study for analyzing current cropping pattern and recommending better alternatives. Remote sensing based images are analyzed for selecting the cropping area for *Tarakeswar* block, West Bengal. Two cloud free 30 m resolution Landsat 8 images were selected each for *Kharif* and *rabi* crop cover for the year 2014 *Kharif* and 2015 *rabi*. The images are collected from earth explorer link of the Landsat image resources. image details:

- Satellite image : Landsat 8 (band 4, 0.63-0.68µm and band 5, 0.845 – 0.885 µm wave length)
- *Images: Kharif* : 31 October 2014;
  Rabi: 08 March 2015
- Cropping Area: 0.2<NDVI<0.5

In this study geometric correction was carried out using Ground Control Points (GCPs) from topographic maps to geo-code the Landsat 8 image. The GCPs values were converted into Universal Transverse Mercator (UTM) values for the purpose of digitization and better distance management. ERDAS 9.2 software is used to assist in carrying out digital image processing steps through unsupervised classifications.

5.1.2.1 Remote sensing data and ancillary data

Data used in this study are Landsat 8 spacecraft and Operational Land Imager (OLI)and the Thermal Infrared Sensor (TRIS) in the year of 2014(*Kharif*) and 2015 (*Rabi*). Remotely sensed data provides accurate, reliable and timely, information on agricultural land (downloaded from http://earthexplorer.usgs.gov).

5.1.2.2 Software used

ERDAS 9.2 and Arc GIS 10.1 software package were used for integration between RS and GIS to estimate the capability and suitability final spatial maps for decision making. Map interpretation was done using GIS software environment.

5.1.2.3 Digital image processing

Digital image processing techniques were carried out for Landsat 8 satellite with Operational Land Imager (OLI) sensor images. Radiometric and geometric corrections, image geo-referencing, image enhancement and the color composites operation were carried out to change and modify the original raw spectral data to increase the availability, and validate the information to provide the best possible output for analysis and interpretation for information extraction. The nearest neighbor resampling method was used to preserve the blocky structure of the agricultural fields and the original radiometry of the image (Eckert *et al*., 2004, Santos *et al*., 2005). Survey of India (SOI, 2011) topographical sheets on 1:50,000 scale were used as reference data for rectification of satellite images and selection of Ground Control Points (GCPs) (Appendix E.2). The unsupervised classification was carried out along with normalized difference vegetation index (NDVI) estimation. The geometric correction of the images was carried out by selecting nine ground control points and the most suitable band combinations were the false colour composite (FCC) of Landsat 8 (RGB) to show the vegetation cover. GIS software was further used to build the soil properties database along with weightage of each properties to work out the spatial model to produce the different suitability maps.

5.1.2.4 *NDVI analysis*

The objective of the multi temporal analysis using remote sensing data was to reconstruct the evolutionary changes that took place between October 2014 and March 2015, that is, the period for the *kharif* and *Rab*i crops with best suited remote sensing images of the study area. In other words, the changes that occur of the land cover for the given crop season. Generally, these changes are comparatively evident on the land cover due to seasonal variations to crop cultivation. However, a distinction was made between the agricultural fields, as crops fields follow a phenological cycle which is controlled by changing seasons. Agricultural fields flourish between June –September/October when there is abundant precipitation and dry up as they get matured for harvest or when they suffer from hydrologic stress usually between December-January of the study area. The false colour composite combinations (FCC) 432 (RGB) of Landsat 8 as well as the true colour combination were loaded in ERDAS 9.2. Multi temporal analyses of the vegetation cover over the same areas in the two images were carried out using the Normalised Differential Vegetation Index (NDVI) estimation. Computed values for NDVI of Landsat 8 image which was acquired in October 2014 (*Kharif*) were higher compared to NDVI values over the same area in Landsat 8 which was acquired in March 2015 (*Rabi*). To further confirm that the differences in NDVI between the two sets of Landsat images were not due to the age of the vegetation, but as a function of the phonological changes that are controlled by the seasons. NDVI analysis revealed that agricultural cropping area covered $0.2<NDVI<0.5$ in the study area.The natural vegetation (sparse and close forest) also showed a similar variation in NDVI values but to a lesser extent compared to that between the forest and agricultural fields since the vegetation cover remains fairly stable all the year round (Figs. 5.1 and 5.2.)

5.1.3 Entry of data

The primary crop practice information for each fifty plots were collected through questionnaire survey (Appendix F). The data after pre-processing was supplied to the GIS database in the form of *dbase* or *tab delimited* files. Data in each field represented a piece of information about all the data points. The individual records kept all the information about the data point including its global position and crop yield. The adoptability of the data was checked through map query and histogram tools in GIS software application before further analysis.

5.1.4 Digitization of the base map

The base map of the study area (1:50,000) was collected during the survey working SOI, 2011. Open series map developed by Survey of India, 2011 was used for creating base map i.e. sheet no. F45K1(79B/1). The base map is created by digitizing the mentioned topographical map in Arc GIS 10.1 (ESRI, Redlands, California,USA) software environment, around nine ground control points (GCPs) were supplied using eTrex 20 GPS Receiver (Garmin Ltd., Olathe, Kansas, USA) for image registration of the study area.

The following information of the study area is acquired through digitization (Fig. 5.3).

- Study area boundary
- The road and railway network
- The canal and water bodies
- The land coverage (agricultural and forest area)
- The temple, settlements and railway station

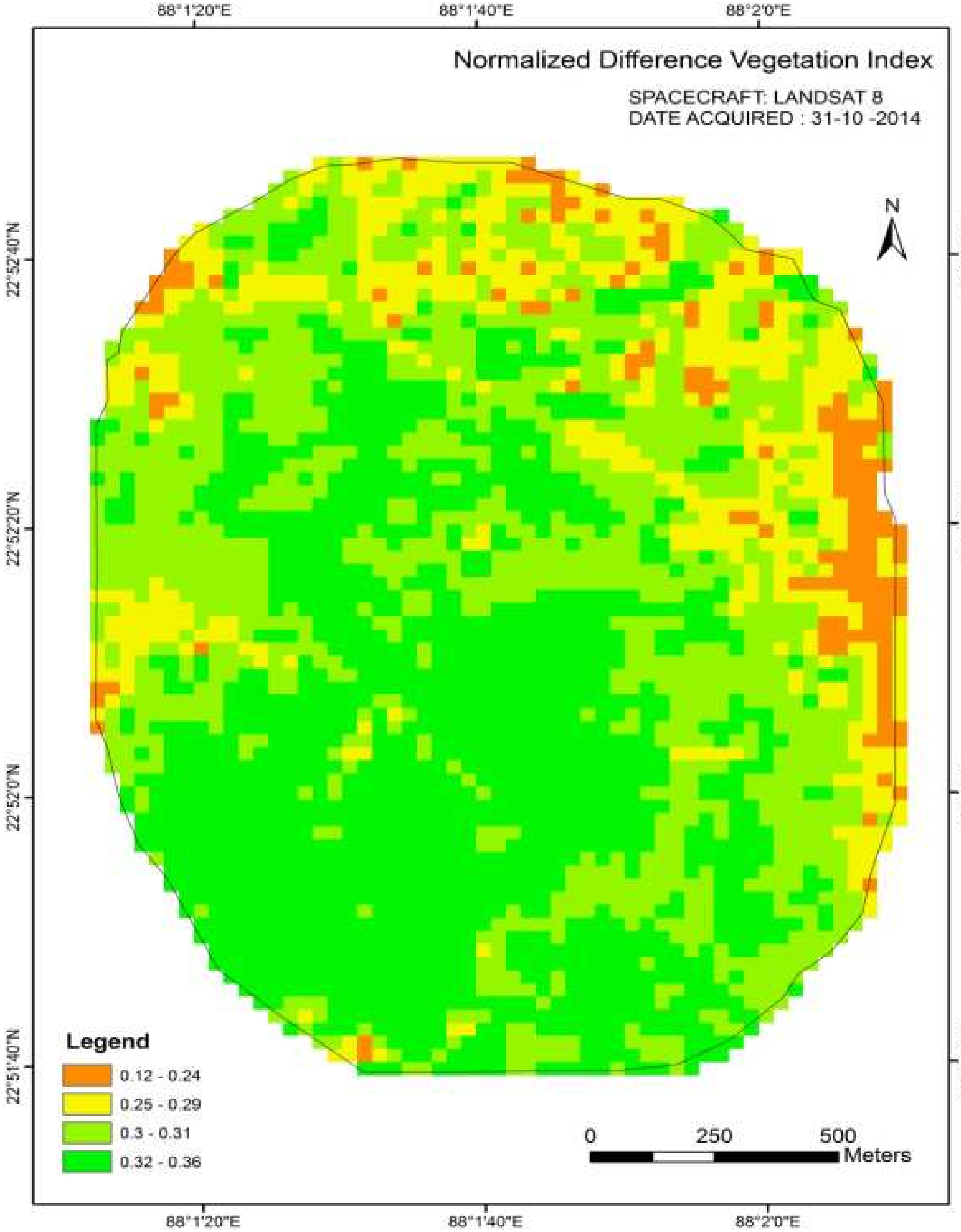


Figure 5.1: NDVI analysis for *Kharif* season crop (false colour composite)

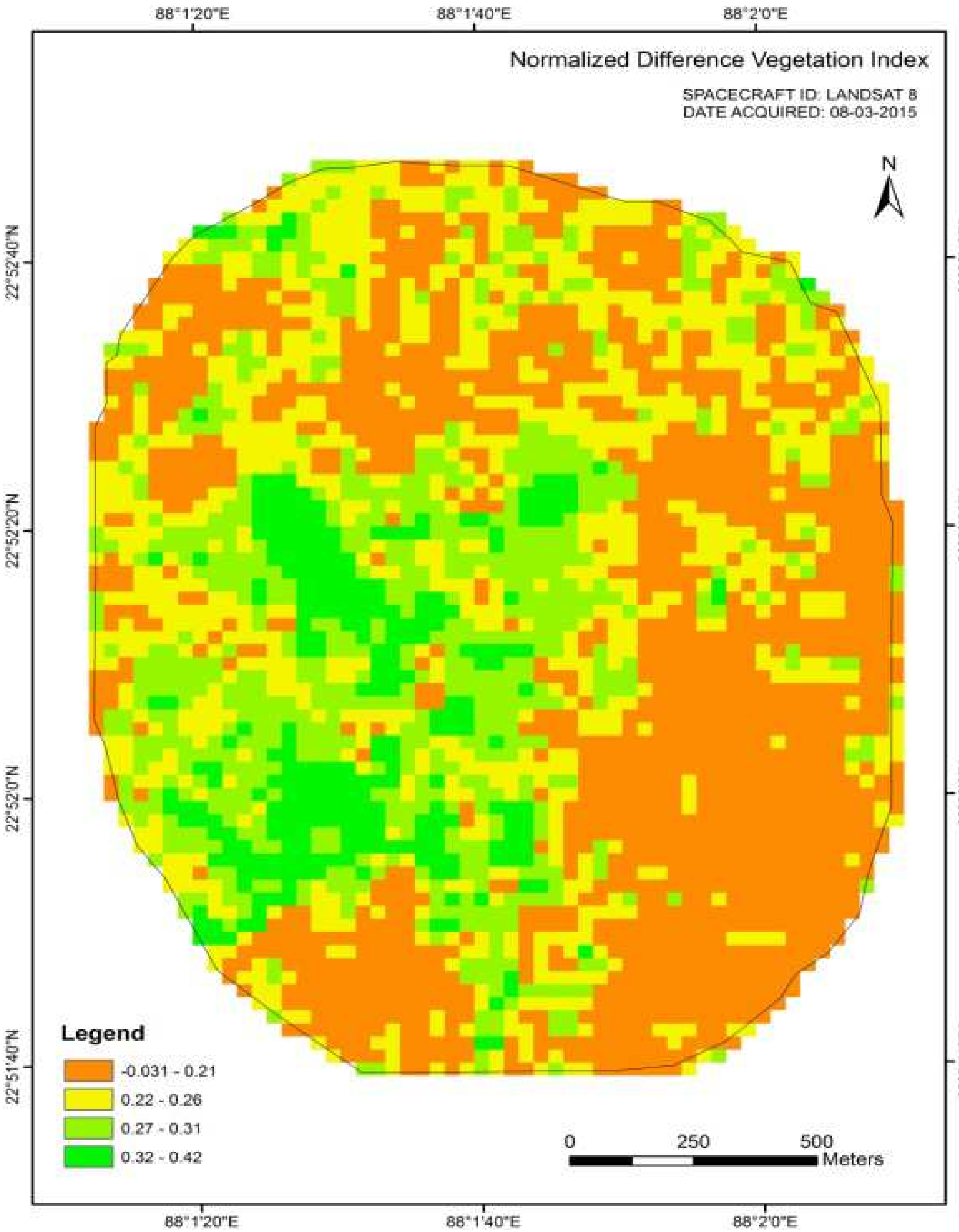


Figure 5.2: NDVI analysis for *Rabi* season (false colour composite)

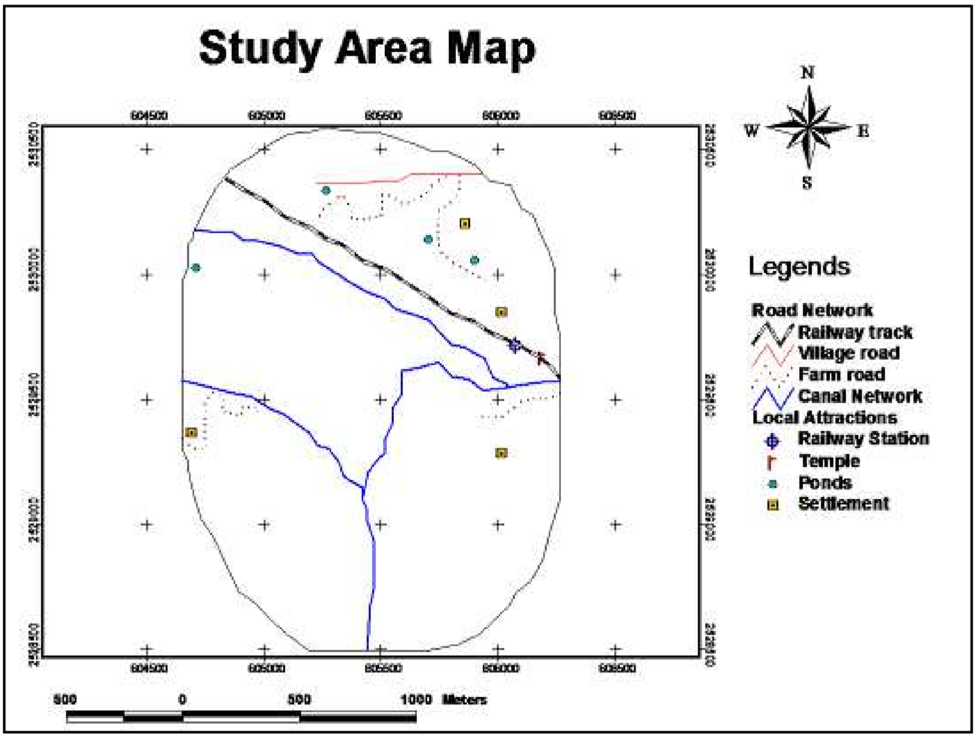


Figure 5.3: Study area map

5.1.5 Soil sample analysis

Nearly fifty soil samples were collected of three soil layer from randomly selected fifty plots from the five villages representing the whole study area at a depth of 0-15 (top layer), 15-30cm (shallow layer), 30-45cm (deep layer) in end of the *Rabi* season of India during May 2015 (Soil Survey Staff, 1975, 1993). The soil samples are dried, cursed and passed through a 2 mm sieved screen. The samples have been undergone laboratory analysis for selected parameters, such as: pH, soil texture, EC, organic C, available N, P, K and Zn, following standard laboratory soil analysis procedures (Appendix G.1). Soil texture of soil samples was determined by estimating percentage of sand, silt and clay according to USDA system by Hydrometer method (Bouyoucos, 1962). The class of soil texture was determined by USDA method using textural triangle diagram (USDA,1980). The readings were estimated in parts per million (PPM) scale (Appendix G.2).

5.2 AHP Weightage Estimation

Some studies (Dahal and Routray, 2011; Batten, 2002; Aimrun, et al., 2011) has followed the impact of individual parameters on crop yield, to define their importance. However, the impact of single parameter on the crop yield is minimal and the regression curves are very insignificant. Hence, the technique was not followed (Ahamed, *et al.*, 2000; Tabi, *et al.*, 2012). As, agriculture is a biological entity, in our study experts' opinions were sort for ranking the relative importance of crop nutrients for a particular crop (i.e. rice) along with previous land suitability works. Opinion of nearly ten experts in the field of agronomy and soil science related to agriculture in general, were taken. In this investigation, the evaluation criteria were selected considering the crop requirements regarding local conditions. In this MCA, the factors were selected based on agronomic knowledge of local experts and reviews of existing literature. Such an approach produced valuable information on the relative importance of the factors under evaluation and could be a useful precedent for future studies of selected four crop cultivation in the study area. Specific effort were made to get agreement on ranking of the parameters. Utilizing the ranking parameters and AHP guidelines, pairwise comparison matrix for selected crop was estimated.

- Using the Satty (1980) technique, the ranking and weightage of each parameter is estimated.
- With the ranking and weightage value the final weightage is estimated in Matlab 2015 software environment.
- The Principal Eigenvector value (λ_{max}), RI, and CI values are estimated;
- The weightage values are validated by estimating CR.
    - If CR<0.10, the weightage is valid
    - If CR≥0.10, the weightage is not valid
- So the ranking and weightage has to be repeated
- Based on AHP pairwise comparison matrix (PCM) technique , the weightage for four crops are estimated

5.2.1 AHP weightage estimation for rice

Rice is the major crops during *Kharif* season of the study area. Principal eigenvalue (λ_{max}) and Consistency Index (CI) were estimated as 8.75 and 0.11, respectively. Consistency ratio (CR) was estimated and found to be 0.08 (<0.10, within the limit). So, the weightage estimated are valid (Saaty and Vargas, 2001) and can be used further for rice land suitability estimation. The pair-wise comparison (PC) matrix table gave highest weightage value to Soil texture (ST) and lowest weightage value of available zinc (Zn) for rice crop (Table 5.1).

Table 5.1: Pair wise comparison matrix and eigenvector of criteria in AHP for rice crop (n=8)

	ST	pH	EC	OC	N	P	K	Zn	Weightage
ST	1	2	3	3	5	7	7	9	0.311
pH	0.5	1	2	2	5	7	7	8	0.227
EC	0.333	0.5	1	2	4	6	6	7	0.171
OC	0.333	0.5	0.5	1	3	4	4	6	0.122
N	0.2	0.2	0.25	0.333	1	3	3	5	0.070
P	0.142	0.142	0.167	0.25	0.333	1	2	4	0.043
K	0.142	0.142	0.167	0.25	0.333	0.5	1	4	0.037
Zn	0.111	0.125	0.142	0.167	0.2	0.25	0.25	1	0.019

Note: λ_{max} =8.75, RI=1.41, CI=0.11; CR=0.08 (<0.10). ST- soil texture, OC- organic carbon, N- available nitrogen, P- available phosphorous, K- available potassium, Z -zinc level, n-number of parameters.

5.2.2 AHP weightage estimation for jute

Jute is the second major crops during *Kharif* season of the study area. Principal eigenvalue (λ_{max}) and Consistency index (CI) were estimated at 8.53 and 0.08, respectively. Consistency ratio (CR) was estimated and found to be 0.05 (<0.10, within the limit). So, the weightage estimated are valid and can be used further for jute land suitability estimation. For jute crop suitability, pH was given highest weightage value of 0.317 and available potassium (K) was given lowest weightage value of 0.026 (Table 5.2)

Table 5.2: Pair wise comparison matrix and eigenvector of criteria in AHP for jute crop (n=8)

	pH	ST	N	Zn	OC	EC	P	K	Weightage
pH	1	2	3	4	5	5	6	7	0.317
ST	0.5	1	2	3	4	4	5	6	0.218
N	0.333	0.5	1	2	4	4	5	5	0.165
Zn	0.25	0.333	0.5	1	2	2	4	5	0.105
OC	0.2	0.25	0.25	0.5	1	1	3	5	0.072
EC	0.2	0.25	0.25	0.5	1	1	2	3	0.06
P	0.167	0.2	0.2	0.25	0.333	0.5	1	2	0.037
K	0.142	0.167	0.2	0.2	0.2	0.333	0.5	1	0.026

Note: λ_{max} =8.53, RI=1.41, CI=0.08; CR=0.05 (<0.10). ST- soil texture, OC- organic carbon, N- available nitrogen, P- available phosphorous, K- available potassium, Z -zinc level, n-number of parameters.

5.2.3 AHP weightage estimation for potato

Potato is the major crops during *Rabi* season of the study area. Principal eigenvalue (λ_{max}) and Consistency Index (CI) were estimated at 8.60 and 0.09, respectively. Consistency ratio (CR) was estimated and found to be 0.06 (<0.10, within the limit). So, the weightage estimated are valid and can be used further for potato land suitability estimation. The pairwise comparision matrix table gave highest weightage value of Available potassium (K) and lowest weightage value of available zinc (Zn) for potato crop (Table 5.3).

Table 5.3: Pair wise comparison matrix and eigenvector of criteria in AHP for potato crop(n=8)

	K	ST	N	pH	OC	EC	P	Zn	Weightage
K	1	2	3	4	5	6	7	8	0.326
ST	0.5	1	2	3	4	4	6	6	0.217
N	0.333	0.5	1	2	3	3	5	6	0.15
pH	0.25	0.333	0.5	1	3	3	5	5	0.119
OC	0.2	0.25	0.333	0.333	1	2	4	4	0.075
EC	0.167	0.25	0.333	0.333	0.5	1	3	3	0.056

P	0.142	0.167	0.2	0.2	0.25	0.333	1	2	0.032
Zn	0.125	0.167	0.167	0.2	0.25	0.333	0.5	1	0.025

Note: λ_{max} =8.60, RI=1.41, CI=0.09; CR=0.06 (<0.10). ST- soil texture, OC- organic carbon, N- available nitrogen, P- available phosphorous, K- available potassium, Z -zinc level, n-number of parameters.

5.2.4 AHP weightage estimation for lentil

Lentil crop is growing during *Rabi* season of the study area. Principal eigenvalue (λ_{max}) and Consistency Index (CI) were estimated at 8.57 and 0.08, respectively. Consistency ratio (CR) was estimated and found to be 0.06 (<0.10, within the limit). So, the weightage estimated are valid and can be used further for lentil land suitability estimation. whereas for lentil Soil texture (ST) was given highest weightage value and available nitrogen (N) was given lowest weightage value (Table 5.4)

Table 5.4: Pair wise comparison matrix and eigenvector of criteria in AHP for lentil crop (n=8)

	ST	pH	Zn	EC	OC	P	K	N	Weightage
ST	1	2	3	5	6	7	8	8	0.345
pH	0.5	1	2	3	3	5	7	8	0.218
Zn	0.333	0.5	1	2	3	4	5	7	0.153
EC	0.2	0.333	0.5	1	2	3	5	6	0.107
OC	0.167	0.333	0.333	0.5	1	2	4	5	0.077
P	0.142	0.2	0.25	0.333	0.5	1	2	3	0.046
K	0.125	0.142	0.2	0.2	0.25	0.5	1	3	0.033
N	0.125	0.125	0.142	0.167	0.2	0.333	0.333	1	0.021

Note: λ_{max} =8.57, RI=1.41, CI=0.08; CR=0.06 (<0.10). ST- soil texture, OC- organic carbon, N- available nitrogen, P- available phosphorous, K- available potassium, Z -zinc level, n-number of parameters.

5.3 Land Suitability Analysis

Soil nutrient based land suitability analysis is gaining popularity among the farmers, planners and researchers. Individual nutrient based suitability distribution maps were developed for different crops in the study area using GIS software. The general nutrient level of N, P, K and Zn are found to be highly suitable for very high range of values for selected crops grown in the study area**.** The soil texture was found to be clay to sandy clay loam in the most part of the study area. The pH level in the study area was found to be 4.5 - 6.0, which is medium to low suitable for rice and potato crop. Similarly, organic matter varied from 0.13 to 0.95 %, very low suitable for rice and potato crop cultivation. The soil may be treated with lime or different soil strengthen material for growing crop profitably. However, these areas may be allotted for alternative crops.

5.3.1 Land suitability evaluation for selecting crops

Individual crop land suitability maps were developed for each soil parameters. The Inverse Distance Weighing (IDW) was used for the interpolation of the data to produce suitability surfaces (Appendix H.1).

The surfaces showing the distribution of available soil nutrients (Appendix H.2) and the rice and potato yield maps were developed. The three soil layers were classified to suitability groups according to their level of soil nutrient requirements for selecting crops.

5.3.1.1 Yield estimation for rice

Rice yield information of the study area was collected during survey work from each plots. The yield information along with location GPS co-ordinates were imported to Arc GIS 10.1 software environment. The yield distribution map was developed (Fig. 5.4a). As seen from the rice yield map, the number of hectares available to each suitability class is as follows: 18.6% of the study area has 'highly suitable' (S_1) and nearly 5.2% area are found to be 'unsuitable' (N) for growing rice crop (Table 5.5). Nearly,75% of the farms also found sound for growing rice, as the study area is a major rice growing zone in the region.

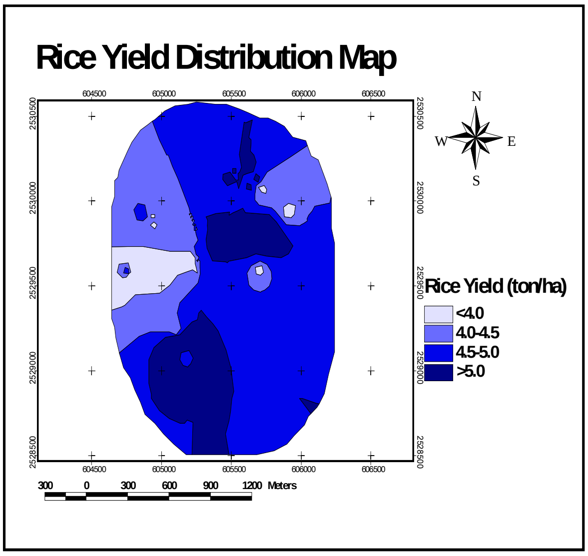
The 'unsuitable' area, where soils have some rice growth limitations, such as: presence acidic soil (pH value\5.5). The soil may be treated with lime or different soil strengthen material for growing rice profitably. However, these areas may be allotted for alternative crops. For better assessment of rice yield, various advanced techniques may be used, such as, aerial photography, image processing (Aggelopoulou et al., 2011), low altitude remote sensing (Swain et al., 2010) and satellite base remote sensing etc.

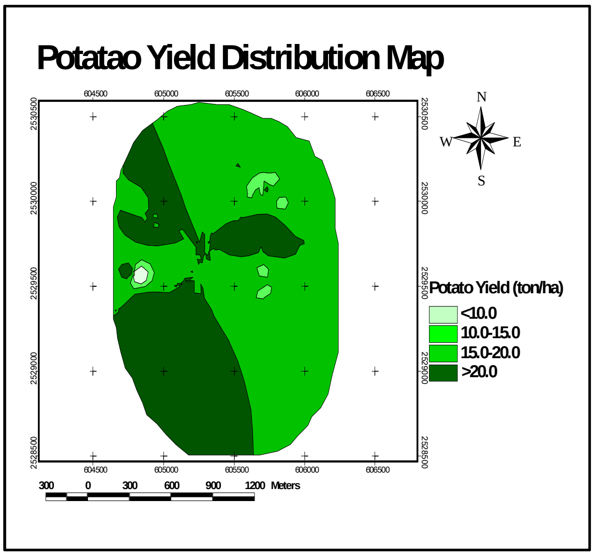
5.3.1.2 Yield estimation for potato

Potato crop is highest production in the study area all over the district. Potato yield information of the study area was collected from each plots along with location GPS co-ordinates points order. The yield information were imported to Arc GIS 10.1 software environment to develop potato yield distribution map (Fig. 5.4b). As seen from the potato yield map, the number of hectares available to each suitability class is as follows: 36.8% of the study area has 'highly suitable' (S_1) and 61.2 % area has 'moderate suitable' (S_2) and nearly 0.3% area are found to be 'unsuitable' (N) for growing potato crop (Table 5.5). Nearly, 90% of the farms also found sound for growing potato, as the study area is a major potato growing zone in the region.

Table 5.5: Rice and Potato yield area distribution of the study area

Class	Description	Rice		Potato	
		yield(ton/ha)	% of area	yield(ton/ha)	% of area
S_1	Highly suitable	>5.0	18.6	>20.0	36.8
S_2	Moderate suitable	4.5-5.0	54.3	15.0-20.0	61.2
S_3	Marginal suitable	4.0-4.5	21.9	10.0-15.0	1.7
N	Not suitable	<4.0	5.2	<10.0	0.3





(a) (b)

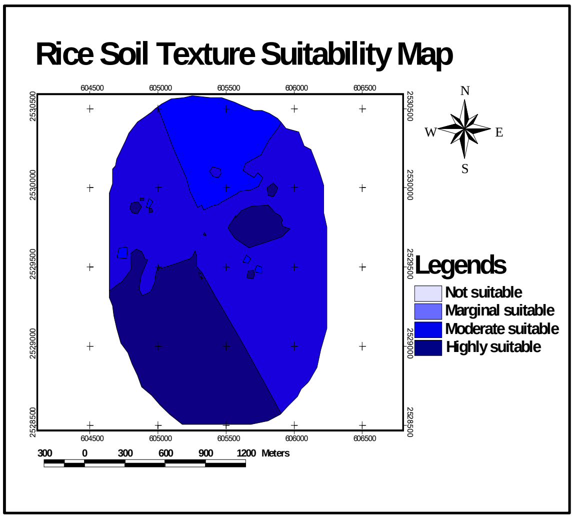
Figure 5.4: Yield distribution map, a) Rice yield; b) Potato yield

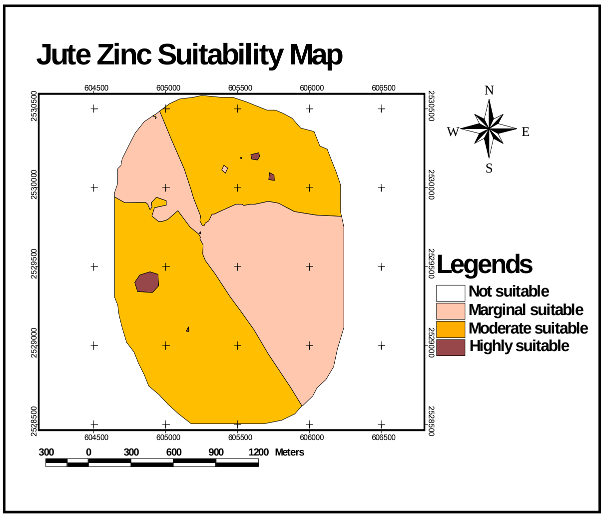
5.3.2 Suitability analysis

Suitability distribution maps for each soil parameter (Appendix I.1 to I.3) for *Kharif crop* (rice and jute), for *Rabi crop* (potato and lentil) at top layer, shallow layer and deep layer were developed in GIS environment (Figure 5.5). Combined suitability distribution map using the AHP weightage of the parameters for a particular crop was mapped in GIS. The comparison of suitability for individual crop based on different layers were carried out. As both the crop, jute and lentil are deep rooted as well as rice and potato are more significant for top and shallow layer, the soil suitability study for top, shallow and deep layer is important to select the best crop a particular field. Even during deep plouging the deep soil layer may come up and contribute to the shallow rooted crops such as rice and potato etc.

5.3.3 Soil morphological suitability analysis

- Land suitability study was also carried out for sub-surface soil layers along with top layer.
- With nutrient parameter ranges and AHP weightage, suitability maps were also developed for the 4 crops at shallow (15-30cm) and deep (30-45cm) soil layers.
- It is useful for deep rooted crop and deep ploughed-shallow rooted crops.


Rice Soil Texture Suitability Map
N
W
E
S
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
300 0 300 600 900 1200 Meters


Jute Zinc Suitability Map
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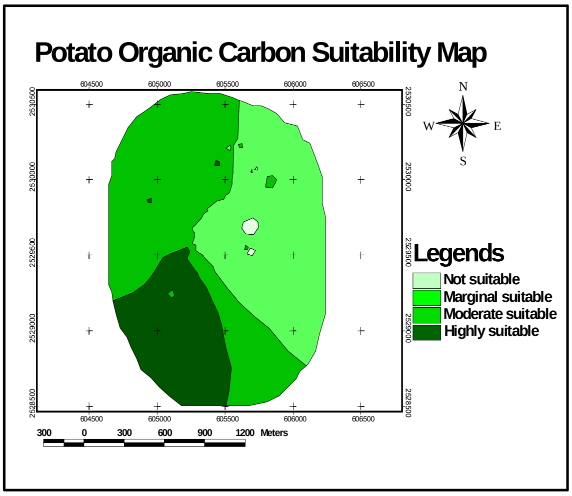
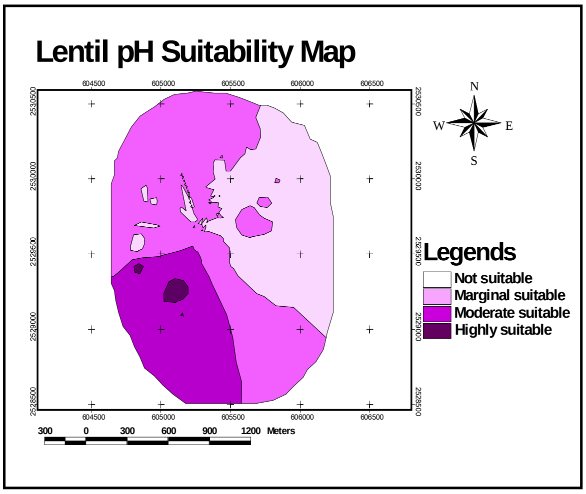
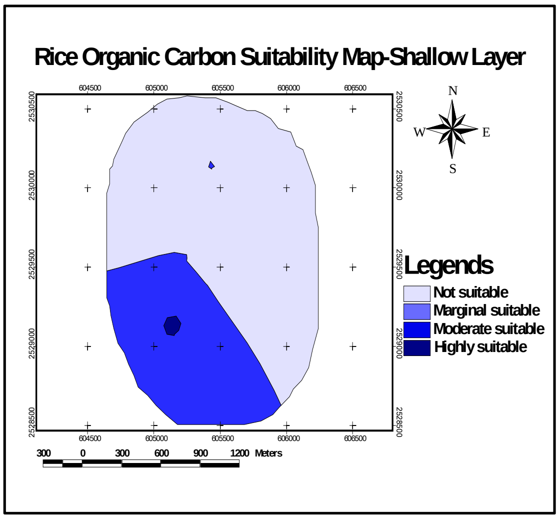
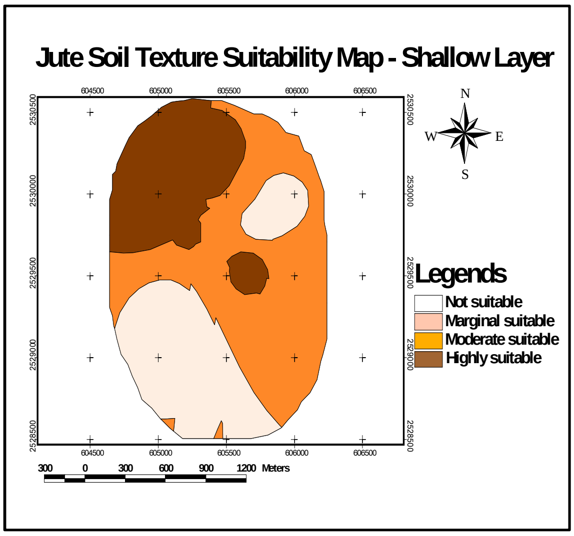
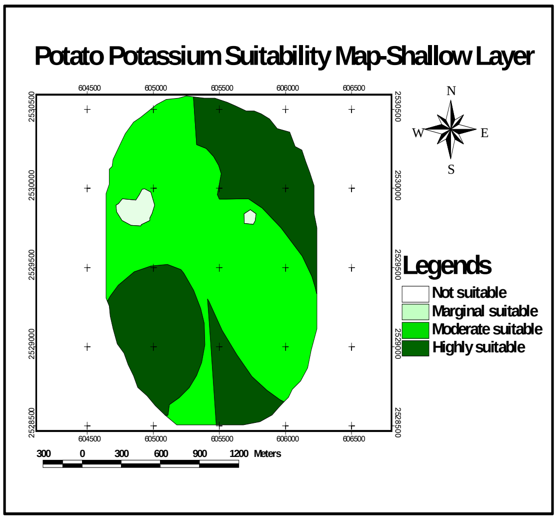
Moderate suitable
Highly suitable
300 0 300 600 900 1200 Meters


Potato Organic Carbon Suitability Map
N
W
E
S
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
300 0 300 600 900 1200 Meters


Lentil pH Suitability Map
N
W
E
S
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
300 0 300 600 900 1200 Meters


Rice Organic Carbon Suitability Map-Shallow Layer
N
W
E
S
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
300 0 300 600 900 1200 Meters


Jute Soil Texture Suitability Map - Shallow Layer
N
W
E
S
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
300 0 300 600 900 1200 Meters


Potato Potassium Suitability Map-Shallow Layer
N
W
E
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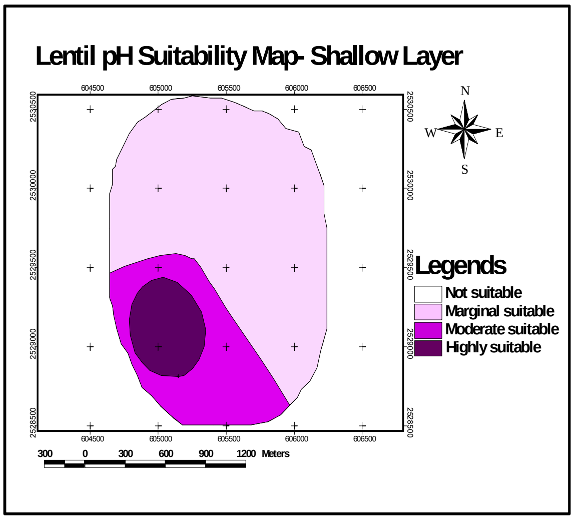
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
300 0 300 600 900 1200 Meters


Lentil pH Suitability Map- Shallow Layer
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Not suitable
Marginal suitable
Moderate suitable
Highly suitable
300 0 300 600 900 1200 Meters

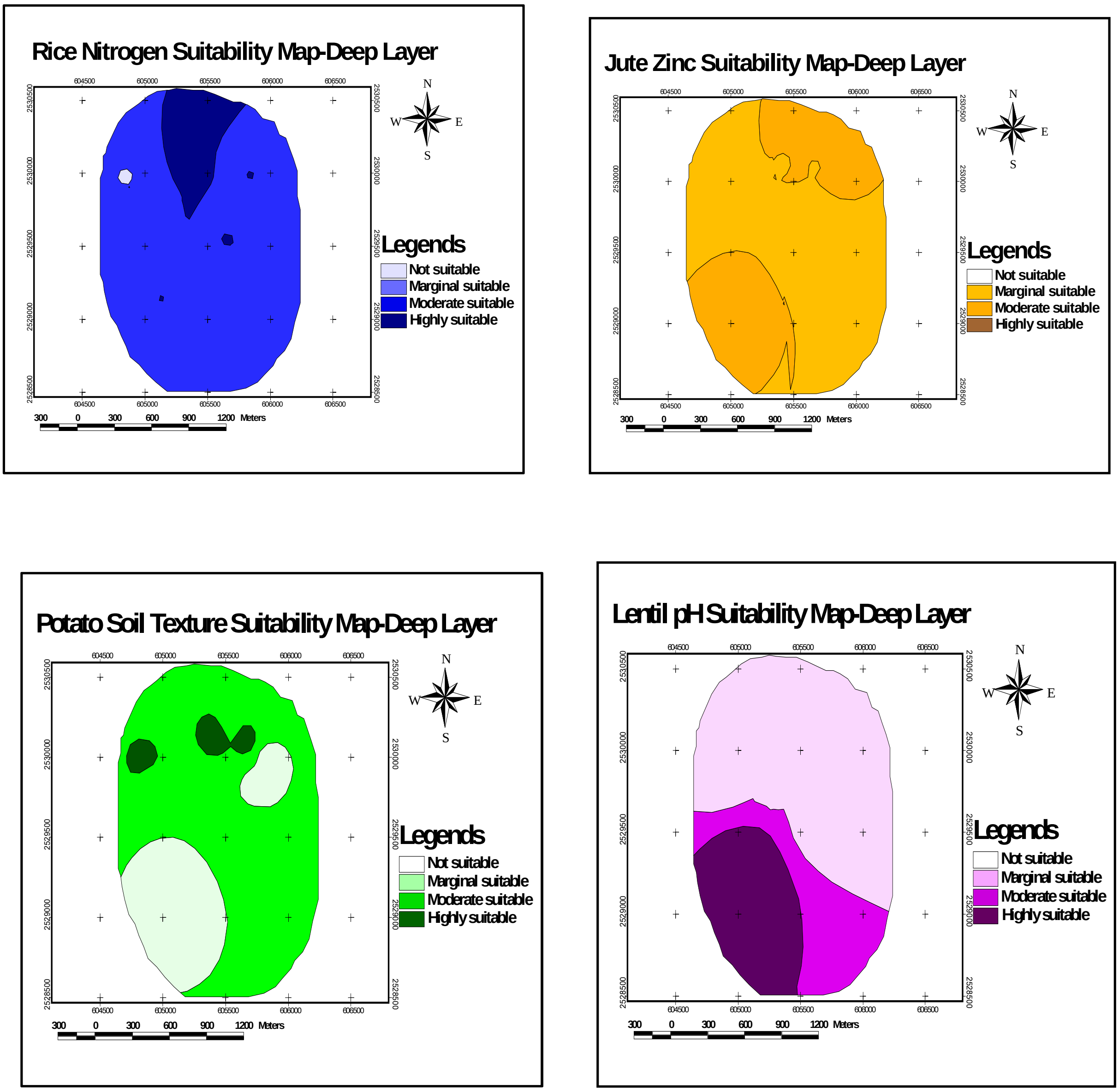


Figure 5.5: Parameters suitability distribution for rice, jute, potato and lentil (selected parameters)

5.3.4 Rice crop suitability

5.3.4.1 Top layer

Rice was cultivated in the *Kharif* season in the area. Rice is a major food staple and a mainstay for the rural population and their food security. It is mainly cultivated by small farmers in holdings of less than 1 hectare. The rice suitability map of the study area showed that nearly

29.2% of area is 'highly suitable' (S_1), 51.2 % area is 'marginal suitable' (S_3) and nearly 13% of area is 'not suitable' (N) (Fig. 5.6a). Nearly, 85.5% of the farms also found sound for suitable rice, as the study area is a major rice growing zone in the region (Table 5.6).

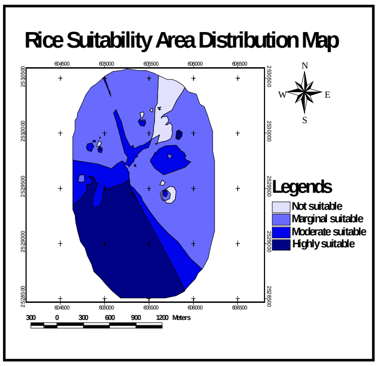
The unsuitable area, where soils have some rice growth limitations, such as: presence acidic soil (pH value\5.5). The soil may be treated with lime or different soil strengthen material for growing rice profitably. However, these areas may be allotted for alternative crops. For better assessment of rice yield, various advanced techniques may be used, such as, aerial photography, image processing (Aggelopoulou et al., 2011), low altitude remote sensing (Swain et al., 2010) and satellite base remote sensing etc.

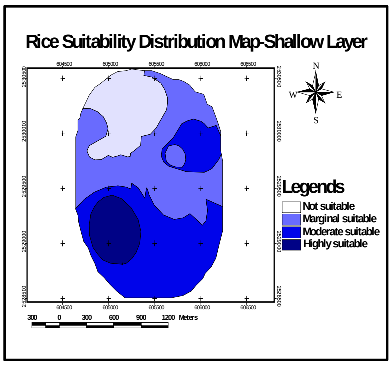
5.3.4.2 Shallow layer

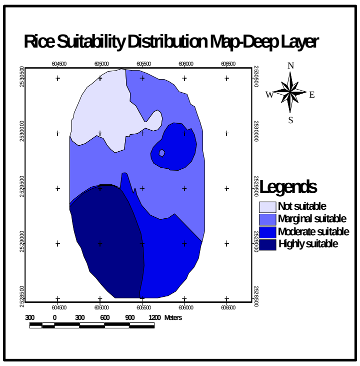
The depth of soils is considerably important for nutrient eluviations and illuviation process both agricultural and non agricultural uses. Its useful for deep rooted crop and deep ploughed-shallow rooted crops. Rice suitability distribution map was developed for top layer using AHP weightage in GIS environment (Fig. 5.6b). The analysis revealed that (Table 5.6) around 9.6% of total rice crop is in 'highly suitable' (S_1) class, 38.0% area is in 'moderately suitable' (S_2) class. A substantial portion (35.3%) was under 'marginal suitable' (S_3) class and 17.1% was under 'not suitable' (N) class. The low fertility of some areas especially organic carbon and subsequently low pH is the paramount limitations. Total Rice suitable shallow layer region cover nearly 77.9% of the study area.

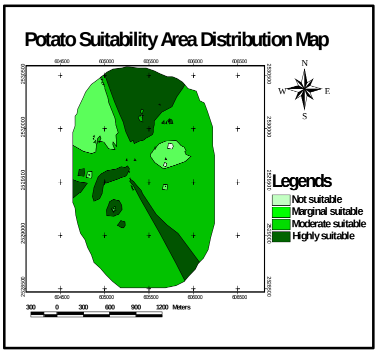
5.3.4.3 Deep Layer

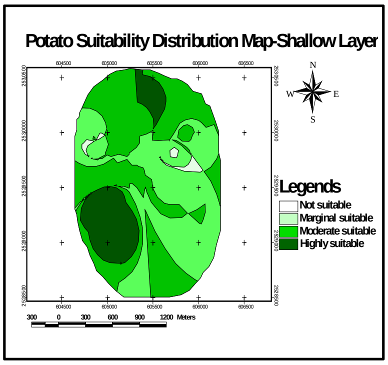
Deep Soils have well-drained and have desirable texture and structure are suitable for the production of most landscape plants. Deep soils can hold more plant nutrients and water than can shallow soils with similar textures. It should be observed that the variation in the result is due apparently to the values of each soil layer assigned, particularly of the study area map. The analysis revealed that (Table 5.6) around 22.7% of total rice crop is in 'highly suitable' (S_1) zone, 23.0% area is in 'moderately suitable' (S_2) zone and 15.5 % is under 'not suitable' (N) zone. Area under 'marginal suitability' (S_3) is enhanced drastically showing high level of nutrient availability in the deep soil layer (Fig. 5.6c). Suitability based on deep soil layer followed the pattern of shallow layer for rice crop.

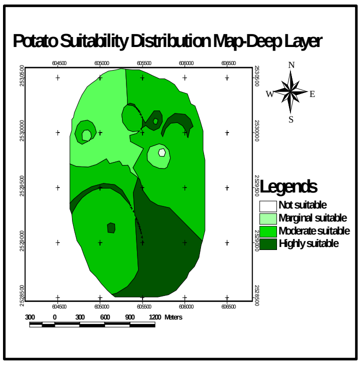

Rice Suitability Area Distribution Map
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
Meters

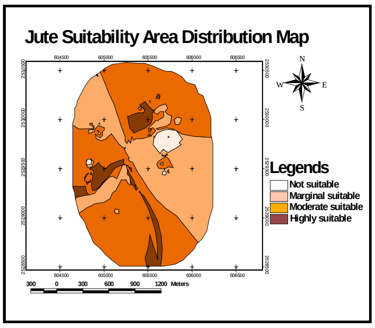

Rice Suitability Distribution Map-Shallow Layer
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
Meters

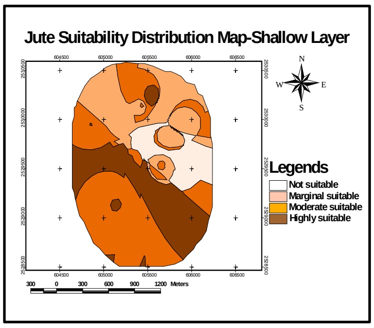

Rice Suitability Distribution Map-Deep Layer
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
Meters

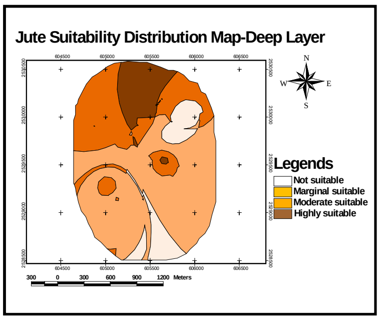

Potato Suitability Area Distribution Map
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
Meters

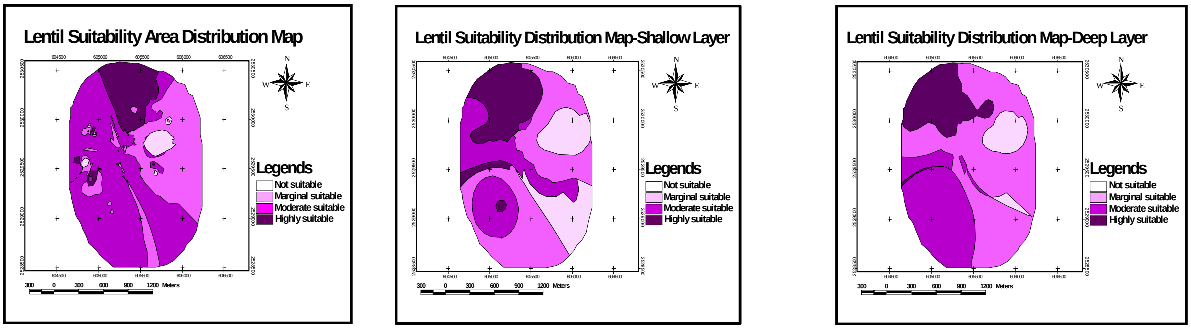

Potato Suitability Distribution Map-Shallow Layer
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
Meters


Potato Suitability Distribution Map-Deep Layer
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
Meters


Jute Suitability Area Distribution Map
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
Meters


Jute Suitability Distribution Map-Shallow Layer
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
Meters


Jute Suitability Distribution Map-Deep Layer
Legends
Not suitable
Marginal suitable
Moderate suitable
Highly suitable
Meters



a) top layer b) shallow layer c) deep layer

Figure 5.6: Land suitability rice, potato, jute and lentil crop; a) top layer b) shallow layer c) deep layer

5.3.5 Jute crop suitability

5.3.5.1 Top layer

Jute is an important major deep rooted cash crop during summer, grown under irrigated condition in the study area. As per the suitability analysis, nearly 6.5% of farm area is classified as 'highly suitable' (S_1); 56% area is 'moderate suitable' (S_2) and nearly 2.1% area is 'not suitable' (N) (Table 5.6). These areas comes under jute cropping belt of the region as per the annual crop output statistics. Here 95% of the land area was fallen under suitable range (Fig. 5.6a). The major suitability limitations reported for these soils were low organic carbon and nitrogen contents with high acidic pH.

5.3.5.2 Shallow layer

Shallow soils restrict plant growth by impeding root growth and provide only limited water and nutrient reserves. The land suitability results for jute crop in shallow layer showed that (Fig. 5.6b) , nearly 23.0% of farm area is classified as 'highly suitable' (S_1); 41.6 % area is 'moderate suitable' (S_2) and nearly 10.7% area is 'not suitable' (N), (Table 5.6).

5.3.5.3 Deep layer

Jute, being a deep-rooted species, is able to bring up the basic cataions from subsoil and deposit them on the surface, as litter may be one remedy for reducing surface acidity and increasing various micro and macro-nutrient availabilities. It requires higher soil depth and precipitation compared to other deep rooted crops. During drought period, crops on shallow soil are usually the first to show stress because of lack of moisture in the upper soil layer. For better management of deep rooted crop, deep layer suitability analysis was carried out. The study revealed that the 10.3% of the study area is 'highly suitable' (S_1) and nearly 52.2% are is 'marginally suitable' (S_3), and around 11.0% area und 'not suitable' (N) for jute crop (Table 5.6). Marginal suitability of deep soil layer may be attributed from increasing irrigation to salinity and other pedogenic process modified by water table distribution (Fig. 5.6c).

5.3.6 Potato crop suitability

5.3.6.1 Top layer

During the field visit time it was observed that potato was one of the dominant crops in the study area during the *Rabi* season. Potato crop is highest production in the study area all over the district in during the winter season. The suitability surface was developed and classified into five classes such as ‘highly suitable’ (S_1), ‘moderate suitable’ (S_2), marginal suitable (S_3) and ‘not suitable’ (N) as recommended by FAO (1993), (Fig.5.6a). The suitability analysis in 21.3% area under in ‘highly suitable' (S_1) and nearly 67.3 % is existed as in case of area under ‘moderate suitable’ class (S_2) (Table 5.6). The first two suitable classes able to hold the area of 88.6 % in the study enhancing the feasibility of adoption of potato in the study area. High EC, low pH and organic carbon are the major limitations of this area which can be improved by specific management and proper agricultural practices such as liming and addition of organic matter would contribute to modifying soil pH.

5.3.6.2 Shallow layer

Shallow layer is important for root development for tuber crop as potato. Suitability analysis indicated that 15.1%, 44.0% , 39.9% , and 1.0% of lands (Table 5.6) are classified as S_1, S_2, S_3, and N suitability classes, respectively, for potato crop. Area under 'not suitability' (N) is enhanced drastically showing low level of nutrient availability in the shallow soil layer (Fig. 5.6b).

5.3.6.3 Deep layer

Depth of soil and its capacity for nutrients and water frequently, determine the yield from a crop, particularly annual crops that are grown with little or no irrigation. Suitability map for potato crop in the deep soil layer is also develop in Arc GIS environment (Fig. 5.6c).Maps were also overlaid to detect four suitability classes, nearly 23.3% of farm area is classified as 'highly suitable' (S_1); 57.6% area is 'moderate suitable' (S_2) and nearly 19.0% area is 'marginal suitability' (S_3) (Table 5.6) for potato crop. Area under 'not suitable' (N) class is enhanced drastically showing low level of nutrient availability in the deep soil layer. Though deep layer soil nutrient not contribute to potato crop, the layer showed nearly 81% of farm area suitable (S_1 and S_2 classes) for the crop.

5.3.7 Lentil crop suitability

5.3.7.1 Top layer

Lentil is also an important pulses crop growing in *Tarakeswar* block, West Bengal. It can be a good replacement for the area unsuitable for jute crop. Lentil suitability distribution map was developed for top layer using AHP weightage in GIS environment (Fig. 5.6a). The analysis revealed that (Table 5.6) around 12.4% of total lentil crop is in 'highly suitable' (S_1) zone, 54.6% area is in 'moderately suitable' (S_2) zone. A substantial portion (30%) was under 'marginal suitable' (S_3) zone and 3% was under 'not suitable' (N) zone. Together, the two categories 'highly suitable' and moderate 'suitable' make up 67% of the total area may be dedicated for lentil crop, if jute is not profitable in the area.

5.3.7.2 Shallow layer

Crops growing on shallow soils, also, have less mechanical support than those growing in deep soils. As per the suitability analysis, nearly 19.2% of farm area is classified as 'highly suitable' (S_1); 23.6% area is 'moderate suitable' (S_2) and nearly 18.5% area is 'not suitable' (N), (Table 5.6). Area under 'marginal suitability' (S_3) is enhanced drastically showing high level of nutrient availability in the shallow soil layer (Fig. 5.6b).

5.3.7.3 Deep layer

Suitability map for lentil crop in the deep soil layer is also carried out using the AHP weightage in GIS environment (Fig.5.6c). The analysis showed that 15.8%, 26.8% , 50.2% , and 7.2% of lands (Table 5.6) are classified as S_1, S_2, S_3, and N suitability classes, respectively, for lentil crop. Area under 'marginal suitability' (S_3) is enhanced drastically showing low level of nutrient availability in the deep soil layer.

5.3.8 Combined suitability

The suitability analysis was carried out for selected crops for *Kharif* (rice and jute) and for *Rabi* (lentil and potato) seasons for three soil layers (namely top, shallow and deep layers). Though, rice and potato crops are not deep rooted crops, still suitability analysis was carried for those crops for deeper soil layer as the soil layer may come up after deep ploughing during primary tillage operation. The deep rooted crops such as jute and lentil need all the three soil layer suitability analysis for selecting best suited crops. The study area being a major cropping area for rice and potato, the suitability distributions also showed major area suitable for the current crops. However, there is some area which are not suitable for these crops may be allotted for alternative crops. The graphical presentation give clear idea of variation in suitability level for different crops in the study area (Fig. 5.7) which can be verified with the combined suitability table below (Table 5.6)

Table 5.6: Land suitability distribution for rice, potato, jute and lentil crop in three soil layers

Class (% of Area)	S_1			S_2			S_3			N		
Description	Highly suitable			Moderate suitable			Marginal suitable			Not suitable		
Soil Layer	Top	Shallow	Deep	Top	Shallow	Deep	Top	Shallow	Deep	Top	Shallow	Deep
Rice	29.2	9.6	22.7	15.1	38.0	23.0	51.2	35.3	38.8	4.5	17.1	15.5
Potato	21.3	15.1	23.3	67.3	44.0	57.6	11.3	39.9	19.0	0.1	1.0	0.1
Jute	6.5	23.0	10.3	56.0	41.6	26.5	35.4	24.7	52.2	2.1	10.7	11.0
Lentil	12.4	19.2	15.8	54.6	23.6	26.8	30.0	38.7	50.2	3.0	18.5	7.2

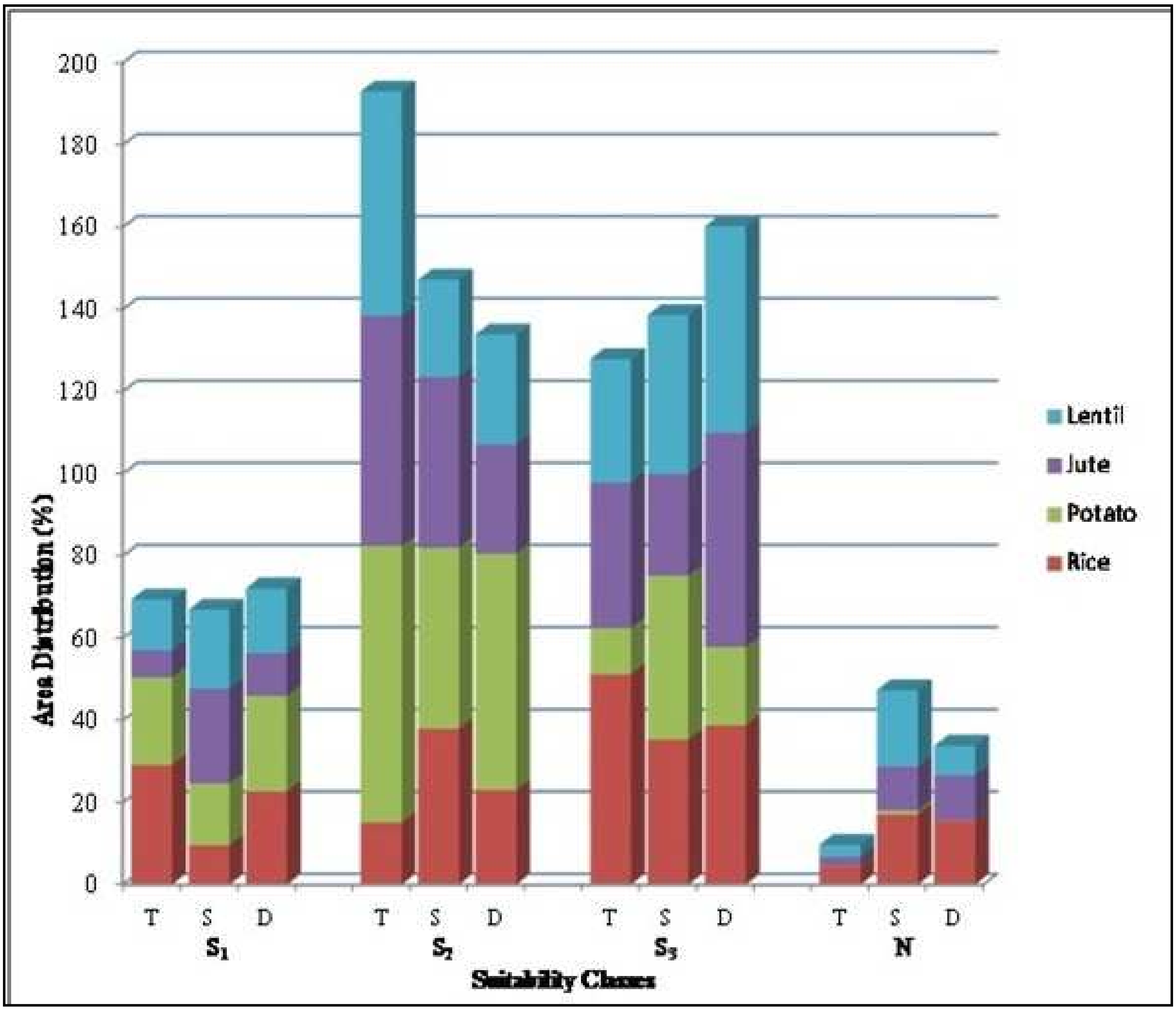


Figure 5.7: Comparative land suitability study for rice, jute, potato and lentil crops

5.4 Crop Rotation

Crop rotations are very important in optimising the land and labour productivities enhancing higher cropping intensities, producing better crop yield. The Analytical Hierarchy Process (AHP) technique coupled with GIS software environment can be an unique tool for better land suitability studies. The present study introduces a method for analysis of cropping systems for main crops, other crops. To fulfill the objectives of the study, two season crop rotational maps were derived from GIS overlay technique with AHP decision was applied. The AHP-GIS technique is used in land suitability study of crop rotation decision for Rice/jute (*Kharif*) and potato/lentil (*Rabi*) crop in the study area.

5.4.1 Kharif **crops**

Using Map Query in Arc GIS 10.1 (Arc view application) was carried out to find the suitable crop area classified as 'unsuitable' for rice crop. Using the application, jute crop was recommended for the area unsuitable for rice crop but classified as suitable for the jute crop (Fig.5.8). We analyzed this found for rice which are coming under the suitability class in S_1 and N (Table 5.7). The amount of area was 'highly' suitable 75% and Not suitable 25 %, respectively for rice. So, *Kharif* season in crop rotational practice we also recommended to 'unsuitable' (N) rice area (25%) dedicated to jute crop as alterative continue growing for economic beneficial.

Table 5.7: Suitable area distribution recommended for jute

class	Description	Area (ha)	(% of area)
S_1	Highly suitable	217	75
N	Not suitable	74	25

5.4.2 *Rabi* crops

Similarly, area unsuitable for potato crop but classified as suitable for lentil crop were recommended for growing lentil in *Rabi* season (Fig. 5.9). We analyzed this found for potato which are coming under the suitability class in S_1 and N. The amount of area was 'highly' suitable 92% and Not suitable 8 % respectively for potato (Table 5.8). So, *Rabi* season in crop rotational practice we also recommended to 'unsuitable' (N) potato area (25%) dedicated to lentil crop as alterative for continue growing for economic beneficial in present market price.

Table 5.8: Suitable area distribution recommended for lentil crop

class	Description	Area (ha)	(% of area)
S_1	Highly suitable	267	92
N	Not suitable	24	8

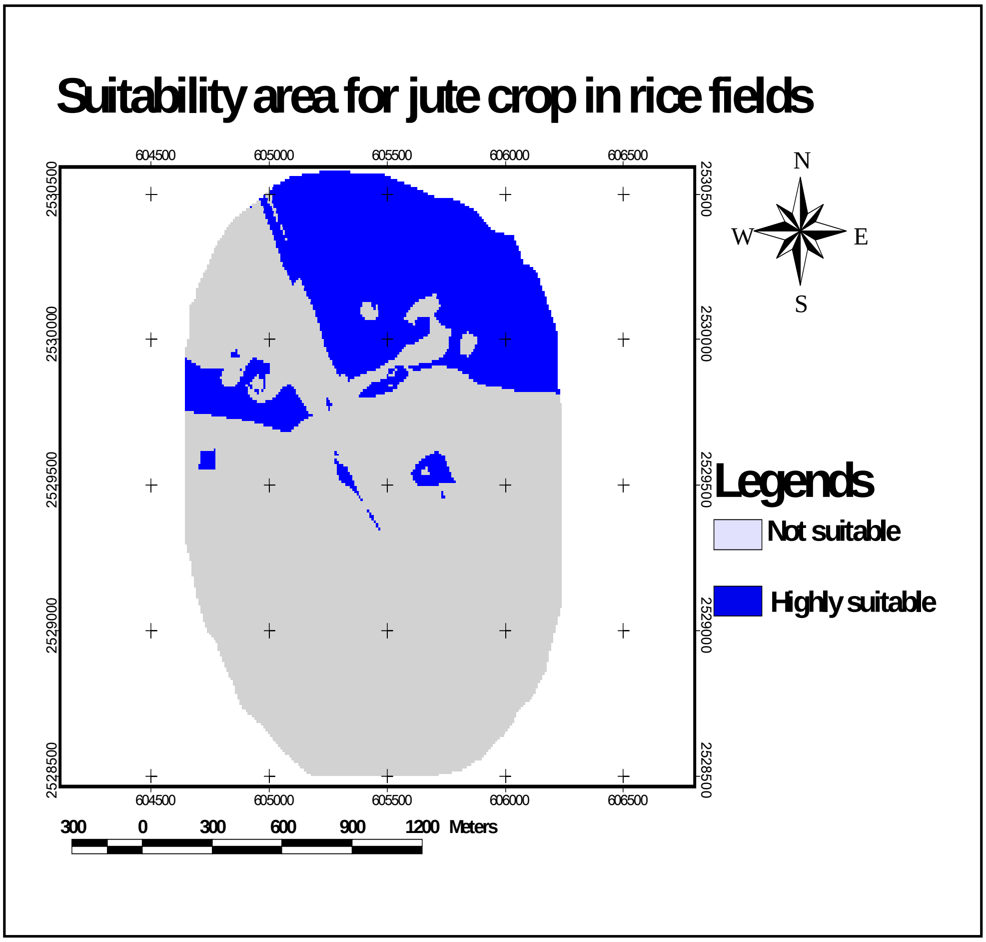


Figure 5.8: Suitable area distribution recommended for jute

Therefore, it can be strongly recommended that the crop land suitability classes must be considered simultaneously for land allocation for new alternative cultivation areas, using GIS-AHP techniques and taking into consideration land-use information, including the results obtained from the present model.

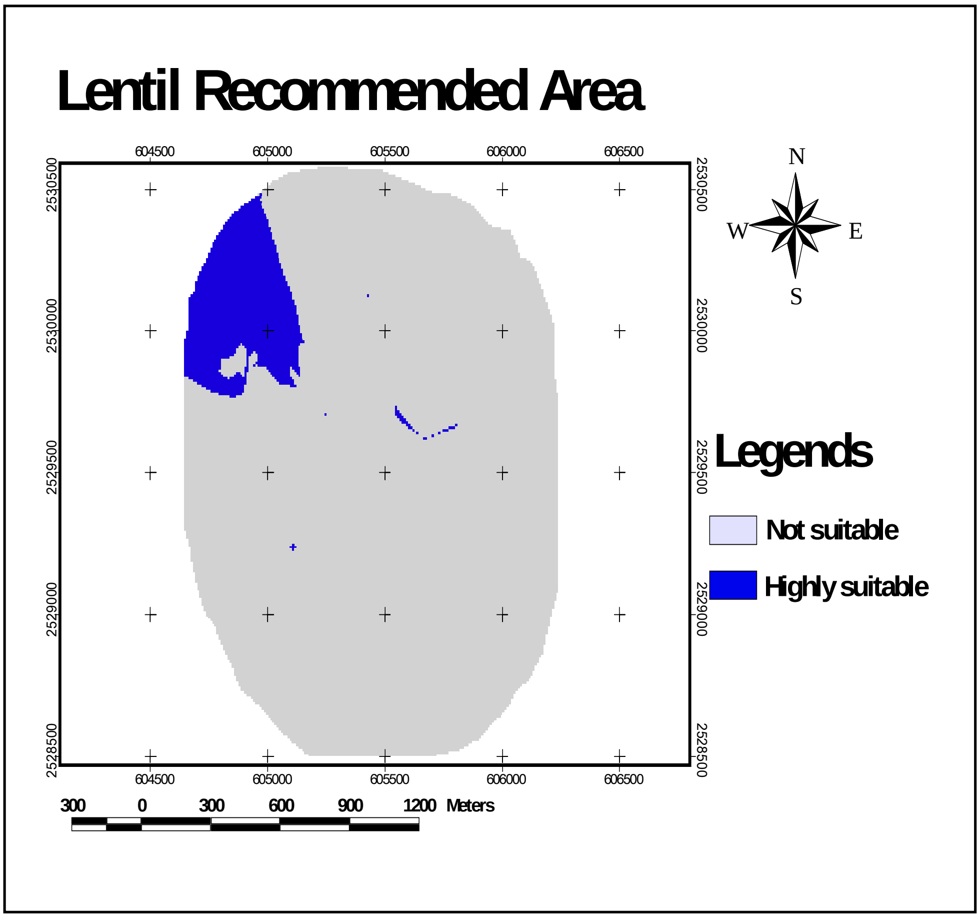


Figure 5.9: Suitable area distribution recommended for lentil

5.5 Discussions

Computer based GIS application and systems for assessing suitability have evolved and been formalised in frameworks and models. A widely accepted modelling framework is the Analytical Hierarchy Process (AHP), which has been extensively applied for MCA purposes and utilised in many decision-making problems. Consequently, the results obtained from this study indicate that the use of AHP in GIS environment could provide a superior database and guide map for decision makers in precision agriculture study of soil morphological pattern for crop (such as: rice, potato, jute and lentil etc.) land suitability analysis. However, any methods that are employed to make these suitability determinations can be subject to uncertainties in both the scope and quality of outputs.

While in this regard, it is important to point out that there will always be an element of subjectivity when applying expert judgment for determining weight of factors. To solve this problem this study has demonstrated that the AHP is best alternative to determine the criteria weights from judgments of decision-making domain of experts. Rice is an important food crop across the world. However, rice ecosystems are currently faced with numerous issues, such as poor crop establishment, unsuitable soil and land conditions, water scarcity, biotic and environmental stresses, and inefficient agronomical practices, which result in low returns from rice production. Therefore, it can be strongly recommended that the crop land suitability classes must be considered simultaneously for land allocation for new rice cultivation areas, using GIS-AHP techniques and taking into consideration.

The land suitability distribution map (Fig. 5.6a, top layer) for rice crop was compared with the rice yield suitability maps (Fig. 5.4a), showed the area classified under highly suitable and moderate suitable class, mostly produce better rice yield compared to other areas. Similar trend prevailed for potato crop, comparing land suitability distribution map (Fig. 5.6a, top layer) and yield distribution map (Fig. 5.4b) of the crop, further validating superiority of the AHP-GIS based land suitability technique for better crop selection.

The land suitability analysis systems was further utilised for recommending 'unsuitable' (N) rice area for growing jute crop as alterative (Fig. 5.8), continue providing better economic benefits to the farmers for *Kharif* season. Similarly, the 'unsuitable' (N) potato area is also dedicated to lentil crop as alterative (Fig. 5.9) for continue providing economic beneficial to the farmers.
Therefore, it can be strongly recommended that the crop land suitability classes must be considered simultaneously for land allocation for new jute and lentil cultivation areas, using GIS-AHP techniques and taking into consideration land-use information, including the results obtained from the present analysis for selecting best crop and crop rotation.