CHAPTER IV
METHODOLOGY

4 General

This chapter includes the details the research methodology, field survey and analysis tools used in the research work. Basically, this study has been devoted towards the land suitability study for various agricultural crops such as rice, potato, jute and lentil etc, keeping an eye on developing a model for sustainable agricultural land use suitability evaluation using GIS/RS. The suitability model is partially based on land suitability rating framework proposed by FAO (1993).

4.1 Study Area Selection

Study area is located in the Hooghly district, West Bengal, India. Along eastern bank of the river Hooghly, the district is economically sound in terms of agriculture production. The total area of Hooghly district is 3149 km$^2$ and the total population is around 55 lakh. There are four sub-divisions, 18 blocks divided in to 1,866 villages, in the district. Tarakeswar block is selected for carrying out research work being home town of the researcher and leading farming belt in the region. The general elevation of the area is up to 40 m above mean sea level (MSL). The area forms flat plains and there is remarkable topographical homogeneity. Blessed by numerous rivers and ample rainfall, the agriculture produce of the district is most satisfactory. The physiochemical properties of soil are helpful for agriculture and soil texture is also suitable for the cultivation of rice, jute, potato, vegetables, pulses, oil-seeds etc. crops, the predominant crops of the district.

Geographical location of the district is between $22^039’32”$ to $23^001’20”$ N latitude and $87^039’32”$ to $88^030’15”$ E longitude. Hooghly district is surrounded by Nadia and North Twenty Four Parganas districts to the east, the districts of Bankura and Burdwan to the north, and Paschim Medinipur district to the west, Howrah to the south (Figure 4.1).
4.1.1 Agricultural crop status

Predominance of fertile soils, land and adequate water resources in the study area is key factors facilitating intensive agriculture in the study area. This zone has high cropping intensity. The farmers follow variety of cropping pattern of the study area such as: Til/Jute/ Aus paddy/ vegetables or Kharif paddy vegetable/ oilseeds/ pulses lentil/ Boro paddy etc. The important Kharif crops are rice, jute, and sesame crops and rabi crops are potato, wheat, mustard, lentil etc. and different types of vegetables. Boro (transplanted) paddy is also widely cultivated in irrigated areas. The Kana Nadi drainage stream of Hooghly river supplies the required irrigation for the crops in the study area.

In recent times, the total area, production and productivity of the different crops remain almost stagnant. In case of Boro paddy negative growth in terms of productivity has been observed due to poor soil health management practice, pest management practice etc. Second major crop of the district is potato accounting for 17% of gross cropped area ranked first with respect to area and production in Hooghly district. Productivity fluctuates when the crop faces natural disasters. Jute has also occupied a good acreage, though its area is decreasing day by day due to high labour requirement and marketing problems.

So, this area would be the most promising area and deserves quick consideration of any conscious planner for proper resources utilization and thereby improving the economic condition of the people. The study designed at creating preliminary work strategy of evaluating land use suitability for better production, farmers are adopting improved scientific agricultural technology using organic farming, precision agriculture, hybrid seeds and pesticides etc. and optimizing the input level for better yield and greater profit margin for sustainable agricultural development in the area.
4.1.2 Topography and soil type
Hooghly district belongs to Gangetic Delta being broadly divided into two major natural divisions, the plain areas and the upland areas, river Dwarakeswar forming the natural dividing line between them. The flat alluvial plains may again be sub-divided into three regions, namely (i) Dwarakeswar plain (ii) Hooghly-Damodar plain and (iii) Hooghly flats. As a part of Gangetic alluvial plains, the predominant group of soil is sandy loam to loamy soils with an area of 32% and 48% cultivated area, respectively. Clay soil covered around 8% area and clay loam 12% area of the total cultivated land. The top soil layer of 72% area is acidic followed by slightly acidic (14.8%); Moderately well drained soils occupy about 45.4% area followed by well drained (38.3%) soils in the district (CDAP -Hooghly, 2009-12). According to NBSS & LUP (2001) Hooghly district which typing pedon isnaranyanapara silty clay loam-cultivated. The area represents “ustic” soil moisture and “hyperthermic” soil temperature regime.

Major portion (58.5%) of the district has very gently sloping (1-3%) lands and remaining 41.5% is under nearly level (0-1%) lands with a gentle gradient from north-west to south-east.

4.1.3 Climate
The area represents moist sub humid bio climate which is characterized by hot summers and mild winters. Regarding the climate, the district is 'D' characterized by monsoon climate. The main seasonal influence upon the climate is the monsoon. According to Chatterjee (1949) the district experiences a climate which is transitional between the CWg3 and AW1 types. Summer is dominated by strong south western monsoon winds (Kal-baisakhi or the Nor-Western storms) and association with heavy rains with hail storms sometimes damages the crops. The average annual precipitation of the district varies from 1200 mm to 1700 mm. The rainy season frequently commences from the middle of June and uses to continue up to September with July and August are the peak rainfall months. On an average the district experiences nearly seventy-five rainy days in a year. There is discrete in variation of the total rainfall of the district for the years (2004-2014) (Table 4.1; Figure 4.2). The District rainfall is estimated as the arithmetic mean of rainfall of all the stations under the district during 2013-2017 (Appendix A.1).
Table 4.1: Total annual rainfall distribution in Hooghly (2004-2014)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Rainfall (in mm.)</td>
<td>1118</td>
<td>1198</td>
<td>1129</td>
<td>1606</td>
<td>1471</td>
<td>1263</td>
<td>1044</td>
<td>1556</td>
<td>1152</td>
<td>1494</td>
<td>1188</td>
</tr>
</tbody>
</table>

Source: District Statistical Handbook, Hooghly, (2010-11); Agricultural Meteorologist, Directorate of Agriculture, Govt. of West Bengal; Meteorological Department, Govt. of India.

Figure 4.2: Total annual rainfall distribution in Hooghly (2004-2014)

The average maximum temperature varies from 28° - 35° C and minimum temperature varies from 15° - 20° C. The cold spell prevails during mid of November to mid of February. Since subtropical humid climate prevail in this district, humidity is a major concern as far as infestations of pest and diseases are concerned in agricultural crops. In winter humidity decreases from south to north and east to west and on an average the variation in relative humidity are smaller than in summer. Relative humidity are generally high throughout the year. The summer season begins with strong Westernly winds from the middle of March and continues up to the middle of May. The post Monsoon season usually starts from middle of October and continues till the end of February with January being the coldest month. There is
slight variation in maximum and minimum temperature for the year 2004-2011 (Table 4.2; Figure 4.3).

Table 4.2: Maximum, minimum temperature variation in Hooghly, 2004-2011.

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max.Temp.(°C)</td>
<td>40</td>
<td>43</td>
<td>40</td>
<td>38</td>
<td>NA</td>
<td>38</td>
<td>42</td>
<td>36</td>
</tr>
<tr>
<td>Min.Temp.(°C)</td>
<td>8</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>NA</td>
<td>10</td>
<td>8</td>
<td>7</td>
</tr>
</tbody>
</table>

Source: District Statistical Hand Book, Hooghly,(2010-11)

Figure 4.3: Maximum, minimum and average temperature in Hooghly, (2004-2011)

4.1.4 Irrigation and drainage
The district of Hooghly is popularly known as the product of its rivers (Figure 4.4). The district is well drainage by a number of rivers, which include large river, like the Bhagirathi, the Damodar and the Rupnarayan, also Darakeswar in its upper reach and the smaller streams like the Behula, the Kana Nadi, the Kunti Nadi, the Saraswati, the Kousiki, the Kana Damodar. Damodar drainage system is one of the most important components of physical environment which influences the agriculture directly as well as indirectly in the study area. Ground water influent becomes the base flow that maintains the flow of streams in fair water. It includes surface as well as ground water of the study area.
Hooghly has comparatively well developed irrigation infrastructure with coverage of over 62% of the area under irrigation contributing to higher cropping intensity of about 245% compared to State average of 184.14% during 2007-2008 (Anon, 2009). In the study area, the main sources of irrigation, are well, tub well, canal and tank etc. The D.V.C. canals run for a total length of 250 miles within the district and operate the *Kana Nadi* and *Kana Damodar* basin which covering the study area with higher agricultural production. The presence of numerous rivers and ample rainfall has helped a lot in the district’s irrigation. The study area irrigated by different sources and there is variation in crop season wise irrigation facilities (Appendix A.2 and A.3).

### 4.1.5 Natural vegetation

Tropical vegetation are found in the district. So, the vegetation are deciduous in nature. In these vegetation, timbers, fuel woods, patches, etc. are available. The forest cover in the district, 3149 sq. km, which is 1.94% of the state’s geographical area. In terms of forest canopy density classes, the district has 9 sq. km moderate dense forest (FSI, 2007). According to the records of the forest department the total forest area as per 2011-12 is 299.41 hectares (including reserve forest, protected forest and un-classed state forest).
4.1.6 Demography

Hooghly district constitutes 6.29% of the state population. The total population of Hooghly district as per 2011 Census is 55,19,145 out of which 33,90,646 reside in rural areas. In the study area the total population 20335 shared in rural population 11681. The rural decadal growth rates of the district is 1.1 during the decade 2001-2011. Total density of population of the district Hooghly has 1,753 per sq. km. in 2011. Similarly, the rural density of population has 1,202 per sq. km. in 2011. The sex ratio of district in 2011 Census is 961 of which rural is 968. The rural Work Participation Rate and Cultivators of the district has 40.5% and 12.06% in the year of 2011.

4.1.7 Land use

The district area under forests and cultivable waste lands is insignificant at 339.6 ha and 1854 ha respectively (CDAP, Hooghly, 2009-12). With respect to land holding pattern, According to Agricultural Censes 2011, there are 345908 number of land of holding families of which 297969 nos. belongs to marginal category 40474 nos. belongs to small category, 6299 nos. belongs medium category, (Appendix A.4). Based on the classification scheme of the “Directorate of agriculture Government of West Bengal” land use of the area can be divided into a number of categories such as: net area sown, forests area etc. (Table 4.3).

Table 4.3: Land use classification of total area in West Bengal, 2011-2014

<table>
<thead>
<tr>
<th>Year</th>
<th>2011-2012</th>
<th>2012-2013</th>
<th>2013-2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification</td>
<td>Area (ha) %</td>
<td>Area (ha) %</td>
<td>Area (ha) %</td>
</tr>
<tr>
<td>Net Area sown</td>
<td>5198 59.9</td>
<td>5205 59.5</td>
<td>5233 60.3</td>
</tr>
<tr>
<td>Current fallows</td>
<td>399 4.6</td>
<td>379 4.4</td>
<td>349 4.0</td>
</tr>
<tr>
<td>Forests</td>
<td>1174 13.6</td>
<td>1174 13.5</td>
<td>1174 13.5</td>
</tr>
<tr>
<td>Area not available for cultivation</td>
<td>1809 20.8</td>
<td>1834 21.0</td>
<td>1846 21.3</td>
</tr>
<tr>
<td>Other uncultivated land excluding current fallows</td>
<td>104 1.2</td>
<td>92 1.2</td>
<td>82 0.9</td>
</tr>
<tr>
<td>Total reporting area</td>
<td>8684 100</td>
<td>6758 100</td>
<td>8684 100</td>
</tr>
</tbody>
</table>


4.1.8 Agriculture output in Hooghly

Agriculture of Hooghly district is on intensive subsistence type. The principal crops in the Hooghly districts are paddy, wheat, potato, jute, oil seeds, pulses and vegetables. The total
The geographical area of this District is 314900 ha of which 223390 ha (71%) is under cultivation. Out of the total area under cultivation, 66% area is covered by irrigation (District Profile; NABARD, 2009-12). The productivity levels of major crops in the district are very high compared to State and National average yields. Knowledge about the area, production and yield of major crops in Hooghly district during 2005-2015 is required for future land suitability analysis (Table 4.4). During 2007-08 Hooghly district witnessed the highest cropping intensity and annual growth rate 2.04%. Tarakeswar block registered the 2nd position for the cropping intensity in the district position (HDR, 2010; District Statistical Handbook, Hooghly, 2006). The area, production and yield of major crops in irrigated/ rain fed conditions in Tarakeswar block is very much required for future analysis (Table 4.5).

Table 4.4: Production, area and yield of major crops in Hooghly (2005-2015).

<table>
<thead>
<tr>
<th>Year</th>
<th>Rice ('000 Hectares)</th>
<th>Potato ('000 Hectares)</th>
<th>Jute ('000 Hectares)</th>
<th>Pulse ('000 Hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005-06</td>
<td>310324</td>
<td>92174</td>
<td>31005</td>
<td></td>
</tr>
<tr>
<td>2006-07</td>
<td>299191</td>
<td>96680</td>
<td>31614</td>
<td></td>
</tr>
<tr>
<td>2007-08</td>
<td>301788</td>
<td>94824</td>
<td>28657</td>
<td>0.4</td>
</tr>
<tr>
<td>2008-09</td>
<td>305691</td>
<td>94759</td>
<td>24570</td>
<td>0.6</td>
</tr>
<tr>
<td>2009-10</td>
<td>299866</td>
<td>91290</td>
<td>29040</td>
<td>0.6</td>
</tr>
<tr>
<td>2010-11</td>
<td>292370</td>
<td>100409</td>
<td>26856</td>
<td></td>
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<td>2011-12</td>
<td>277200</td>
<td>94435</td>
<td>26897</td>
<td></td>
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<tr>
<td>2012-13</td>
<td>273450</td>
<td>100155</td>
<td>26665</td>
<td>0.3</td>
</tr>
<tr>
<td>2013-14</td>
<td>286045</td>
<td>99830</td>
<td>19953</td>
<td>0.4</td>
</tr>
<tr>
<td>2014-15</td>
<td>276032</td>
<td>100745</td>
<td>22933</td>
<td></td>
</tr>
<tr>
<td>2005-06</td>
<td>849949</td>
<td>2350043</td>
<td>603883</td>
<td>2.4</td>
</tr>
<tr>
<td>2006-07</td>
<td>846820</td>
<td>1065693</td>
<td>585847</td>
<td>1.2</td>
</tr>
<tr>
<td>2007-08</td>
<td>845148</td>
<td>2465212</td>
<td>516911</td>
<td>0.2</td>
</tr>
<tr>
<td>2008-09</td>
<td>876257</td>
<td>881590</td>
<td>444807</td>
<td>0.5</td>
</tr>
<tr>
<td>2009-10</td>
<td>861334</td>
<td>3434459</td>
<td>510424</td>
<td>0.4</td>
</tr>
<tr>
<td>2010-11</td>
<td>904162</td>
<td>3530571</td>
<td>573241</td>
<td></td>
</tr>
<tr>
<td>2011-12</td>
<td>806836</td>
<td>2439938</td>
<td>444494</td>
<td></td>
</tr>
<tr>
<td>2012-13</td>
<td>793043</td>
<td>3246422</td>
<td>526374</td>
<td>0.3</td>
</tr>
<tr>
<td>2013-14</td>
<td>807732</td>
<td>2077513</td>
<td>421854</td>
<td>0.5</td>
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<tr>
<td>--------------</td>
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<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yield (ton/ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2005-06</td>
<td>2.74</td>
<td>25.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2006-07</td>
<td>2.83</td>
<td>11.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2007-08</td>
<td>2.8</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2008-09</td>
<td>2.87</td>
<td>9.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2009-10</td>
<td>2.87</td>
<td>37.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2010-11</td>
<td>3.09</td>
<td>35.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2011-12</td>
<td>2.91</td>
<td>25.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2012-13</td>
<td>2.9</td>
<td>32.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2013-14</td>
<td>2.82</td>
<td>20.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2014-15</td>
<td>3.12</td>
<td>34.8</td>
</tr>
</tbody>
</table>

Source: Directorate of Economics & Statistics Department of Agriculture & Cooperation
Ministry of Agriculture Government of India.

Table 4.5: Production, area and yield of major crops in Tarakeswar block (1997-2008).

<table>
<thead>
<tr>
<th>Region</th>
<th>Crops</th>
<th>Area('000 MT)</th>
<th>Production area (000' MT)</th>
<th>Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tarakeswar</td>
<td>Aus</td>
<td>6</td>
<td>0.016</td>
<td>2715</td>
</tr>
<tr>
<td></td>
<td>Aman</td>
<td>8210</td>
<td>7728</td>
<td>26.214</td>
</tr>
<tr>
<td></td>
<td>Boro</td>
<td>2159</td>
<td>653</td>
<td>5.746</td>
</tr>
<tr>
<td></td>
<td>Jute</td>
<td>2775</td>
<td>3246*</td>
<td>48.313*</td>
</tr>
<tr>
<td></td>
<td>Potato</td>
<td>8125</td>
<td>7172</td>
<td>57.476</td>
</tr>
<tr>
<td></td>
<td>Pulses</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * In thousand bales of 180 kg; ** In bales per hectare
Sources: 1) B.A.E.S. and Govt. of W. B. 2) Directorate of Agriculture, Government of West Bengal

4.1.9 Survey for village selection
Agriculture land suitability analysis required intensive field information and thorough analysis of the information. Land suitability analysis is an assessment of an area to determine how proper or appropriate it is for a particular use of the land (such as growing a crop
variety) in a particular location. It targets to find out the entire yield limiting factors in the crop field and the solution for them. This process takes sequential steps and that need to be carried out for few seasons or for few years with continuous monitoring, diagnosis of the cause followed by the recommended practices.

Rice, potato, jute, lentil are the major cultivated crops in maximum villages of Hooghly district. Primary survey was carried out in five villages to selected for the study, considering the availability of resources for the work with relevant statistics were consider for necessary evaluation. The study area and district crop wise area, production and productivity details are also furnished for future data analysis (Appendix A.5 to A.8).

The study targeted to include all the crop (rice, potato, jute, lentil etc.) growers in the selected villages to maintain the uniformity of data interpretation. The total area of study covers nearly 50 farmers with a land holding of 0.50 ha or more.

4.2 Standard Classification of Suitability Grades

The individual factors have variable influence level for different crops. The whole suitability range was categorized into four zones as per the standard practice defined by FAO (1993).

a) Highly suitable ($S_1$)

This area has very good potential for the mentioned crop and currently it is showing its highest potential. Land without significant limitations. Include the best 20-30% of suitable land as $S_1$. This land is not perfect but is the best that can be hoped for. The yield limiting factors are at the lowest level.

b) Moderately suitable ($S_2$)

Land having limitations that are in aggregate have stained applications of a given crop use. The limitation can be removed with proper measures. Land that is clearly suitable but which has limitations that either reduce productivity or increase the inputs needed to sustain productivity compared with those needed on $S_1$ land.

c) Marginal suitable ($S_3$)

A land having limitations that are in aggregate have medium to high level of severeness for sustained application for given use. It may reduce the benefits to a considerable extent. Land with limitations so severe that benefits are reduced and/or the inputs needed to sustain production are increased so that this cost is only marginally justified.
46

e) Not suitable (N)
These areas are not suitable for the sustain growth of the current crop under consideration. These areas could be used for other purposes avoiding farmers making unprofitable investment. Land that cannot support the land use on a sustained basis, or land on which benefits do not justify necessary inputs.

4.3 Analysis of Soil Properties
For analyzing the soil nutrient levels and other parameters we have to go for direct chemical analysis process due to the unavailability of information from the individual farmlands. The available information is also not in the required scale and form, sometimes outdated.

4.3.1 Site selection for obtaining soil samples
In agricultural land use suitability evaluation, two soil sampling methods are in practice; grid based and farm-plot based. The former is usually practiced in developed countries and the later may be most suitable for developing countries as the size of the farm holdings is very small unlike in the developed countries. The agricultural practices followed in each farmland could also be different from one another. Soil nutrient played an important role in plant growth and its vegetation. Plant collects different essential nutrients and moisture from the soil for photosynthesis along with light from sunshine. The type of nutrient and their levels required for individual crops varies between and within the crops, respectively. There are some major nutrients like nitrogen, phosphorus and potassium that are needed by all agricultural crops including other macro & micro nutrients. These major factors were also found to have greater contribution for proper growth of the selecting crop of the study area. The other factors included in the study were level of organic matter, electrical conductivity and pH and texture of soil.

The soil conditions could also varied widely due to different agricultural practices conducted for long periods. Without considering the size of the farmland it is decided to collect the information from each individual farmland for uniformity of the data.

The samples considered from the farmers having different farm holding sizes
(1) the landless farmers with no land of their own,
(2) the marginal farmers having land up to 0.5 hectare of their own,
(3) the small farmers owning land between 0.5 hectares to 1 hectares,
(4) the medium farmers owning lands between 1.5 hectares to 2 hectares and
(5) the big farmers owning land above 3 hectares in the study area.

The number of sample collection is also restricted by the time and cost involvements. The number of samples to be collected will be ranged from 5-9 spots for better justification as per the standard practices (Fig. 4.5).

![Figure 4.5: Locations and pattern of soil sample collection](image)

The nutrient level of soil also varies in the vertical direction. Hence, a major part of the roots of the most crops is concentrated in the upper 0–20 cm soil depth (Gregory, 1994). Potatoes have a fibrous root system which usually proliferates in the upper 20-50cm depth. Under severely compacted soils, Roo and Waggoner (1961) found few roots below the plough layer (23 cm). The percentage of roots distributed in the top 0-20 cm soil layer averaged over all root traits was 62%-67% in potato and 86% in rice (Yamaguchi and Tanaka, 1990). So the depth of soil sample collection was limited to 45 cm of the soil layer for crops such as rice, potato, jute and lentil etc.

### 4.3.2 Collection of samples

Work under first part of the study was carried out in fifty locations in Hooghly districts of West Bengal viz. Basudebpur, Bajitpur, Jothsombhu, Kolaikundu and Aligorii villages in entire district. The soil samples were collected at the onset of the rainy season month of May 2015. A special type of soil auger was used for soil collection. When the auger was pushed and screwed in clockwise direction, soil moved upward in to the auger after driving up to required depth it was pulled out and the soil collected in side was removed. With the help of this auger soil sample was collected from upper 0 to 15cm of surface soil. Field profiles investigations were also carried out in the study area for sub surface soil.
The Garmin e-Trex 20 GPS receiver was used for the study for zone 45 in UTM system with WGS-84. Soil samples were collected from randomly selected location with Global Positioning System (GPS) coordinates recorded at each sampling point. The plot based grid size was selected based on results of previous reports (Mueller et al., 2001; Hammond, 1992). Soil samples were taken at each corner and centre of the farmland at three standard depth. The soil layer depths varied 0 – 15cm (top soil), from shallow layer with lithic contact within 15-30 cm depth which limited the root penetration for deep rooted crops, sub soil or deep soil layer 30-45cm. All the soil sampling site exists under uniform environmental characteristics (climatic, geomorphic and vegetation cover etc.) considering localized study area.

4.3.3 Preparation of soil sample for analysis

The samples collected from the individual spot were properly mixed for different soil horizon. Firstly, the 0-15cm represent the average plough layer in the area, while the 15 – 30cm depth is the layer where clay particles accumulate following their elevation from the upper layer. Also, the deep soil layer (30-45cm) mostly utilized by deep rooted crops. Secondly, at these predetermined depth, we ensure comparability between the different samples selected.

Soil samples collected from soil profiles were air-dried, grounded in wooden mortar, pestle and passed through a 2 mm sieve. Morphological characteristics (soil pH, N, P, K, EC, Zn, Soil texture and Organic carbon) of fifty soil profiles of each layer were studied in the field according to procedures laid out in the Soil Survey Manuals (Soil Survey Staff, 1993). Soil samples were collected horizon wise from each profile and kept separately in plastic bags, which was labelled with profile number, layer code, name and location. The total weight of the sample for testing was around 500 grams, subsequently used for nutrient level determinations.

4.3.4 Chemical analysis

Composite sample was used for mechanical and chemical analysis. Description and morphological characteristics of different nutrient at profile sites were documented and soil samples from various horizons in all profiles were collected for laboratory based chemical analysis. The soil samples were analyzed for some common soil productivity attributing parameters viz. pH, soil texture, EC, organic Carbon, available N, P, K and Zn levels. Relevant physical and chemical properties were determined following standard analytical
procedures (Jackson, 1973; Black, 1965; Subbaiah and Asija, 1956; Olsen et al., 1954; Walkeley and Black, 1934).

a) **Soil pH**
The pH of the soil was determined in 1: 2.5 soil water suspensions using a glass electrode digital pH meter (Jackson, 1973).

b) **Electrical conductivity**
The electrical conductivity of 1: 1.25 soil water suspensions was measured using conductivity meter (Chopra and Kanwar, 2005).

c) **Organic carbon**
The organic carbon content of soil was determined by wet digestion method as outlined by Walkley and Black (1934).

d) **Available nitrogen**
Available nitrogen was estimated using Kjeldahl distillation method (Subbaiah and Asija, 1956).

e) **Available phosphorus**
The available Phosphorus was estimated by ascorbic acid method described by Olsen (1954) and the concentration was quantified using spectrophotometer.

f) **Available potassium**
Available Potassium was extracted by 1 N ammonium acetate solution at pH 7 as described by Jackson (1973) and determined by flame photometer.

g) **Available zinc**
The available zinc (a micro nutrient) in the soil was determined by using DTPA extractant (Lindsay and Norvell, 1978). Twenty gram soil with 40 ml of DTPA was shaken for 2 hours in an environmental shaker. Estimation of Zn was done by Perkin Elmer Atomic Absorption Spectrophotometer (AAS).

h) **Soil texture**
Texture of soil samples was identified, determining percentage of sand, silt and clay by standard method (Piper, 1942). The particle size of soil was analyzed by hydrometer method and the textural class was determined using textural triangle diagram of United States Department of Agriculture (USDA) (Fig. 4.6), namely sand, loamy sand, sandy loam, silt loam, loam, sandy clay loam, silt loam, clay loam, clay, sandy clay, silt clay and silt. Clay, silt clay, silt clay loam, textures of soil are best for crops such as rice, jute, potato, lentil etc.

The formula to calculate the above parameter is estimated as follows:

\[
\text{% Sand} = 100 - \frac{\text{First hydrometer reading (corrected for temp)} \times 100}{\text{Sample Wt. (50 g)}} \quad \ldots(4.1)
\]

\[
\text{% Clay} = \frac{\text{Second Hydrometer reading (corrected for temp)} \times 100}{\text{Sample Wt. (50 g)}} \quad \ldots(4.2)
\]

\[
\text{% Silt} = 100 - (\text{% sand} + \text{% clay}) \quad \ldots(4.3)
\]

![Figure 4.6: Soil texture classification, USDA (1980)](image)

4.4 Registration of Location

The location of the farmland was determined by using the Global position system (GPS) receiver. The GPS receiver continuously receives information from the GPS satellites. It shows the latitude, longitude and altitude of the position estimated in terms of time lag.
Generally the farmlands are rectangular in shape. In order to record the globally referenced location of the field, GPS readings were obtained in all the corners of the field. For irregular shaped fields, the number of readings can be increased to 7-8 points. During data analysis the average of all the readings is to be taken for better accuracy and also to represent the farm land as a point data. Survey of India, 2011 topographical sheets on 1:50,000 scale were used as base map, for rectification ground truth data, selection of ground control points, locating training samples as well as to identify and authenticate the various features in the topo sheets. The sheet number F45K1(79B/1), 45 UTM projection system with WGS-1984 datum was used. The readings can be used to calculate the distance between the points and also to find out the area of the polygons for the study area.

4.5 Database Information

The study is furnished based on available data and pre-processed information from primary and secondary sources (pre-field) and empirical observations (field). The researcher used both primary data sources and secondary data sources for crop pattern analysis in this study.

4.5.1 Collection of preliminary data

Primary data collection accomplished by questionnaire survey, which is one of the important social research methodologies. The primary data is collected through survey by one-to-one discussion with farmers, questioner’s method (Appendix B). It is also proposed to collect crop practice information, crop history and crop rotation etc information, at the farmer’s level.

4.5.1.1 Village level database

Database for preparation and information identification of micro-regions for the collection of data from the sample farmer households, interviews have been undertaken through a structured questionnaire. It is best used to identify problem in the study area and for setting up priority of requirement to be made. Final decision was derived as attribute data and its supporting information. Direct and indirect unstructured interview (Participatory Research Appraisal, PRA) were also done with farmers. This research makes use of well structured questionnaire to farmer households in intensive farming areas. Formal and informal interviews, group discussion were also conducted to gather information. Seminars and meetings conducted with experts, officials, and policy makers were also used to make assessment of the monsoon agriculture condition. The questionnaire has been prepared into
local language (Bengali), when it was administered. The interrogations were mainly carried
on among the heads of the families but answers had to be supplemented with the questions
put to the younger generations. In addition to this, cross verifications were done through a
series of interrogations put to the Government officials like, Krishi Projukti sahayak,
Agricultural Development Officer, Agricultural Officers etc., and the progressive and well
informed persons of the villages, members of the Panchayat Society also rendered their
valuable opinions.

4.5.1.2 Field work procedure
Includes collection of above said data by different methods such as GPS reading survey,
questionnaire survey, discussion with local people; planning strategy includes preparation of
draft plan for different villages having different status. Using infield survey method, firstly,
the researcher selected the topic by studying the available literature; Secondly, the researcher
visited to identify the location and then prepared the base map and the database of the
selected region. Most of the observations in this study, however, have been based on
intensive field work in the area under consideration. The study thus is based on both
available data and empirical observations. Field observations includes, observation of topo
sheets and collection of soil samples, which are directly related to land use pattern of the area.
In this work, modern equipments help to gather data and information relating to this input
data, yield data, crop production estimation information and size of the farmlands and the
economic condition of farmers.

Available land survey information was collected from the recognized authority of the study
area. The secondary information collected during the survey was as follows;

- Landholding size and location
- Crop yield, production information
- Map of the study area of Topographical sheets (1:50,000), Cadastral and, National
  Atlas and Thematic Mapping Organisation (NATMO), National Bureau of soil
  survey (N.B.S.S.) and Land use planning (LUP) map, Survey of India (SOI),
  2011.
- Different publication, journal article/reports/census/statistical handbook of
  Government offices and publications e.g. Block development offices, Panchayet
  offices, Agricultural development offices, Land and land revenue office and
  District irrigation office.
• Recommended crop input levels etc.

4.5.2 Application of GIS
GIS is now widely used for data storage, data presentation and manipulation in various sectors. Geo-referenced soil survey data and field work observations have been integrated in a GIS based agricultural land use suitability assessment work for agricultural planning. The study used GIS software for database creation, data storage, and data manipulation and for producing different maps. The study also showed that GIS based approach is a useful tool in land suitability assessment for agricultural planning.

4.5.2.1 Software and equipment tested

• Data storage and manipulation: MS Access/ MS Excel
• Map preparation and analysis: Arc GIS 10.1(ESRI, Redlands, California USA)
• GPS Receiver: eTrex 20 GPS receiver (Garmin Ltd., Olathe, Kansas, USA).(Appendix C)
• Weighting/rating determine: Mat lab 2015(Mathworks Inc., MA, USA)
• Output information: Camera, Printer

4.5.3 Application of remote sensing
Remote sensing system was used for identifying cropping area by estimating vegetation index with NDVI for the study area. The study also showed that RS based approach is a useful tool for faster site selection for land suitability assessment to select best agriculture crops and cropping system for the study area.

4.5.3.1 Remote sensing image details
Lunched on 11 February 2013, Landsat (Land Satellites) 8 is the latest Landsat series satellite available during 2014 and 2015 data collection seasons. The Landsat 8 satellite was selected for this study as, with 16 days revisit time, can easily get cloud free images at the time of observations. The overall objectives of the Landsat mission are as follows:

• Provide similar service as that of Landsats 4, 5, and 7.
• Give 16-day revisit Earth coverage, an 8-day repeat with a Landsat 7 offset.
periodically refresh and build a global archive of sun-lit, cloud-free, high resolution land images.

The basic information on the images used are given as follows (Appendix D)

- Satellite image: Landsat 8
- Sensor: Operational Land Imager (OLI)/TRIS
- Delineation data source: Earth explorer website,
- Path-Row: 138/44 (for the study area)
- Band: 4 (Red) & 5 (NIR)
- Spatial resolution: 30 m
- Swath width (km): 185 km
- Year/season: Kharif 2014, Rabi 2015
- ERDAS 9.2 Imagine software environment
- Images used of 31 October, 2014 and 08 March 2015.

4.5.3.2 Cropping area identification

The pre-processing involves preparation for some ground reference data for image digitization. Survey of India, 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). Nine ground control point (GCPs) were marked on the topographical map. For image processing purposes, GCPs are essential for computing a transformation matrix for use in rectifying an image (ERDAS field guide, 1991). In this study, geometric correction was carried out using 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 software is used to assist in the following digital image processing steps to identify the cropping area:

- Image preprocessing/rectification and restoration
- Ground truthing
- Unsupervised classification
- NDVI estimation
- Masking cropping area
4.5.3.3 Integration of GIS and remotely sensed data

The topographic map (1: 50,000) and digital thematic maps could be used to extract the feature information such as railway, road, drainage network, ponds etc. and study area boundaries. The road/drainage network from the topographic map is be digitized. The spatial as well as attribute data will be stored as a layer for overlaying with the classified images. The road/drainage and railway from each image are to be separated and overlay on all the supervised images. Selection for the cropping area in two season (Kharif and Rabi) were carried out by analyzing for the NDVI value of the study area as follows:

\[
NDVI = \frac{NIR - R}{NIR + R}
\] … (4.4)

Where,
NDVI- Normalized Differential Vegetation Index,
R- Reflectance values of Red (Band 4 in Landsat 8 images),
NIR- Reflectance values of Near Infrared (Band 5 in Landsat 8 images).

Due to limited resources and time, the remote sensing information was only used for cropping area identification. The raw data of crop inputs and chemical analysis results were stored in the database developed in MS Access software application. This database could also be used for the future analysis work.

4.5.3.4 Storage of collected information

The raw data of crop production and chemical analysis results were stored in the database developed in MS Access (MS Office 2007, Microsoft Inc. Ltd., USA) software application. This database could also be used for the future purpose for storing historical records. All these soil data were tabulated in the MS Access format and further processing was done under specific heading. These data can also be stored in the MS Excel application for further data manipulation. The information is converted to unit area and stored in the form of dbase or tab delimited file format to be used in the GIS software. Arc GIS 10.1 software was used to make analysis of all the GIS work in the thematic layers of the study area map. Such map are used to check real time changes in the study area and make necessary amendments on the thematic layers. Arc GIS software can be used to analyze, store, query, and generate outputs and convert the GIS data collected from different sources.
Application of GIS for overlaying thematic layers to establish land databases, all the layer maps has to be converted into consistent coordinate system. Geometric correction performed for the maps of different origin and converted into Universal Transverse Mercator (UTM) projection system.

4.6 Procedure for Developing the Suitability Criteria

4.6.1 Basic criteria for generating suitability maps
The general land use suitability maps were developed using the collected and available information on crops, crop yield, soil nutrients etc. The most of the physical factors were found to vary slightly between the adjacent plots as the extent of study area was small. The suitability classes were determined using all the measured soil parameters during the study. The suitability maps were created for each of the criteria and were integrated using the software to get the final land suitability map using eight soil factors, such as: N, P, K, EC, Organic carbon, pH, Zn and Soil texture etc.

4.6.2 Suitability criteria with AHP
Various methods for analysis of land suitability exist; most of these methods are mathematical in nature and facilitate the assessment of a piece of land on the basis of various factors for its suitability. The purpose of weighting is to express the importance of each factor relative to other factors’ effect on crop yield and growth rate. The most important factor should be considered as first priority. The weight of factors was determined depending on the relative importance of each factor in comparison with the others (Eastman et al., 1995). Based on crop requirement, the multi factor priority model was structured on discussion with local soil scientist, senior researchers, crop growers and other professionals.

In this study, suitability criteria priority were selected using the literature reviews of previous works through internal and external references, questionnaires and one-to-one interviewing with experts followed by ranking of parameters (Appendix E.1). Weighting the model criteria provides relative measures of the interaction and importance of the criteria. Weights for the model criteria have been obtained through the multi-criteria analysis. For determining the relative importance of suitability criteria, the AHP pair-wise comparison (PC) matrix system was used being guided by Saaty's nine-point weighing scale (Table 4.6). In PC matrix, the AHP calculates the weighting for each criterion/parameters (wi) by largest Eigenvector value of the matrix; then normalising the sum of the components to unity (Saaty, 1977 Eq. 4.5).
\[
\sum_{i=1}^{n} w_i = 1 \quad \ldots \quad (4.5)
\]

Table 4.6: Nine-point weighing scale for pair-wise comparison matrix (Saaty, 1980).

<table>
<thead>
<tr>
<th>Relative importance</th>
<th>Meaning</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equally important</td>
<td>Two criteria influencing equally to the objective</td>
</tr>
<tr>
<td>3</td>
<td>Slightly important</td>
<td>Experience and judgments slightly favouring one criteria over another</td>
</tr>
<tr>
<td>5</td>
<td>Fundamentally</td>
<td>Experience and judgments strongly favour one over the other</td>
</tr>
<tr>
<td>7</td>
<td>Really important</td>
<td>One is strongly favoured and validated by established practice</td>
</tr>
<tr>
<td>9</td>
<td>Absolutely important</td>
<td>Evidence favouring a criteria over other is of the highest order of affirmation</td>
</tr>
<tr>
<td>2,4,6,8</td>
<td>Adjacent</td>
<td>Used when intermediate importance values needed</td>
</tr>
</tbody>
</table>

Note: Reciprocals: If criteria \(i\) carry as per the numbers designated to it when it is compared with criteria \(j\), then \(j\) will take the reciprocal value when compared with \(i\).

It is important to note that for preventing bias thought of criteria weighting the Consistency Ratio (CR) was used. As a rule of thumb, the CR value of 10% \((< 0.1)\) or less is acceptable and validate the ranks. The CR can be estimated as follows:

\[
CI = \frac{\lambda_{\text{max}} - n}{n - 1} \quad \ldots \quad (4.6)
\]

\[
CR = \frac{CI}{RI} \quad \ldots \quad (4.7)
\]

Where,
- \(\lambda_{\text{max}}\): Largest Eigenvector value
- CR : Consistency ratio
- CI : Consistency index
- RI : Random consistency index (from table)
n: Represents the numbers of criteria in each PC matrix

The PC based 9-point continuous scale (i.e. 1/9, 1/7, 1/5, 1/3, 1, 3, 5, 7 and 9) was checked in the matrices on the basis of discussion with local experts to derive the CR for the selected land attributes within the established acceptable limits (0.1). The ranking of the different classes to the different factors/parameters of classes with higher scores are most suitable or preferred. It derives the weights by comparing the relative importance of the criteria in a pairwise manner. RI is the mean of the resulting consistency index based on the order of the matrix (Saaty and Vargas, 2001, Table 4.7).

Table 4.7: Values of random inconsistency index (RI) for n =15

<table>
<thead>
<tr>
<th>n</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>0.00</td>
<td>0.00</td>
<td>0.58</td>
<td>0.90</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.45</td>
<td>1.49</td>
<td>1.51</td>
<td>1.54</td>
<td>1.56</td>
<td>1.57</td>
<td>1.59</td>
</tr>
</tbody>
</table>

Source: Saaty and Vargas, (2001)

Classes with higher scores are most suitable for crop suitability evaluation (WLC) Eq. (4.8).

\[ S = \sum_i W_i X_i \prod_j C_j \]

... (4.8)

While,

S: Suitability composite score.

W_i: Weight assigned to the factor i.

X_i: Score of the factor i.

C_j: Constraint j score (0 out 1).

Once the factor maps and the weight of composite layers were obtained, then the MCE procedure was applied for crop suitability evaluation maps using spatial analyst tools in “ArcGIS 10.1” software by weighted overlay. The spatial analysis tools (pre-processing, reclassification, conversion and overlay) was used for suitability mapping (Corbett, 1996). Finally, the present land use/cover map and the suitability map for four crops were overlaid to compare the distribution of current rice/potato cultivated area within the different land suitability zones.
4.6.3 Accuracy assessment

The accuracy of maps prepared under this study was assessed by quality check by verifying field photos, morphological, physical and chemical properties of soil against the ground control points collected with GPS. The Analytic Hierarchy Process (AHP) method commonly used in multi-criteria decision making exercises was found to be a useful method to determine the weights. It can deal with inconsistent judgments and provides a measure of the inconsistency of the judgment of the respondents. The GIS is found to be a technique that provides greater flexibility and accuracy for handling digital spatial data. The combination of AHP method with GIS in our experiment proves it is a powerful combination to apply for land-use suitability analysis in sustainable agricultural planning.

4.7 Suitability assessment of crops

4.7.1 Crop selection

The study area cropping intensity is very high with 2-3 crops per year under irrigated condition. The farmers generally practice both Kharif and Rabi cropping pattern. The important Kharif crops are rice, jute, and Rabi crops are potato, mustard, pulse (lentil) and different types of vegetables. So, in this research work, to select best cropping pattern, two crops for each season have been selected. They are, rice and jute crops for Kharif season, and, potato and lentil crops for Rabi season in the study area. However, there is some small duration intermittent crops, such as: sesame, different vegetables etc. not considered for suitability analysis for this research work.

4.7.2 Selection of suitability classes

The first stage includes a sequence of evaluated crop selection, relevant criteria selection, criteria standardization, weight calculations, and final aggregation of criteria into the LSE results. The suitability levels for each of the criterion layers were defined based on literatures, experts’ knowledge and author’s practical experiences. Then, the layers were reclassified into different suitability level in ArcGIS 10.1 software environment. The suitability levels for each factor were ranked as: ‘Highly suitable’-S$_1$, ‘Moderately suitable’-S$_2$, ‘Marginal suitable’- S$_3$, ‘Not suitable’-N, as per the structure proposed by FAO (1993) land suitability classification. The methodology is based on matching soil/land characteristics against agronomical requirements of crop and then the suitability classification will be assessed.
Before the field work, required procedure was developed to carry out the research work including all the soil parameters (Fig. 4.7).

The selection of criteria is the crux of the suitability analysis. Physical land suitability evaluation is based on biophysical conditions of the study area. The process of selecting the main criteria and sub-criteria is iterative in nature. Literature review, analytical study and the local opinions were basic tools for selection of evaluation criteria. Based on FAO Framework for Land Evaluation mapping unit was determined physical land suitability will be assessed on the basic of soil parameter as follows: a) Soil unit type (according to FAO soil classification system), b) Soil texture, c) Soil nutrient availability, d) Soil effective depth.

4.7.3 Hierarchy structure for suitability

Pair-wise comparison (PC) matrix gives rating on the basis of relative importance of the two parameters influencing the suitability of the cropland for establishing the relative importance/weight of criteria of the parameters, sub criteria and classes of suitability. Malczewski (1999) stated that the relationship existing between the mentioned objectives and their attributes, follows a hierarchy structure. At highest level it is easy to differentiate the objectives and the attributes can be decomposed accordingly. The hierarchical structure for suitability includes all the important parameters and processes (Fig. 4.7).

4.7.4 Suitability range of the parameters for crops

The suitability range for the crops with four suitability classes (‘Highly suitable’-S₁, ‘Moderately suitable’-S₂, ‘Marginal suitable’- S₃, ‘Not suitable’-N,) need to be decided before going for land use suitability analysis. The specific suitability level for individual parameters under irrigated condition were estimated using local experts' opinion and previous works on suitability analysis. The ranges for rice crop (Table 4.8), for potato (Table 4.9) crop, for jute crop (Table 4.10), for lentil crop (Table 4.11) were estimated for land suitability evaluation.
Figure 4.7: Hierarchical structure of the suitability criteria for the study area

Table 4.8: Rice crop land suitability classes

<table>
<thead>
<tr>
<th>Land use requirements</th>
<th>Diagnostic factor</th>
<th>Unit</th>
<th>High($S_1$)</th>
<th>Moderate($S_2$)</th>
<th>Marginal($S_3$)</th>
<th>Not(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient availability</td>
<td>Soil pH</td>
<td>React</td>
<td>6.0-7.5</td>
<td>7.5-8.0</td>
<td>8.0-8.5</td>
<td>&gt;8.5,  &lt;4.0</td>
</tr>
<tr>
<td></td>
<td>Available nitrogen (N)</td>
<td>ppm</td>
<td>&gt;30</td>
<td>20-30</td>
<td>10-20</td>
<td>&lt;10</td>
</tr>
<tr>
<td></td>
<td>Available phosphorous (P)</td>
<td>ppm</td>
<td>&gt;50</td>
<td>25-50</td>
<td>10-25</td>
<td>&lt;10</td>
</tr>
<tr>
<td></td>
<td>Available potassium (K)</td>
<td>ppm</td>
<td>&gt;60</td>
<td>45-60</td>
<td>30-45</td>
<td>&lt;30</td>
</tr>
<tr>
<td></td>
<td>Organic carbon (OC)</td>
<td>%</td>
<td>&gt;1.0</td>
<td>0.66-1.0</td>
<td>0.33-0.66</td>
<td>&lt;0.33</td>
</tr>
<tr>
<td></td>
<td>Electrical</td>
<td>(dS/m)</td>
<td>0.0-3.0</td>
<td>3.0-4.0</td>
<td>4.0-5.0</td>
<td>&gt;5.0</td>
</tr>
<tr>
<td>Nutritio retention</td>
<td>Soil texture (ST)</td>
<td>Class</td>
<td>Sandy clay, silty clay loam</td>
<td>Sandy clay loam, silt loam, clay loam</td>
<td>Sandy clay loam, sandy loams, silt</td>
<td>Loamy sands, sands</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------</td>
<td>-------</td>
<td>-----------------------------</td>
<td>----------------------------------------</td>
<td>-------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>conductivity (EC)</td>
<td>Available Zinc Zn</td>
<td>ppm</td>
<td>&gt;1.5</td>
<td>1.0-1.5</td>
<td>0.5-1.0</td>
<td>&lt;0.5</td>
</tr>
</tbody>
</table>

Table 4.9: Potato crop land suitability classes

<table>
<thead>
<tr>
<th>Land quality</th>
<th>Land use requirements</th>
<th>Ranges for suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient availability</td>
<td>Soil pH Reaction</td>
<td>High(S₁)</td>
</tr>
<tr>
<td></td>
<td>ppm</td>
<td>&gt;55</td>
</tr>
<tr>
<td></td>
<td>ppm</td>
<td>&gt;11</td>
</tr>
<tr>
<td></td>
<td>ppm</td>
<td>&gt;55</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>&gt;0.7</td>
</tr>
<tr>
<td></td>
<td>(dS/m)</td>
<td>&lt;4</td>
</tr>
<tr>
<td></td>
<td>ppm</td>
<td>&gt;1.2</td>
</tr>
<tr>
<td>Nutrition retention</td>
<td>Soil texture (ST)</td>
<td>Sandy loams, sandy clay loam</td>
</tr>
</tbody>
</table>

Source: Mongkolsawat and Paiboonsak, 2015; Dengiz, et al., 2013; Prakash, 2003; Samanta, et al., 2011; FRG(BARC), 2012

Source: Vinay, 2007; FAO 1976; FRG(BARC), 2012; WW-03425-GO, 2017
Table 4.10: Jute crop land suitability classes

<table>
<thead>
<tr>
<th>Land use requirements</th>
<th>Ranges for suitability</th>
<th>Land quality</th>
<th>Diagnostic factor</th>
<th>Unit</th>
<th>High(S₁)</th>
<th>Moderate(S₂)</th>
<th>Marginal (S₃)</th>
<th>Not (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient availability</td>
<td></td>
<td>Soil pH</td>
<td>Reaction</td>
<td>ppm</td>
<td>6.5 - 7.5</td>
<td>5.0-6.5</td>
<td>4.5-5.0</td>
<td>&lt;4.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Available nitrogen (N)</td>
<td>ppm</td>
<td>&gt;45</td>
<td>30-45</td>
<td>15-30</td>
<td>&lt;15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Available phosphorous (P)</td>
<td>ppm</td>
<td>&gt;8</td>
<td>5-8</td>
<td>2-5</td>
<td>&lt;2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Available potassium (K)</td>
<td>ppm</td>
<td>&gt;30</td>
<td>20-30</td>
<td>10-20</td>
<td>&lt;10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Organic carbon (OC)</td>
<td>%</td>
<td>&gt;1.0</td>
<td>0.66-1.0</td>
<td>0.33-0.66</td>
<td>&lt;0.33</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electrical conductivity (EC)</td>
<td>(dS/m)</td>
<td>&lt;1.0</td>
<td>1.0-2.0</td>
<td>2.0-5.0</td>
<td>&gt;5.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Available zinc (Zn)</td>
<td>ppm</td>
<td>&gt;3</td>
<td>2-3</td>
<td>1-2</td>
<td>&lt;1</td>
<td></td>
</tr>
<tr>
<td>Nutrition retention</td>
<td></td>
<td>Soil texture (ST)</td>
<td>Class</td>
<td></td>
<td>Sandy clay loam, clay loam, sandy loam, sandy loam or sandy loam</td>
<td>Sandy clay, silty clay, silty clay loam</td>
<td>Loamy sand, clay</td>
<td>Heavy clays, sandy and heavy clay</td>
</tr>
</tbody>
</table>

Source: NBSS & LUP (1990); FRG(BARC),2012

Table 4.11: Lentil crop land suitability classes

<table>
<thead>
<tr>
<th>Land use requirements</th>
<th>Ranges for suitability</th>
<th>Land quality</th>
<th>Diagnostic factor</th>
<th>Unit</th>
<th>High(S₁)</th>
<th>Moderate(S₂)</th>
<th>Marginal (S₃)</th>
<th>Not(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient availability</td>
<td></td>
<td>Soil pH</td>
<td>Reaction</td>
<td>ppm</td>
<td>6.0-7.5</td>
<td>7.5-8.0</td>
<td>8.0 – 8.5</td>
<td>&gt;8.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Available nitrogen (N)</td>
<td>ppm</td>
<td>&gt;7.5</td>
<td>5.0-7.5</td>
<td>2.5-5.0</td>
<td>&lt;2.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Available phosphorous (P)</td>
<td>ppm</td>
<td>&gt;11</td>
<td>8-11</td>
<td>5-8</td>
<td>&lt;5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Available potassium (K)</td>
<td>ppm</td>
<td>&gt;5</td>
<td>10-15</td>
<td>5-10</td>
<td>&lt;5</td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th></th>
<th>Potassium (K)</th>
<th>Organic Carbon (OC)</th>
<th>Electrical Conductivity (EC)</th>
<th>Available Zinc (Zn)</th>
<th>Nutrition Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>&gt;1.5</td>
<td>1.0-1.5</td>
<td>0.5-1.0</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td></td>
<td>(dS/m)</td>
<td>0-1.0</td>
<td>1.0-1.5</td>
<td>1.5-2.0</td>
<td>&gt;2.0</td>
</tr>
<tr>
<td></td>
<td>ppm</td>
<td>&gt;1.0</td>
<td>0.8-1.0</td>
<td>0.5-0.8</td>
<td>&lt;0.5</td>
</tr>
</tbody>
</table>

Source: Sys et al. (1991; 1993); NBSS & LUP (1990); FRG (BARC), 2012

### 4.8 Agriculture Land use Suitability Approach

Land suitability is the ability of different type of land to support a specific use, and the process of land suitability classification includes the evaluation and grouping of particular land areas by means of their suitability for a defined land use (Prakash, 2003). This approach is mainly based on the matching of qualities of the land units in a specific area, guided by the requirements of actual or potential land use. In order to develop a set of themes for evaluation and ultimately to produce a suitability map for rice, jute, potato and lentil. The crop requirement by means of land qualities was used as previously followed by researchers (Sys et al., 1993). Each characteristic is considered as a thematic layer in the GIS. Eight attributes namely; soil texture, pH, organic carbon, EC, N, P, K, Zn were added to the polygon attribute table (Fig. 4.8). The attribute values were then compared to the crop requirements and soil limitation map is generated. Each of land qualities with associated attribute data is overlaid in a GIS environment and generated ten thematic layers. The diagnostic factors of each thematic layer were assigned values of degree of limitation ranging rice and potato using the individual crop requirements. In agriculture land use suitability approach can be divided into two groups in terms of selection of size of the field for data collection.

- Grid-based precision agriculture or within-field variability
- Small farmland-based precision agriculture or between-field variability
4.9 Best Crop Rotation Selection for Site-Specific Management

The selection of best crop rotation of the study area takes an important role for the success of land suitability evaluation in agriculture. The management zones can be selected and categorized for the areas having similar yield limiting factors. Zones can also be selected on the basis of soil nutrient factors. The zones can be shown in the form of maps, created using the GIS software. The suitability range of the parameter for the zone selection was determined for total available rate of nutrients for the current crop. The range for parameters like N, P and K was selected on the basis of recommended value for suitability class. There is also many other parameters like pH, organic carbon, EC, Soil texture, Zn etc. controlling the
crop growth showed wide variability, but the change of status to those factors seems out of control of farmers. So no special zones were elected for those factors.

The best crop recommendations has to be carried out in GIS software environment using "Map Query" tool based on most and least suitable area for the alternative crops. The least suitable area for a particular crop is further evaluated for suitability of alternative crop. If the alternative crop found suitable, then the alternative crop may be recommended to replace the current crop. However, if the alternative crop also found unsuitable for that area, the current crop may be continued or test of suitability for new alternatives may be evaluated.

The best crop for an area and the rotation practices can be recommended after series of experiments conducted with different crops considering agronomic and ecological factors for few seasons. For achieving success, the experiments should be continued for 4-6 seasons or 2-3 years.

4.10 Field Work and Crop Scouting

Intensive fieldwork and crop scouting are required to be carried out to acquire the detailed soil type, crop practice and climatic condition information. The total fieldwork can be done through number of field visits to the study area during crop growing and post crop harvesting seasons.

As the primary step the area for research work was selected. The individual crop lands were marked in presence of the owners. Soil samples were collected from individual crop lands from particular number of sites. The information about the crop inputs and practices were collected through the questionnaire survey. This procedure was carried out in the initial field visit. The missing data points and the extra information were collected in the following field visit before entering the data in to the database. Crop scouting was also carried out during the field visits. The best suited crop recommendation will be supplied to the farmers in the future visits.