Agropedology 2015, 25 (02), 181-194

Development of Integrated Land Use Plan for Upper Brahmaputra Valley under Rain-fed Ecosystem: A Case Study in Jorhat District, Assam

Siladitya Bandyopadhyay[1]*, S. K. Reza[2], D. P. Dutta[1], Utpal Baruah[1], K.D. Sah[1] and S.K. Singh[3]

[1]*ICAR – National Bureau of Soil Survey and Land Use Planning, Regional Centre, Jorhat – 785004, India*
[2] *ICAR –National Bureau of Soil Survey and Land Use Planning, Regional Centre, Kolkata – 700091, India*
[3] *ICAR –National Bureau of Soil Survey and Land Use Planning, Nagpur – 440033, India*

Abstract: An attempt was made to develop land use plan for Upper Brahmaputra Valley Region in Assam under rain-fed ecosystem. A tribal village named, Upar Deurigaon in Jorhat district of Assam was selected for the investigation. Land resource inventorying was carried out in the village. Two soil series were identified along with three phases as mapping units. The soil site suitability was assessed for *rabi*-crops grown in the study area. Interpretation of farm level socio-economic data helped in recognizing problems and potentials of the study area and the opportunities for *rabi*-cropping with adequate agronomic measures. However, the classical method of land suitability assessment was not adequately efficient to understand site specific limitations of soil parameters for crop growth. Study of soil-crop relationship with soil parameters *viz.*, pH and texture against crop yield data showed statistically significant relationship. Slightly acidic to neutral soils with silt loam phase produced significant improvement in yield of mustard and pea, whereas, strongly acidic soils with loamy sand to sandy loam phases showed significant yield of cabbage and potato. Agricultural land use plan was developed by effective planning of *rabi*-crops for the region.

Key words: *Land resource inventory, Land suitability assessment, Site specific land use plan, Soil-crop relationship, etc.*

Introduction

Land use planning (LUP) is a systematic assessment of physical, social and economic factors to encourage and support land user in selecting options, which increase productivity and sustainability of lands (FAO 1996). Land use planning should pursue some fundamental steps *viz.*, ascertaining bio-physical suitability of lands, interpretation of socio-economic factors followed by integration of both to obtain an interactive Decision Support System (DSS) for agro-technology transfer (Baruah *et al.* 2014). In India, rain-fed areas constitute 55% of the area net sown. Realizing the importance of characterization of rain-fed areas of the country, prioritization of the rain-fed districts was done by National Rain-fed Area Authority (NRAA). The state of Assam is by and large, dependent on rainfed agriculture. Jorhat is one of the districts in the state representing Upper Brahmaputra Valley Zone (UBVZ) agro-ecological region (Bhowmick *et al.* 1999). UBVZ is regarded as highly potential one for agricultural development comprising maximum variability in farming systems. However, major constraints of this region are the poor level of farm management with deprived crop performances (Barah 2001). As a consequence, despite its richness in bio-diversity with humid subtropical climatic conditions, Jorhat is still regarded as agriculturally backward district and ranks in priority index of 401 in the country (NRAA 2012). A rational and site specific land use planning is of utmost importance in this region for sustainable agricultural development. Soil resource information of Jorhat is available in 1: 50,000 scale (Vadivelu *et al.* 2004), which may not be useful for site specific land use planning. Therefore, systematic and site specific land resource information must be generated to develop land use plan in this region. Assessment of land suitability for crops can enhance the agricultural productivity of the zone manifold. This may be achieved by detailed soil resource inventory programme.

*Corresponding Author Email: siladitya_555@yahoo.co.in

In this paper, an attempt is made to develop agricultural land use plan for Upper Brahmaputra Valleys Zone by showcasing land resource inventory (LRI) in Upar Deurigaon tribal village of the district.

Materials and Methods

Developing land use plan of Jorhat

The concept of land management unit (LMU) has been the recent inception in district level land use planning approach (Annual Report, 2012-13; 2013-14). The methodology of land use plan under rain-fed ecosystem of Assam is described at length by Bandyopadhyay *et al.* (2014) and Baruah *et al.* (2014). The methodology involved multi-disciplinary approach with multi-factors overlay (Fig. 1 and Table 1). The factors were bio-physical (including soil and land uses/ land covers) and socio-economic (including farming systems and crop performances). Soil resource map (at 1:50,000 scale) of Jorhat district was generalized considering salient soil and site characteristics. Broad land use-land covers were recognized by visual interpretation of Reourcesat-1, IRS LISS –III imageries (2008-09). Major farming systems under rain-fed situation were identified by interpretation of secondary and socio-economic information. An integration of all the factors generated 8 homogeneous blocks of land with unique management intervention, otherwise called, land management units (LMU) (Fertilizer Association 2012). In the district, LMU-2 has been found to be the most representative unit to characterize Upper Brahmaputra Valley Zone.

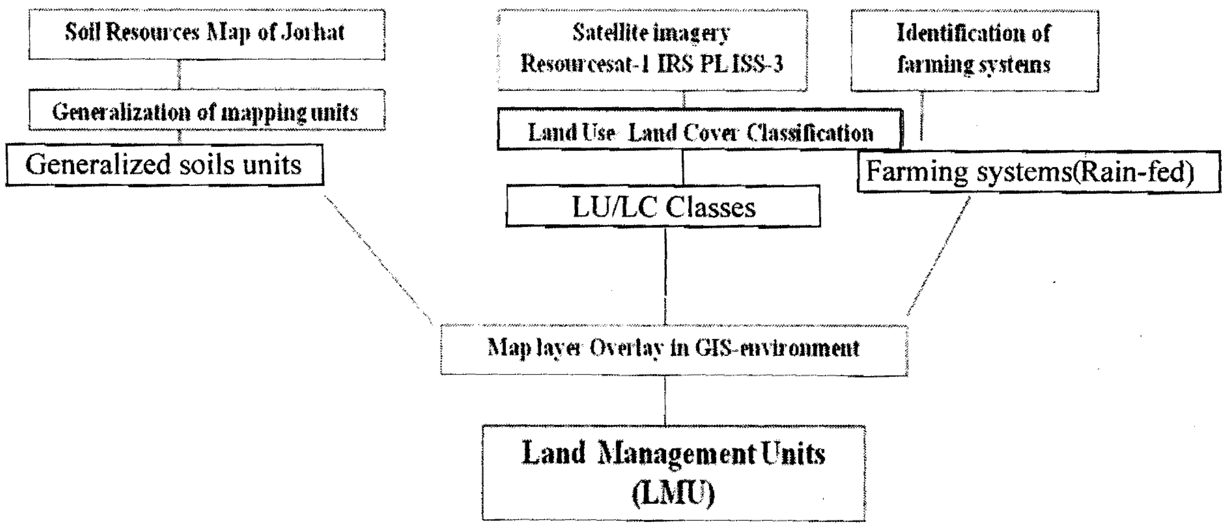

Fig. 1 Flow-chart of developing land management unit (LMU) in Jorhat district (Assam)

Table 1. Land Management units of Jorhat district (Assam)

LMU	Soil	Land use/ land covers	Farming system
1	Sandy loam, imperfectly drained soils on active flood plains	Cultivated, homestead, water bodies, channel bars, marshes and swamps	Integrated paddy based cropping system Triple cropping (Paddy-Paddy-Paddy) Triple cropping (Paddy-Paddy-Mustard)
2	Silt loam to sandy loam, poorly to imperfectly drained soils on flood plains and plains	Cultivated, homestead, water bodies, channel bars, marshes and swamps	Integrated paddy based cropping system Double cropping (Paddy-Paddy) Triple cropping (Paddy-Paddy-Mustard) Triple cropping (Paddy-Paddy-Rabi-veg.)
3	Silt loam to sandy loam imperfectly drained soils on plains	Cultivated, homestead, plantation	Mono-cropping (Paddy) Double cropping (Paddy-Paddy) Tea plantation
4	Sandy loam to loam, imperfectly drained soils on plains & uplands	Cultivated, homestead, plantation	Mono-cropping (Paddy) Tea plantation
5	Silt loam, moderately well drained soils on dissect ed uplands	Cultivated, homestead, plantation	Mono-cropping (Paddy) Tea & citrus plantation
6	Sandy loam, well drained soils on dissected uplands	Plantation, cultivated, homestead, forest	Tea & citrus plantation Mono-cropping (Paddy)
7	Silty clay loam to silt loam, poorly drained soils on plains	Cultivated, homestead, plantation	Mono-cropping (Paddy) Tea & citrus plantation
8	Loam to clay loam, well drained soils on piedmonts and hills	Hills, forest, plantation, homestead, cultivated	Mono-cropping (Paddy) Tea & citrus plantation

Study area

Upar Deurigaon is a tribal village, situated in the North West block of Jorhat district of Assam (26^{0}49' 30" N to 26^0 50' 09" N latitude and 94^0 06' 46" E to 94^0 07' 26" E longitude) comprising 1515 ha area (Fig. 2). The annual rainfall is fairly high (2077 mm) (Vadivelu *et al.* 2004). The agro-ecological sub region is characterized by hot per-humid climate of Upper Brahmaputra Plains with moderately deep to deep loamy alluvium derived soils with medium available water capacity and length of growing period of more than 300 days (15.4) (Velayutham *et al.* 1999).

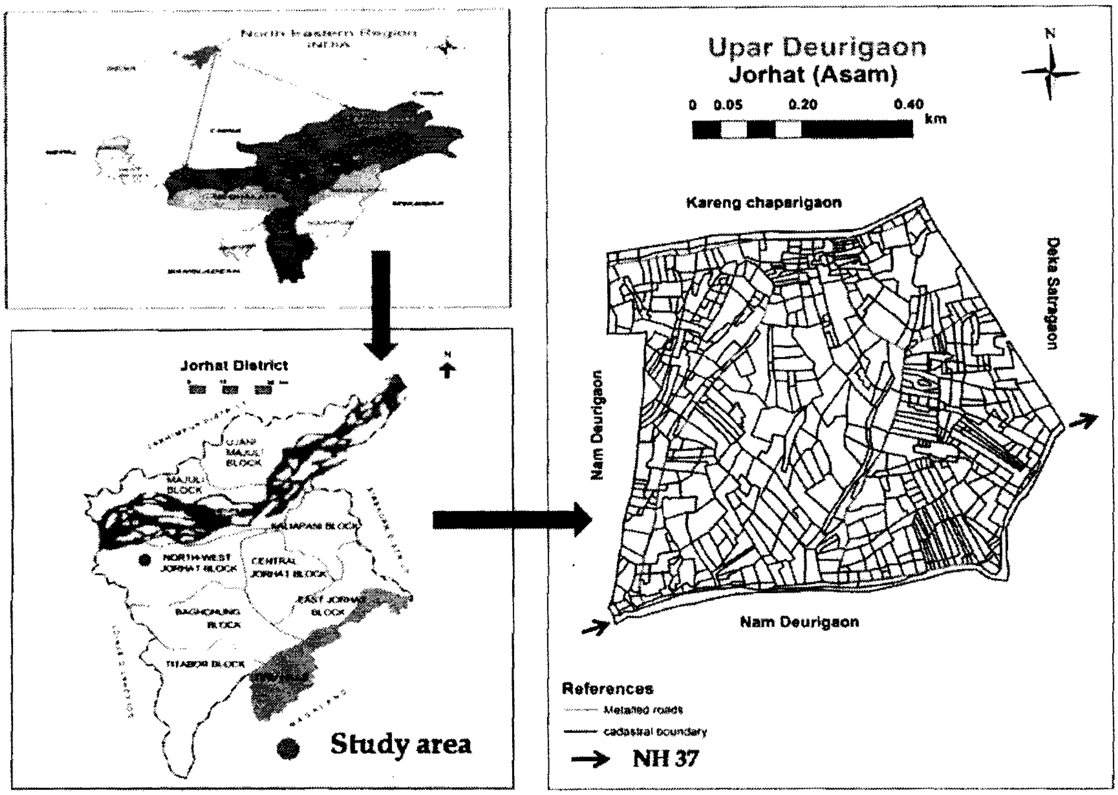

Fig. 2 Location map of the study area

Land resource inventory

Detailed soil survey was carried out in the village using cadastral map (1: 4,000 scale) as base map. Intense traversing of the village was done to identify sites for soil profile examination. Based on the profile study, soils were characterized for their morphological and physical characteristics (Soil Survey Staff 2003). Based on the soil-site characteristics recorded from survey, the soils were grouped into different soil series through soil correlation. After grouping the soils into different soil series, the phases of soil series were identified by intensive field traversing, checking thoroughly for variability in surface texture, the boundaries of soil mapping units were delineated on base maps (IARI 1971). Soils were analyzed for routine physical and chemical properties (Black *et al.* 1965; Jackson 1973; Sparks 1996). Additionally, 200 no. of random surface soil samples (0-25 cm) were collected from cultivated fields grown under cabbage, mustard, potato and pea (with a sample size of 50 for each crop).

Evaluation of Socio-economic status

The crop performances were recorded by interviewing 60 house-holds of the study area with standard questionnaire (including crop yield in farmers' field, cost of cultivation, gross income and net returns). The secondary information including district level yield in 2014-15 and attainable yield at research stations were collected from District Agricultural Department, Regional Agricultural Research Station (RARS), Krishi Vigyan Kendra (KVK) of Assam Agricultural University (AAU). Benefit-cost ratio for each crop was estimated by dividing net returns to the cost of cultivation. Yield gap was analyzed by deducting average yield of crop in farmers' field from the attainable yield obtained in experimental research stations (from RARS, AAU, KVK, *etc.*). Percentage of yield gap was estimated as {100 – (average yield at farmers' field/ attainable yield at research station) × 100}. Income gap was calculated as net returns × percentage of yield gap for each crop. Anticipated maximum net returns were calculated as net returns plus income gap for each crop (Handbook of Agriculture 2009; Lakshmanan 2007; Nirmala *et al.* 2009).

Land suitability assessment

The soil site suitability for important *rabi* crops *viz.*, mustard, potato, cabbage, and pea were assessed by maximum limitation method (Sys *et al.* 1991; 1993) using the land resource data of the study area.

Soil-crop relationship

Limiting soil parameters affecting crop yield were chosen from land suitability assessment. Statistical correlation was built up between important soil parameters and crop yield data to obtain soil-crop relationship in the study area using Pearson bivariate statistics in SPSS ver. 15.

Developing integrated land use plan

Finally, integrated and alternative land use options were developed for the soil of the study area based on interpretation of land resource and socio-economic data bases.

Results and Discussion

Soil resources

Two soil series were identified *viz.*, Deuri A and Deuri B along with three number of phases as mapping units (Fig. 3). Deuri A series was characterized by very deep, imperfectly drained, coarse loamy soils with loamy sand surface (phase), occurring in very gently sloping active flood plains with moderate erosion hazard and classified as *Coarse loamy, mixed hyperthermic Typic Fluvaquents.* Deuri B series was characterized by very deep, imperfectly drained, coarse loamy soils with sandy loam surface (phases), occurring in nearly level flood plains with slight erosion hazard and classified as *Coarse loamy, mixed hyperthermic Fluvaquentic Endoaquepts.* The ranges in characteristics of soils of Upar Deurigaon are described in (Table 2).

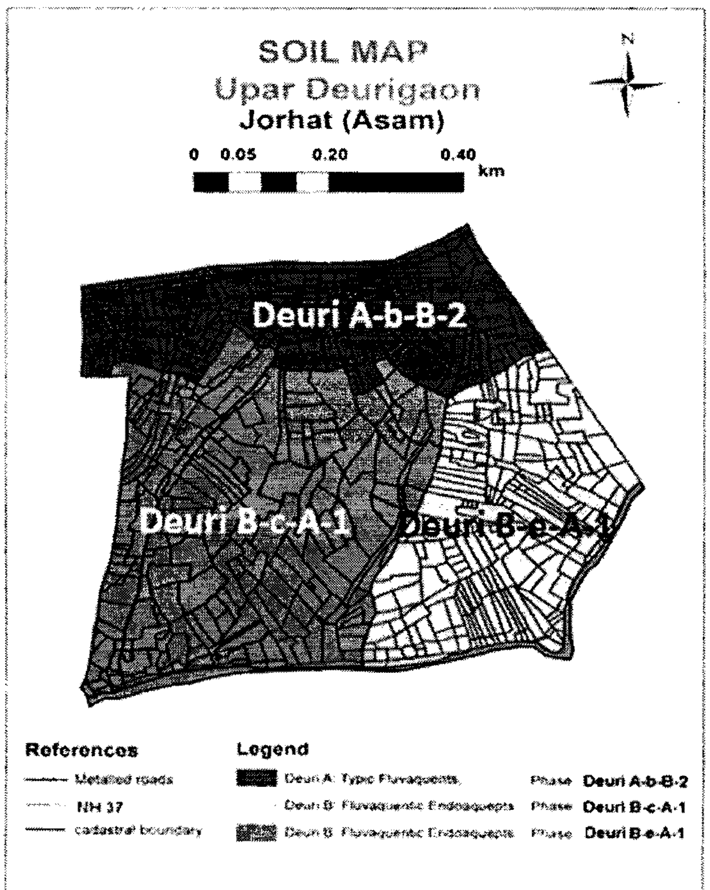

Fig. 3 Soil map of the study area

Table 2. Ranges in characteristics of soils of Upar Deurigaon, Jorhat, Assam

Soil-site characteristics	Descriptions	Mapping units (Phases of soil series)		
		Deuri A-b-B-2	Deuri B-c-A-1	Deuri B-e-A-1
Climate (c)	Rainfall (mm)		2077	
	Temperature (°C)		24.5-29.5	
Topography (t)	Slope (%)	1-3	0-1	0-1
	Landform	Active flood plains	Flood plains	Flood plains
Wetness (w)	Flooding	Frequent (Soil is inundated for > 3 months)	Occasional (Soil is inundated for 1-3 months)	Occasional (Soil is inundated for 1-3 months)
	Internal drainage	Somewhat poor with prominent mottles formation between 50-75 cm from surface soils with water table below 1.5m depth	Somewhat poor with prominent mottles formation between 50-75 cm from surface soils with water table below 1.5m depth	Somewhat poor with prominent mottles formation between 50-75 cm from surface soils with water table in 1.0-1.5m depth
Soil physical properties (s)	Surface texture	Loamy sand	Sandy loam	Silt loam
	Soil depth	Very deep (> 150 cm)	Very deep (> 150 cm)	Very deep (> 150 cm)
Soil fertility parameters (f)	pH	5.2-5.3	5.4-5.5	6.3-6.9
	O.C. (%)	0.51-0.63	0.56-0.90	0.72-0.99
	*App. CEC	42-52	41-45	49-56
	**B.S. (%)	54-68	41-59	49-52

**App. CEC: Apparent CEC (cmol/ kg) = (CEC/ Clay) × 100;*
***BS: Base saturation = (Sum of base forming cations/ CEC) × 100*

Soil site suitability evaluation

It was observed that soils of Deuri-A series were marginally suitable for mustard, pea and cabbage with severe limitations of wetness, pH and surface texture and moderately suitable for potato with moderate limitations of pH, surface texture, and wetness. However, soils of Deuri-B series were moderately suitable for mustard and cabbage with limitation of pH and wetness and marginally suitable for pea and potato with limitation of impeded drainage situation (Table 3).

Although, this suitability evaluation followed quantitative assessment of land (FAO 1996; Sys 1991), it was obscure to find out the actual and site specific limiting soil factors affecting crop growth. On the contrary, crop performances in the study area showed incongruity with suitability rating. The inconsistency of crop performance against land suitability assessment may lead to incorrect land use plan. To avoid such discrepancy it was solicited to establish soil-crop relationship with a statistical correlation approach. Two important soil parameters namely, pH (1: 1.25 Soil: Water ratio) and surface texture were recognized from this assessment as the major soil factors determining crop yield.

Establishing soil-crop relationship

The soil data base including soil pH (at 1: 2.5 soil-water ratio) and particle size distribution (sand, silt and clay contents) along with respective crop yield data of cabbage, mustard, potato and pea (Table 4) were analyzed for correlation-study. The correlation statistics is depicted in Table 5. Soil-crop relationship (Table 6) was evaluated using regression equation technique. It was observed that sand fraction of soils were significantly positively correlated with yield of cabbage (0.88**) and potato (0.96**), whereas, silt fraction of soils were positively correlated with yield of mustard (0.95**) and pea (0.92**) and *vice versa*. Similarly, pH was significantly positively correlated with yield of mustard (0.81**) and pea (0.76**) and negatively with cabbage (-0.78**) and potato (-0.72**). With increasing silt content, pH significantly increases (0.78**) and with increasing sand content, the same significantly declines (-0.77**).

Table 3. Soil site suitability rating for crops

Mapping units	Site characteristics					Soil characteristics						Suitability rating
	Climate (c)		Topography	Wetness (w)		Physical (s)			Soil fertility (f)			
	Rainfall	Temp.	(t) (Slope gradient)	Drainage	Flooding	Depth (cm)	Surface texture	pH	Organic Carbon	App. CEC	B.S.	
					Mustard							
Deuri A-b-B-2	S1	S1	S1	S2	S3	S1	S3	S3	S2	S1	S1	S3 (fsw) 3
Deuri B-c-A-1	S1	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1	S2 (fw) 2
Deuri B-e-A-1	S1	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1	S2 (fw) 2
					Pea							
Deuri A-b-B-2	S1	S1	S1	S3	S3	S1	S3	S3	S2	S1	S1	S3 (fsw) 3
Deuri B-c-A-1	S1	S1	S1	S3	S3	S1	S1	S2	S2	S1	S1	S3 (w) 3
Deuri B-e-A-1	S1	S1	S1	S3	S3	S1	S1	S1	S2	S1	S1	S3 (w) 3
					Cabbage							
Deuri A-b-B-2	S1	S1	S1	S2	S3	S1	S3	S3	S2	S1	S1	S3 (fsw) 3
Deuri B-c-A-1	S1	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1	S2 (fw) 2
Deuri B-e-A-1	S1	S1	S1	S2	S2	S1	S1	S1	S2	S1	S1	S2 (fw) 2
					Potato							
Deuri A-b-B-2	S1	S1	S1	S2	S2	S1	S2	S2	S2	S1	S1	S2 (fsw) 2
Deuri B-c-A-1	S1	S1	S1	S3	S3	S1	S1	S2	S2	S1	S1	S3 (w) 3
Deuri B-e-A-1	S1	S1	S1	S3	S3	S1	S1	S1	S2	S1	S1	S3 (w) 3

Table 4. Soil-crop data base of the study area

S. No.	Soil properties: Particle size distribution (%)			pH	Yield of Mustard (t/ ha)	Soil properties: Particle size distribution (%)			pH	Yield of Pea (t/ ha)	Soil properties: Particle size distribution (%)			pH	Yield of Cabbage (t/ ha)	Soil properties: Particle size distribution (%)			pH	Yield of Potato (t/ ha)
	Sand	Silt	Clay			Sand	Silt	Clay			Sand	Silt	Clay			Sand	Silt	Clay		
1	32.5	60.0	7.5	5.9	1.3	38.3	50.7	11.0	6.0	2.4	79.3	12.3	8.4	5.2	59.9	1.7	92.3	6.0	6.7	11.7
2	14.1	59.1	26.9	6.1	1.5	17.1	72.8	10.1	6.3	2.8	73.4	11.6	15.0	5.7	48.0	8.0	82.5	9.5	6.6	11.7
3	31.4	57.6	11.0	5.9	1.3	17.9	70.9	11.2	6.1	2.8	82.5	8.0	9.5	6.2	59.9	12.3	79.3	8.4	6.3	12.1
4	33.8	55.2	11.0	5.8	1.3	23.0	71.0	6.0	6.0	2.8	92.3	1.7	6.0	6.1	59.9	15.3	74.7	10.0	6.4	12.1
5	32.7	51.3	16.0	5.9	1.3	18.1	70.9	11.0	6.0	2.8	1.7	92.3	6.0	6.7	33.9	11.6	73.4	15.0	6.4	12.1
6	38.3	51.7	10.0	6.0	1.3	2.1	91.9	6.0	6.7	2.8	12.3	79.3	8.4	6.3	35.2	17.1	72.8	10.1	6.3	12.1
7	26.8	47.2	26.0	5.9	1.3	6.0	82.5	11.5	6.6	2.8	43.1	35.4	21.5	5.7	43.3	17.1	71.4	11.5	6.1	12.1
8	1.9	92.3	5.8	6.7	1.6	12.3	79.3	8.4	6.3	2.8	57.6	33.4	9.0	5.4	48.8	23.0	71.0	6.0	6.0	14.2
9	10.0	82.5	7.5	6.6	1.6	15.3	74.7	10.0	6.4	2.8	60.0	32.5	7.5	5.3	50.1	18.1	70.9	11.0	6.0	12.1
10	10.3	79.3	10.4	6.3	1.5	11.6	73.4	15.0	6.4	2.8	71.0	23.0	6.0	5.3	58.1	20.1	69.9	10.0	6.0	14.2
11	15.3	74.7	10.0	6.4	1.5	20.1	69.9	10.0	6.0	2.8	69.9	20.1	10.0	5.8	40.2	22.2	65.8	12.0	5.9	14.2
12	11.6	72.4	16.0	6.4	1.5	22.8	65.2	12.0	5.9	2.8	71.4	17.1	11.5	5.3	58.1	32.5	60.0	7.5	5.9	14.2
13	17.1	72.8	10.1	6.3	1.5	32.5	60.0	7.5	5.9	2.4	46.8	32.7	20.5	5.7	43.3	14.9	58.1	27.0	6.1	12.1
14	15.1	71.4	13.5	6.1	1.5	14.9	58.1	27.0	6.1	1.8	51.3	32.7	16.0	5.5	48.8	33.4	57.6	9.0	5.9	16.8
15	25.0	69.0	6.0	6.0	1.4	33.4	57.6	9.0	5.9	2.4	60.0	32.5	7.5	5.3	50.1	34.8	54.2	11.0	5.8	15.8
16	18.1	70.2	11.7	6.0	1.4	34.8	54.2	11.0	5.8	2.4	48.2	26.8	25.0	5.7	43.3	32.7	51.3	16.0	5.9	15.8
17	20.1	69.4	10.5	6.0	1.4	33.7	51.3	15.0	5.9	2.4	71.0	23.0	6.0	5.3	58.1	38.3	50.7	11.0	6.0	16.8
18	32.7	45.8	21.5	5.9	1.3	46.6	41.9	11.5	5.7	1.8	65.8	22.2	12.0	5.8	40.2	26.8	48.2	25.0	5.9	14.0
19	41.9	45.6	12.5	5.8	1.3	50.7	38.3	11.0	5.6	1.8	72.8	17.1	10.1	5.2	58.1	32.7	46.8	20.5	5.9	15.8
20	35.4	43.1	21.5	5.9	1.3	43.1	35.4	21.5	5.7	1.8	74.7	15.3	10.0	5.2	58.1	41.9	46.6	11.5	5.8	16.8
21	46.6	41.9	11.5	5.7	1.0	54.2	34.8	11.0	5.4	1.7	1.7	92.3	6.0	6.7	33.9	35.4	43.1	21.5	5.9	15.8
22	52.7	36.3	11.0	5.6	1.0	57.6	33.4	9.0	5.4	1.7	8.0	82.5	9.5	6.6	33.9	46.6	41.9	11.5	5.7	16.8
23	46.1	33.4	20.5	5.7	1.0	45.8	32.7	21.5	5.7	1.8	12.3	79.3	8.4	6.3	35.2	50.7	38.3	11.0	5.6	15.8
24	55.2	33.8	11.0	5.4	1.0	12.3	79.3	8.4	6.3	2.8	15.3	74.7	10.0	6.4	35.2	43.1	35.4	21.5	5.7	16.8
25	57.6	33.4	9.0	5.4	0.8	45.1	35.4	19.5	5.7	1.8	11.6	73.4	15.0	6.4	35.2	54.2	34.8	11.0	5.4	15.8

26	46.8	32.7	20.5	5.7	1.0	59.6	31.4	9.0	5.4	1.7	17.1	72.8	10.1	6.3	35.2	57.6	33.4	9.0	5.4	16.8
27	82.5	8.0	9.5	6.2	0.6	62.0	32.5	5.5	5.3	1.7	17.1	71.4	11.5	6.1	35.2	46.8	32.7	20.5	5.7	16.8
28	92.3	1.7	6.0	6.1	0.6	70.0	23.0	7.0	5.3	1.6	23.0	71.0	6.0	6.0	40.1	51.3	32.7	16.0	5.5	15.8
29	1.7	92.3	6.0	6.7	1.6	68.9	20.1	11.0	5.8	1.7	18.1	70.9	11.0	6.0	40.1	60.0	32.5	7.5	5.3	19.5
30	10.3	79.3	10.4	6.3	1.5	72.4	17.1	10.5	5.3	1.6	20.1	69.9	10.0	6.0	40.1	48.2	26.8	25.0	5.7	16.8
31	43.1	35.4	21.5	5.7	1.0	68.9	20.1	11.0	5.8	1.7	22.2	65.8	12.0	5.9	40.1	71.0	23.0	6.0	5.3	20.0
32	55.6	33.4	11.0	5.4	0.8	71.9	18.1	12.0	5.2	1.7	32.5	60.0	7.5	5.9	40.1	65.8	22.2	12.0	5.8	19.5
33	61.1	32.4	6.5	5.3	0.8	71.4	17.1	11.5	5.3	1.6	14.9	58.1	27.0	6.1	35.2	69.9	20.1	10.0	5.8	19.5
34	71.9	23.1	5.0	5.3	0.8	72.8	17.1	10.1	5.2	1.7	33.4	57.6	9.0	5.9	40.1	70.9	18.1	11.0	5.2	20.0
35	69.9	20.1	10.0	5.8	0.8	26.8	48.2	25.0	5.9	1.8	34.8	54.2	11.0	5.8	40.1	71.4	17.1	11.5	5.3	20.0
36	71.6	17.1	11.3	5.3	0.6	33.7	45.8	20.5	5.9	1.8	32.7	51.3	16.0	5.9	40.1	72.8	17.1	10.1	5.2	20.0
37	22.0	65.8	12.2	5.9	1.4	41.9	46.6	11.5	5.8	1.8	38.3	50.7	11.0	6.0	40.1	74.7	15.3	10.0	5.2	22.3
38	65.8	22.2	12.0	5.8	0.8	35.4	43.1	21.5	5.9	1.8	26.8	48.2	25.0	5.9	40.1	58.1	14.9	27.0	5.4	16.8
39	67.9	20.1	12.0	5.8	0.8	72.7	15.3	12.0	5.2	1.6	32.7	46.8	20.5	5.9	40.1	79.3	12.3	8.4	5.2	22.3
40	72.9	16.1	11.0	5.2	0.8	58.1	14.9	27.0	5.4	1.6	41.9	46.6	11.5	5.8	43.3	73.4	11.6	15.0	5.7	20.0
41	70.4	18.1	11.5	5.3	0.6	78.3	12.3	9.4	5.2	1.6	35.4	43.1	21.5	5.9	40.1	82.5	8.0	9.5	6.2	22.3
42	72.8	17.1	10.1	5.2	0.6	75.4	11.6	13.0	5.7	1.7	46.6	41.9	11.5	5.7	43.3	92.3	1.7	6.0	6.1	22.3
43	74.7	15.3	10.0	5.2	0.6	80.5	8.0	11.5	6.2	1.5	50.7	38.3	11.0	5.6	48.8	1.7	92.3	6.0	6.7	11.7
44	56.1	16.9	27.0	5.4	0.8	90.3	1.7	8.0	6.1	1.5	43.1	35.4	21.5	5.7	43.3	12.3	79.3	8.4	6.3	12.1
45	79.3	12.3	8.4	5.2	0.6	1.7	92.3	6.0	6.7	2.8	54.2	34.8	11.0	5.4	48.8	43.1	35.4	21.5	5.7	16.8
46	73.4	11.6	15.0	5.7	0.6	52.3	32.7	15.0	5.5	1.8	57.6	33.4	9.0	5.4	48.8	57.6	33.4	9.0	5.4	16.8
47	51.3	32.7	16.0	5.5	1.0	56.0	32.5	11.5	5.3	1.7	58.1	14.9	27.0	5.4	48.8	60.0	32.5	7.5	5.3	19.5
48	60.0	32.5	7.5	5.3	0.8	48.2	26.8	25.0	5.7	1.8	69.9	20.1	10.0	5.8	40.2	71.0	23.0	6.0	5.3	20.0
49	48.2	26.8	25.0	5.7	1.0	70.5	23.5	6.0	5.3	1.6	70.9	18.1	11.0	5.2	58.1	69.9	20.1	10.0	5.8	19.5
50	71.0	23.0	6.0	5.3	0.8	63.8	22.2	14.0	5.8	1.7	71.4	17.1	11.5	5.3	58.1	71.4	17.1	11.5	5.3	20.0

Table 5. Statistical relationship for soil-crop parameters

Soil-crop parameters	Regression equations	Correlation coefficient (r)	R^2
% of Sand vs. Yield of Mustard	Yield of Mustard (Y)= {-0.013 × Sand (X)} + 1.650	-0.97**	0.94
% of Sand vs. Yield of Pea	Yield of Pea (Y)= {-0.018 × Sand (X)} + 2.876	-0.86**	0.73
% of Sand vs. Yield of Cabbage	Yield of Cabbage (Y)= {0.305 × Sand (X)} + 31.20	0.88**	0.78
% of Sand vs. Yield of Potato	Yield of Potato (Y)= {0.129 × Sand (X)} + 10.73	0.96**	0.93
% of Silt vs. Yield of Mustard	Yield of Mustard (Y)= {0.013 × Silt (X)} + 0.503	0.95**	0.90
% of Silt vs. Yield of Pea	Yield of Pea (Y)= {-0.019 × Silt (X)} + 1.240	0.92**	0.84
% of Silt vs. Yield of Cabbage	Yield of Cabbage (Y)= {-0.287 × Silt (X)} + 57.19	-0.84**	0.70
% of Silt vs. Yield of Potato	Yield of Potato (Y)= {-0.124 × Sand (X)} + 21.88	-0.93**	0.86
pH vs. % of Sand	pH (Y) = {-0.013 × Sand (X)} + 6.374	-0.77**	0.59
pH vs. % of Silt	pH (Y) = {0.013 × Silt (X)} + 5.211	0.78**	0.61
pH vs. Yield of Mustard	pH (Y) = {1.014 × Yield of Mustard (X)} + 4.712	0.81**	0.65
pH vs. Yield of Pea	pH (Y) = {0.619 × Yield of Pea (X)} + 4.508	0.76**	0.57
pH vs. Yield of Cabbage	pH (Y) = {-0.038 × Yield of Cabbage (X)} + 7.522	-0.78**	0.60
pH vs. Yield of Potato	pH (Y) = {-0.092 × Yield of Potato (X)} + 7.317	-0.72**	0.52

(**) Significant at 0.01 P level

Table 6. Soil-crop relationship (based on regression equation)

Crops	Yield (t/ ha)	Sand	Silt (%)	Clay	Texture	pH	Revised land suitability assessment for crops
				Soil Parameters with Maximum Yield attained for *Rabi*-crops			
Mustard	1.56	6.9	81.2	11.9	Silt loam	6.29	Highly suitable in silt loam soils with slightly acidic reaction.
Pea	2.84	2.0	84.0	14.0	Silt loam	6.97	Highly suitable in silt loam soils with slightly acidic/ neutral reaction.
Cabbage	59.9	84.3	9.4	6.3	Loamy sand	5.25	Highly suitable in loamy sand soils with strongly acidic reaction.
Potato	22.3	89.7	3.4	6.9	Loamy sand	5.27	Highly suitable in loamy sand soils with strongly acidic reaction.
				Soil Parameters with Minimum Yield attained for *Rabi*-crops			
Mustard	0.64	77.7	10.5	11.8	Sandy loam	5.36	Least suitable in sandy loam soils with strongly acidic reaction.
Pea	1.52	75.3	14.7	10.0	Sandy loam	5.45	Least suitable in sandy loam soils with strongly acidic reaction.
Cabbage	33.9	8.9	81.2	9.9	Silt loam	6.23	Least suitable in silt loam soils with slightly acidic reaction.
Potato	11.7	7.5	82.1	10.4	Silt loam	6.24	Least suitable in silt loam soils with slightly acidic reaction.

It was obvious from the study that slightly acidic to neutral soils with silt loam surface texture produced encouraging yields for mustard and pea and low yields of cabbage and potato, whereas, strongly acidic soils with loamy sand to loamy and texture produced the best yield of cabbage and potato and poor yield of mustard and pea.

Evaluation of socio-economic status

Interpretation of socio-economic status provided a comprehensive insight on the crop performance of the study area (Table 7). It was observed that the *pre-kharif* (Ahu) and *kharif* (Sali) rice has low average productivity (1.72-2.28 t/ ha for Ahu-rice and 1.47-3.74 t/ ha for Sali-rice) with low benefit to cost ratios (0.47-0.50 for Ahu-rice and 1.15-1.19 for Sali rice) and lower net annual returns (Rs. 4585/- for Ahu-rice and Rs. 12828/- for Sali-rice). As a consequence, the percentage of yield gap was also substantially high for Ahu-rice (60%) and Sali-rice (52.5%). However, *rabi*-crops have shown satisfactory crop performances with net returns of Rs. 45,000/- for pea to Rs. 2,05,000/- for cabbage. The benefit to cost ratio ranged from 1.05 to 1.43 for potato to 4.88 to 5.85 for cabbage. The percentage of yield gap for the *rabi*-crops is not as high (6.8 for cabbage to 29.3% for mustard) as compared to *kharif* and *pre-kharif* crops (52.5-60%). Thus it is obvious that the farmers are likely to suffer with high income gap for *pre-kharif* and *kharif* crops as compared to *rabi*-crops.

Table 7. Crop performances of the study area (2014-15)

Crops	*Pre-kharif*	*Kharif*	*Rabi*			
Agronomic parameters	**Ahu-rice**	**Sali-rice**	**Mustard**	**Potato**	**Pea**	**Cabbage**
Range of yield obtained at farmers' field (t/ ha)	1.72-2.28	1.47-3.74	0.64-1.56	11.7-22.3	1.52-2.80	33.9-59.9
Maximum yield (t/ ha) obtained	2.28	3.74	1.56	22.3	2.80	59.9
Average yield obtained at farmers' field (t/ ha)	2.0	2.61	1.06	16.49	2.07	44.74
Yield at Research station (t/ ha)	5.0	5.5	1.50	20.0	2.84	48.0
District level yield (t/ ha)	2.0-3.0	3.0-4.0	0.85-10.0	7.5-10.0	0.6-0.8	25-30
Yield Gap	-3.0	-2.89	-0.44	-3.51	-0.77	-5.26
Yield Gap (%)	60.0	52.5	29.3	17.6	27.1	6.8
B/ C ratio	0.47-0.50	1.15-1.19	4.11-4.28	1.05-1.43	3.85-4.09	4.88-5.85
Net Average Returns (Rs/ ha/ year)	4,585/-	12,828/-	60,000/-	1,06,000/-	45,000/-	2,05,000/-
Income Gap (Rs/ ha/ year)	2,751/-	6,735/-	17,580/-	18,656/-	12,195/-	13,940/-
Anticipated Max. Net Returns (Rs/ ha/ year)	7,336/-	19,563/-	77,580/-	1,24,656/-	57,195/-	2,18,940/-

High profitability of *rabi*-crops over the *pre-kharif* and *kharif* crops is anticipated in the study area if grown at large scale. However, poor level of farm management, inadequate crop planning are the major hindrances for cultivation of *rabi*-crops in the village. However, *rabi*-crops are grown sporadically in some tiny pockets of the study area, leaving the vast fertile lands uncultivated.

Land use planning of the study area

It was realized that from classical method of land suitability assessment, the limitations are recognized in generalized manner. Thus, there is a risk of losing the information of actual site specific soil constraints and/ or potential for each crop. Adoption of soil-crop relationship technique appeared to be a superior approach to comprehend that texture and pH of surface soils were the determining parameters determining crop yield. Hence, alternate land suitability options were prescribed for each soil mapping units. Socio-economic data interpretation helped in crop planning with efficient agronomic measures for *rabi*-crops in variable land situations. Agronomic information collected from district agricultural department and KVKs of Assam Agricultural University revealed that *pre-kharif (Ahu)* rice yield was maximum in Luit variety whereas, maximum *kharif (Sali)* rice yield was recorded with Ranjit and Masuri varieties on flood plains. However, in inundated soils (low-lying flood plains), two water logging tolerant varieties namely, Plaban and Jalkuwari (derived from Regional Agricultural Research Station, A.A.U.) improved yields for *kharif (Sali)* rice. In cases of *Rabi*-crops like mustard, cabbage, pea and potato, improved crop varieties *viz.*, TS-38, Green express, Azad P-1 and Kufri-Jyoti resulted in promising yields, respectively. Farmers may be encouraged for *Rabi*-crops with efficient agronomic management practices *viz.*, cultivation in raised bedded furrows and adoption of Shallow Tube Well with pump-set as micro-irrigation system depending on the land situation. Finally, from the above study, it may be concluded that mustard and pea are likely to respond well in slightly acidic to neutral silt loam soils , whereas, cabbage and potato are likely to produce promising results with strongly acidic loamy sand soils. Thus, with, integrated and alternative land use options for each soil mapping units could be suggested (Table 8).

Table 8. Land use plan of the study area

Mapping units	Deuri A-b-B-2	Deuri B-c-A-1	Deuri B-e-A-1
Phase level characteristics	Surface soils are loamy sand textured with strongly acidic soil reaction	Surface soils are sandy loam textured with strongly acidic soil reaction	Surface soils are silt loam textured with slightly acidic to neutral soil reaction
Present land use	Pre-*Kharif*- Fallow *Kharif*- Rice (rain-fed) *Rabi*- Fallow	Pre-*Kharif*- Fallow *Kharif*- R Rice (rain-fed) *Rabi*- Mustard (Small scale) with low productivity	Pre-*Kharif*- Rice *Kharif*- Rice (rain-fed) *Rabi*- *Rabi*-vegetables (small scale) with low productivity
Land suitability constraints	Not suitable for Mustard and Pea due to limitation of wetness, texture & pH	Not suitable for Mustard and Pea due to limitation of wetness, texture & pH	Not suitable for Cabbage and Potato due to limitation of texture & pH
Alternate land use plan	Pre-*Kharif*- Fallow *Kharif*- Rice (var. *Ranjit, Masuri*) *Rabi*- Cabbage (*Var. Green express*) + Potato (*var. Kufri Jyoti*) with adoption of Shallow Tube Well-pump-set as microirrigation	Pre-*Kharif*- Fallow *Kharif*- Rice (var. *Ranjit, Masuri*) *Rabi*- Cabbage (*Var. Green express*) + Potato (*var. Kufri Jyoti*) in raised bedded furrows with adoption of Shallow Tube Well -pump-set as micro-irrigation	Pre-*Kharif*- Rice (var. *Luit*) *Kharif*- Rice (var. *Plaban, Jalkuwari*) *Rabi*- Mustard (*var. TS-38* + Pea (*var. Azad P1*) in raised bedded furrows with adoption of Shallow Tube Well-pump-set as micro-irrigation

Conclusions

Site specific Soil parameter-crop yield -data base correlation study proved to be superior over the classical approach of land suitability assessment for site specific crop planning in Upper Brahmaputra Valley agro-climatic zone in Assam. It was evident that pH and texture of surface soils are the determining soil parameters significantly controlling the yields of *Rabi*-crops. Soils of Deuri-A series are suitable for practicing Cabbage (*var. Green express*) and Potato (*var. Kufri Jyoti*) as *Rabi*-crops with adoption of shallow tube well-pump-set for micro-irrigation. Soils of sandy loam phase of Deuri-B series are suitable for the same in raised bedded furrows, whereas, soils of silt loam phase of Deuri-B series are suitable for cultivation of mustard and pea with similar agronomic measures. This study can be replicated in similar agro-climatic environment (under rain-fed system) with a scope to encourage further research on establishing soil-crop relationship.

References

Annual Report. (2012-13). ICAR-NBSS&LUP, Nagpur, Maharashtra.

Annual Report. (2013-14). ICAR-NBSS&LUP, Nagpur, Maharashtra.

Bandyopadhyay, S., Reza, S.K., Baruah, U and Sarkar, D. (2014). District Level Land Use Plan for Jorhat District, Assam under Rainfed Ecosystem. *Report No. 1077*, NBSS&LUP, Nagpur, pp.47.

Barah, B.C. (2001). North Eastern India: Strategies for agricultural development- An Overview. National Centre for Agricultural Economics and Policy Research, New Delhi.

Baruah, U., Bandyopadhyay, S. and Reza, S.K. (2014). Land use planning and its strategic measures in the context of North Eastern Regions of India. *Agropedology* **24(2)**, 292-303.

Bhowmick, B.C., Sarma, A.K., Talukdar, T.C. (1999). Farming systems in Assam. Department of Agricultural Economics, Assam Agricultural University, Jorhat.

Black, C.A., Evans, D.D., Ensminger, L.E., White, J.L. and Clarke, F.E. (1965). Methods of Soil Analysis. Part-I. American Society of Agronomy, Madison, Wisconsin, pp 909-913.

FAO. (1996). The State of Food and Agriculture. Food and Agriculture Organization of the United Nations. Rome, Italy.

Fertilizer association of Newzealand. http://www.fertiliser.org.nz. Copyright Fertiliser Association, 2012.

Handbook of Agriculture. (2009). Indian Council of Agricultural Research, New Delhi.

IARI. (1971). Soil Survey Manual. All India Soil and Land Use Survey, New Delhi.

Jackson, M.L. (1973). Soil Chemical Analysis, Prentice Hal Publication, New Delhi.

Lakshmanan, S. (2007). Yield gaps in mulberry sericulture in Karnataka: An econometric analysis, Indian Journal of Agricultural Economics 62(4), 623-636.

Nirmala, B., Muthuraman, P., Shaik, N.M. and Mangal Sain. (2009). Yield gap analysis of rice in Raichur district of Karnataka. Karnataka *Journal of Agricultural Sciences*, **22(1)**, 238-239.

NRAA. (2012). Prioritization of Rainfed Areas in India. National Rain-fed Area Authority, Planning Commission, Govt. of India, New Delhi

Soil Survey Staff. (2003). *Soil Taxonomy* - A Basic System of Soil Classification for Making and Interpreting Soil Surveys. 3rd Edition, Agricultural Handbook No. 436, USDA, Washington, DC.

Sparks, D.L. (1996). In Methods of Soil Analysis, Part-III: Chemical Methods, SSSA Book Series No. 5, Madison, Wisconsin.

Sys, C., Van Ranst, E. and Debaveye. J. (1991). Land Evaluation, Part-II. Methods in land evaluations, Agricultural Publication No. 7, Brussels, Belgium.

Sys, C., Van Ranst, E., Debaveye. Ir.J. and Beernaert, F. (1993). Land Evaluation, Part-III. Crop Requirements, Agricultural Publication No. 7, Brussels, Belgium.

Vadivelu, S., Baruah, U., Bhaskar, B.P., Mandal, C., Sarkar, D., Walia, C.S. and Gajbhiye, K.S. (2004). Soil Resource Atlas, Jorhat District (Assam), NBSS Publ. 107, NBSS & LUP (ICAR), Nagpur, pp 10-33.

Vadivelu, S., Sen, T.K., Bhaskar, B.P., Baruah, U., Sarkar, D., Maji, A.K. and Gajbhiye, K.S. (2004). Soil Series of Assam, NBSS Publ. 101, NBSS & LUP (ICAR), Nagpur, pp 68-108.

Velayutham, M., Mandal, D.K., Mandal, C. and Sehgal, J.L. (1999). Agro-ecological Sub Regions of India for Planning and Development, NBSS Publ. 35, NBSS & LUP (ICAR), Nagpur, p 269.

Received : June, 2015 Accepted : August, 2015