Probe - Water Conservation and Sustainability

GIS-Based Comparative Land Suitability Analysis in Sub-Sahara Africa

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Abstract: Land use conflict has been observed between maize vs., banana in Southern Rift Valley of Ethiopia since two to three decades past. Thus, this study was aimed at analyzing physical suitability of land for maize and banana upon six land parameters. Data of the parameters were acquired through laboratory test and field measure, and "interpolation" using GIS. Overlay analysis was made using the "weighing and scoring" technique to decide overall suitability of land for both land uses separately. Result of the study revealed that 47.1% (521.74ha) of Lante Alluvial Fan was "highly suitable" for banana farming; but, only 23.6% (261.63ha) of the area was "highly suitable" for maize cultivation. Deficiency of N and poor drainage were key threats on the suitability of land for maize and banana. So, farmers should integrate application of organic and inorganic fertilizers, and drain poorly drained-plots so as to surmount the productivity bottlenecks of land for both crops.

Keywords: *suitability, maize, banana, interpolation, weighing and scoring, Lante Alluvial Fan, etc.*

1. Background and Statement of the Problem

Land evaluation is an assessment of landscape, soil, climate, etc., attributes of land in order to compare promising kinds of land uses, and identify the best use (FAO, 2007). Land evaluation could be initiated by LULC change as land use dynamics may result in positive, negative or both consequences (Turner and Meyer, 1994). However, most LULC alterations, in Ethiopia, often result in adverse effects such as soil degradation, climatic variability, increasing soil loss rate, declining land productivity, destruction of habitat, loss of biodiversity (Belay, 2002; Wondamlak, 2002; Hurni et al., 2005; Lemenih et al., 2005; Meles et al*.,* 2008; Binyam, 2015; Zewdu et al., 2014), etc. This in turn threatens food availability and food security of people in the country. Land use change is also common in the lowland areas like Lante Alluvial Fan, Southern Ethiopia, where subsistence (e.g. maize…) and cash (e.g., cotton …) croplands have been replaced by smallholder market-oriented banana farming (Abren and Daniel, 2007) - which is a manifestation of land use conflict between competing uses (i.e. maize vs., banana) (FAO, 2007).

Land suitability evaluation-based use of land for crop farming is valuable in many ways (Hurni, 2000; Briza et al., 2001; Henok, 2010; Al-Mashreki et al., 2011; Kassa and Mulu, 2012). That is, the result from the evaluation is useful for recognizing productive potential of croplands (Henok, 2010; Al-Mashreki et al., 2011), identifying yield limitations of farm-plots (Briza et al., 2001; Kassa and Mulu, 2012), devising sustainable land management options (Hurni, 2000; Kassa and Mulu, 2012), improving yield and mitigating food insecurity problem (Abera, 2014). For instance, Al-Mashreki et al. (2011) showed that over 3/4th (61%) of the land was "highly to marginally" suitable for sorghum in Ibb area of Yemen; Henok (2010) also revealed that over 4/5th (85%) and nearly 2/3rd (65%) of the land in Legambo Woreda (District) of Ethiopia was "highly to marginally" suitable for wheat and maize farming, respectively. Attributes such as lime content, slope gradient (Briza et al., 2001), soil pH, effective soil depth, texture, CEC, organic matter, etc., (Kassa and Mulu, 2012) were the most limiting factors of land suitability for crop farming. But, these limiting factors could not be equally significant in impacting land suitability everywhere globally. Land evaluation is more urgent to the Sub-Sahara nations of Africa, like Ethiopia, where food insecurity problem is still challenging and exploitation of land is traditional (i.e., without concrete evidences about the best land uses) (Abren and Daniel, 2007).

Land use changes could originate from suitability differences upon physical land use requirements or economic returns or both between specific land uses (FAO, 1983; FAO, 2007). In Lante Alluvia Fan, although perennials (e.g. banana, mango) have progressively been expanding at the cost of maize-dominated land uses, the physical land suitability was not evaluated for maize, banana, etc. This requires suitability evaluation for these and other land uses (FAO, 1984; FAO, 2007), which would be useful for decisions about specific land use choices, and for the judgment about sustainability of the ongoing land use change (FAO, 2007) in the area. This study was targeted to: (1) analyze suitability of Lannte Alluvial Fan for maize and banana cultivation upon selected land attributes; (2) compare level of land suitability between the land use types accounted in the evaluation, and (3) identify crucial productivity threats (limiting factors) on both land uses.

2. Study Area and Research Methods

2.1 Description of Study Area

Lante Kebele Peasant Administration (KPA), an alluvial fan, is found in Arba Minch Zuria District, in the Rift Valley of Southern Ethiopia. It is located within 06^0 07' 23" - 06^0 08'44'' N latitude, and 37^{0}37'85" - 37^{0}40'23" E longitude. It is situated in low-lying, tropical area of Ethiopia. High temperature and scanty rainfall characterizes the climate of the area. Based on the records of the nearby station (Arba Minch University), which has similar elevation (1196 m a.s.l.) and is 8 - 10 km away from Lante, the mean annual temperature is 24^0 C and total annual rainfall is 883.7 mm (MAE, 2016). That is, the area could be categorized under semi-arid, *kola* (tropical) climate.

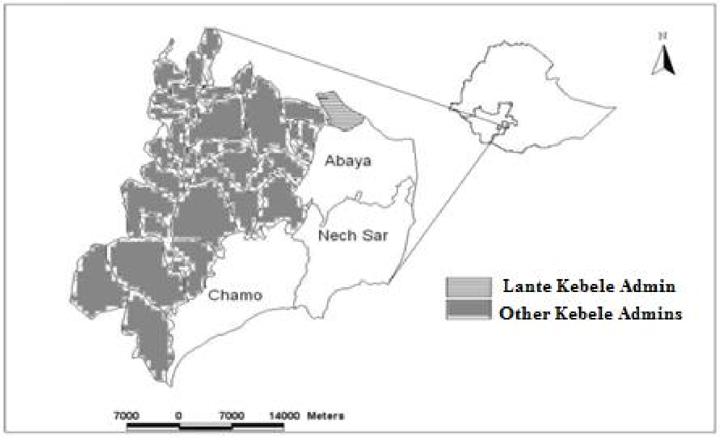


Figure 2.1: Location of study area (Source: Own Design upon Ethio-GIS, 2016)

Soils of Lante alluvial fan are results of the parent matter (rock), topography and climate. Run-on, stream and lake deposits of sediments are parent materials of the soils. In fact, the area is dominated by quaternary deposits (EMA, 1981). Deep soils (>200 cm), dark-brown soils (away from Lake Abaya), black soils (nearby the lake), slightly alkaline (pH = 7.06 - 8.06), rich available P (15.8 – 36.2 ppm) and exchangeable K (0.72 – 3.59 me/100g), deficient total N, and poor drainage are features of the soils in the area. In general, soils of Lante alluvial fan are mainly calcaric fluvisols (EMA, 1981).

2.2 Research Methods

2.2.1 Evaluation Approach, Assumptions, Selection of Attributes and Justification

A "qualitative, physical suitability analysis" is the kind of suitability evaluation approach followed by this study. Land evaluation can be made using either "parametric method" or "limiting factor" (FAO, 2007). But, the parametric method was used in this study. Land suitability evaluation was conducted upon the assumption that land is exploited by smallholder farmers, under traditional farming system with low application of farm inputs. It is also assumed that evaluation was made for maize which is grown within 120 – 150 days (April – August) in Lante alluvial fan, and for banana - a perennial crop. The evaluation was initiated from replacement of maize by banana farming at 4.76% annually (Abren and Daniel, 2007), which indicates a conflict between competing land uses in the area.

"Physical land suitability evaluation" was made based on some key soil-related attributes; this is because: (**a**) It was not essential to incorporate topographic attributes (e.g. slope gradient) as Lante alluvial fan is largely plain where its elevation is 1153 – 1225m; (**b**) Climate variables (temperature, rainfall, etc.) were assumed to bring little suitability difference between maize vs., banana due to limited altitudinal variation as stated in N0 "a," small study area (1107.75ha) and also due to the use of irrigation for crop cultivation by farmers; and (**c**) As a tradition, greater weight is often given to soil-related land attributes in physical suitability evaluation (FAO, 1984). Hence, attributes such as Nitrogen (N), Phosphorous (P), Potassium (K), soil pH, Depth to the occurrence of mottles (Dm) and Depth of Ground Water Table (Dgwt) were used for evaluation.

2.2.2 Data Sources, Procedures of Acquisition, and Sampling Design

Soil data about total N, available P, exchangeable K, and soil pH were acquired using laboratory test of soil samples. Field measurements were conducted to gather data about depth of mottles (Dm) (i.e. an indicator of oxygen unavailability in the soil) and Dgwt (i.e. an indicator of workability and salinity of soil, de-nitrification and retarded organic matter decomposition) (London, 1991). FAO guidelines and other manuals, and GIS were also used to generate data for the study.

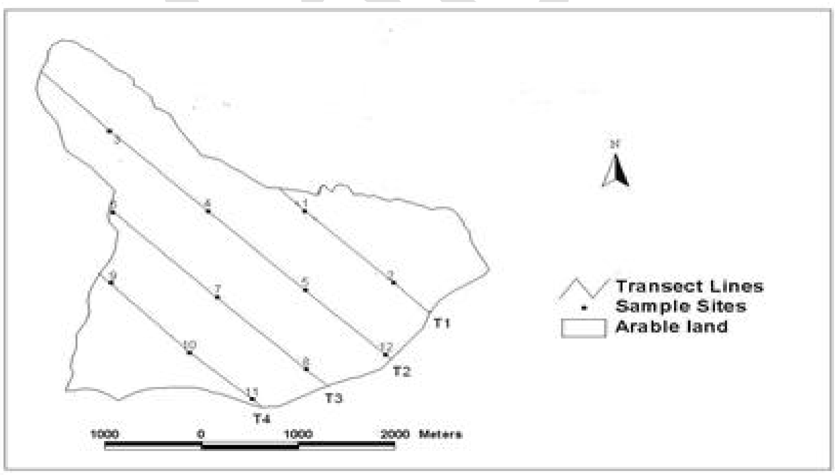


Figure 2.2: Soil Sampling Design, Lante Alluvial Fan (**Source**: Own Design using Arc GIS 9.3)

The topo-sheet of 1:50,000 was digitized to acquire base-map of Lante using Arc GIS (9.3). About 12 sample sites were identified using systematic sampling at 1km interval along four (4) lines of transect walk (Figure 2.2). Soil samples (1kg each) were acquired from the upper 100cm soil depth using "composite" sampling - each was a mixture of 3 auger soil samples taken from depth of 1-33, 34-66 and 67-99cm. The 100cm depth is the optimum nutrient and moisture adsorption zone for maize and banana (FAO, 1983). Since Lante area was 1107.75ha, one sample was used to represent 92.3ha - which enables inference at semi-detail level of evaluation (FAO, 1984; Deckers et al., 2001).

2.2.3 Methods of Data Analysis

Database was developed with reference to the 12 sample points for Lante Alluvial Fan. I.e., data of the six attributes (N, P, K, pH, Dm, and Dgwt) were entered into the GIS and displayed on the base-map (Figure 2.2). Surface data were generated from point data for the six attributes using the Inverse Distance Weight (IDW) "interpolation" technique. Upon each of the six land characteristics, levels of land suitability of maize and banana were classified using criterions set in Tables 2.1 and 2.2.

Table 2.1 Criteria of Land Suitability Classification for Maize

N0	Land Use Requirements	Suitability Class			
		S1	S2	S3	N
1	Nitrogen-N (%)	> 0.4	0.1-0.4	0.03-0.1	< 0.03
2	Available P (ppm) – Olsen	> 15	8-15	5-8	< 5
3	Exchangeable K (me/100 g)	> 0.4	0.1-0.4	0.02-0.1	< 0.02
4	Soil pH	6.0 – 6.7	5.5-6.0 & 6.7-7.5	5.0-5.5 & 7.5-8.0	< 5.0 & > 8.0
5	Depth to Mottling (cm)	>100	75-100	50-75	< 50
6	Ground Water Table (cm)	> 150	110-150	75-110	< 75

Source: Own design upon FAO (1983, 1984); London (1991)

Level of significance of each attribute was determined for each crop according to its level of requirement for overlay suitability analysis. In Figure 2.3, the "weighing and scoring" expressed as 2, 3, 4 …, indicate the "estimated/or assumed level of significance" of each variable in influencing the yield of maize and banana. The estimation was made upon literature on crop-environment requirement manuals (FAO, 1983; FAO, 1984; London, 1991). Here, numerical values 2, 3, and 4 are assumed to represent "low," "moderate" and "high" level of significance of the attributes, respectively, for production of the crops. For e.g., the weight given to N for evaluating maize was 4 and banana was also 4 since both maize and banana require "high" level of N for optimum yield. Upon phosphorous requirement, while the level of significance of P for maize was estimated at 2, the weight given to this nutrient for banana was 3; this decision was made because, maize requires "low" P supply but banana needs "moderate" level of P in the soil (Figure 2.3). Significance level of the other variables was decided upon similar procedure.

Table 2.2 Criteria of Land Suitability Classification for Banana

N0	Land Use Requirement	Suitability Class			
		S1	**S2**	**S3**	**N**
1	Nitrogen (%)	> 0.4	0.1-0.4	0.05-0.1	< 0.05
2	Available P (ppm) – Olsen	> 20	15-20	8-15	< 8
3	Exchangeable K (me/100 g)	> 0.8	0.4-0.8	0.1-0.4	< 0.1
4	pH	6.0-7.5	5.5-6.0 & 7.5-8.0	5.0-5.5 & 8.0-8.5	< 5.0 & > 8.5
5	Depth to Mottling (cm)	>110	85-110	60-85	< 60
6	Ground Water Table (cm)	> 150	125-150	100-125	< 100

Source: Own design upon FAO (1983, 1984); London (1991)

Overlay analysis was run for maize and banana separately upon "weighing and scoring" technique; and reclassification was run to evaluate the degree of suitability of land for maize and banana farming in Lante alluvial fan. That is, land was rated as Highly Suitable (HS/S1), Moderately Suitable (MS/S2), Marginally Suitable (MrS/S3), and/or Not Suitable (NS/N) for both crops. Results were analyzed using percent, and interpretations and discussions were made about land suitability of both land uses.

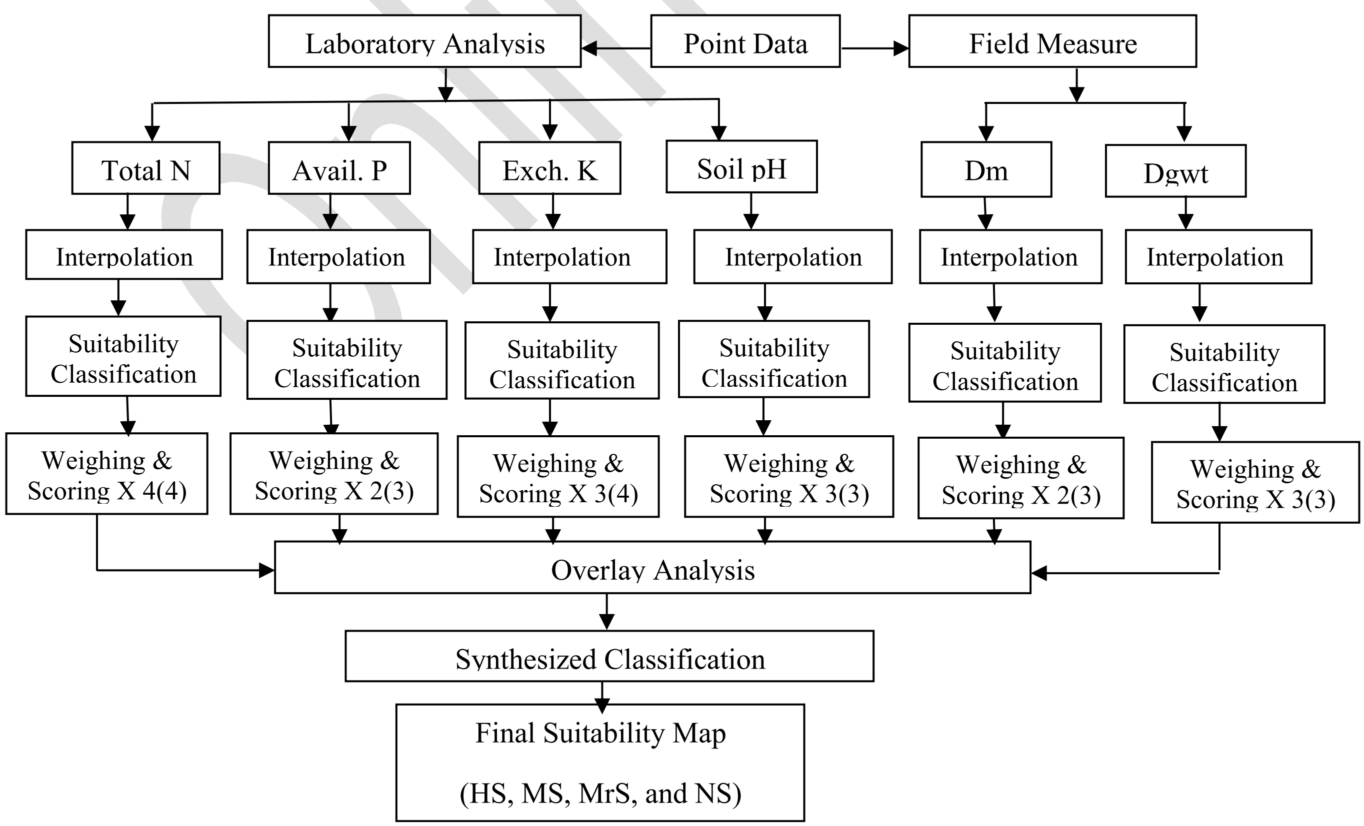


Figure 2.3 Own Design of the GIS based Suitability Evaluation of Lante Area for Maize and Banana Farming (2016) ***(Notice: Values out of the brackets represent estimated level of significance of each attribute used for maize suitability rating; but, values within the brackets are those used for banana suitability rating)***

3. Results and Discussion

3.1 Land Suitability for Maize Vs., Banana Cropping upon Selected Land Attributes:

Here, presentation and discussion of results was made with emphasis on similarities and differences in degree of land suitability between maize and banana upon requirements of total N (%), available P (ppm), exchangeable K (me/100g), soil pH, depth of mottles (cm) and GWT (cm).

3.1.1 Level of Land Suitability for Maize vs., Banana upon Total Nitrogen (N) Supply

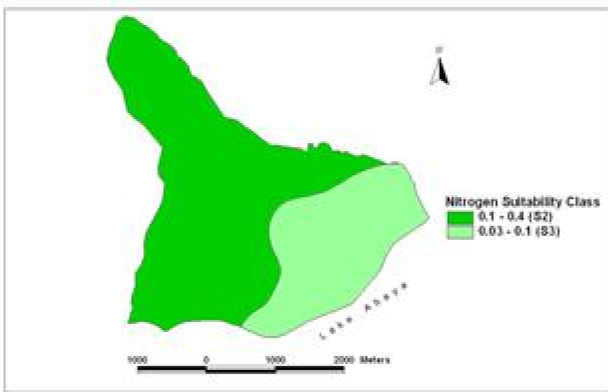
The optimum production of maize and banana requires high to very high level of total nitrogen in the soil (FAO, 1983; Landon, 1991). Nitrogen is significant for the growth of the green pigment, chlorophyll, in plants which is a base for the process of photosynthesis (Glendenning, 2000). However, deficiency of nitrogen characterizes soils of Lante alluvial fan, where total N in soil was 0.06 - 0.32%. Level of N was low to very low in 76.47% (847.13ha) of the study area (Table 1, Appendix). Total N was rated "very high," "high," "moderate," "low," and "very low" if its supply in the soil is ≥ 1.0, 0.5 – 1.0, 0.2 – 0.5, 0.1 – 0.2 and < 0.1 percent, respectively (Landon, 1991).

Table 3.1 Suitability of Land for Maize and Banana upon N (%) and P (ppm) Supply, Lante Area

Suitability Class	Total Nitrogen (%)				Available P (ppm)			
	Maize		Banana		Maize		Banana	
	Area (ha)	P (%)	Area (ha)	P (%)	Area (ha)	P (%)	Area (ha)	P (%)
S1	0	0.0	0	0.0	1107.75	100	905.38	81.73
S2	752.42	67.92	752.42	67.92	0	0.0	202.35	18.27
S3	355.34	32.08	355.34	32.08	0	0.0	0	0.0
NS	0	0.0	0	0.0	0	0.0	0	0.0
Total	**1107.75**	**100.0**	**1107.75**	**100.0**	**1107.75**	**100.0**	**1107.75**	**100.0**

Source: *Computed by the author*, 2016 (**Notice**: NS = Not Suitable)

As it is shown in Table 3.1, about 67.92% of Lante Alluvial Fan was moderately suitable (S2) and 32.08% was marginally suitable (S3) for maize cultivation. The same proportions of the area were "moderately" (67.92) and "marginally" (32.08%) suitable for banana production. This implies that there was no suitability difference between the two crops upon requirement of this nutrient in the area (Figures 3.1 & 3.2). Total nitrogen supply decreases from the northwest towards the southeast (Lake Abaya) direction (Figures 3.1 & 3.2). That is why part of the area classified under the "marginal suitability" class is situated adjacent to the lake for both land uses. The low nitrogen supply in plots around Abaya Lake could be due to denitrification and sluggish rate of mineralization underlain by poor drainage. I.e., total nitrogen was very low where the depth to mottling and GWT was too shallow. The poor drainage in plots nearby the lake should have favored denitrfication (by hindering aeration), a process by which nitrate and nitrite are reduced to form nitrous oxide and molecular nitrogen as anaerobic bacteria use the oxygen component of nitrates (Olaintan et al., 1984).



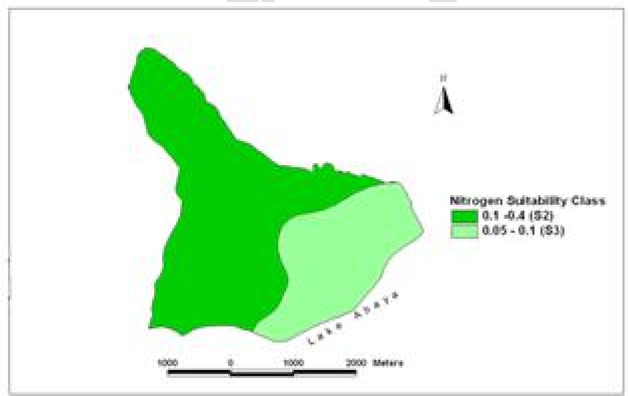


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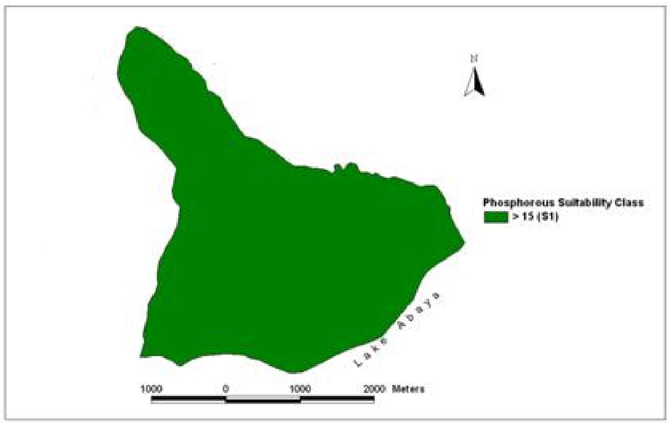
Figure 3.1 Suitability of N for Maize Growth **Figure 3.2 Suitability of N for Banana Growth**

Inadequate aeration (owing to water logging) inhibits micro biological activities such as decomposition of organic matter in the soil, which retards mineralization process (i.e. buildup of nitrate and ammonia). This is because; almost 95 - 99% of the total nitrogen in the soil might be derived from organic matter (Glendenning, 2000). That is why the total nitrogen was as low as 0.06% for sample sites 11 and 12 (Figure 2.2 above), which were gathered around Abaya Lake.

3.1.2 Level of Land Suitability for Maize vs., Banana upon Available Phosphorous (P) Supply

Lante Alluvial Fan was rich in available P. Available P was high to very high (20.00 - 36.20 ppm) in 69.57% of the area; its supply was relatively smaller in 30.43% (15.80 - 20.90 ppm) of the land (Table 1, Appendix). Available P is rated "high," "medium," and "low" if its supply is > 15, 5 – 15 and < 5 ppm, respectively (Landon, 1991). The rich available P should have evolved from the rare fixation of the nutrient owing to medium pH (7.06-8.06) and the low-lying, plain nature of the area favoring deposition to exceed erosion. About 100% of Lante area was "highly suitable" for maize farming; but, 81.73 and 18.27% of the area was rated "highly suitable" and "moderately suitable" for banana, respectively (Table 3.1; Figure 3.3 & 3.4). Maize is among the crops that require relatively low level of available P. Available P is adequate for optimum production of maize if its value, tested using Olsen's method, is > 8 ppm (London, 1991). Available P, in the alluvial fan, was ≥ 15.8 ppm. That is why 100% of the area was highly suitable for maize. Yerima (1993), upon interpretation of Ethiopian soils, recommends no P fertilizer for maize farming where available P is > 10 ppm.



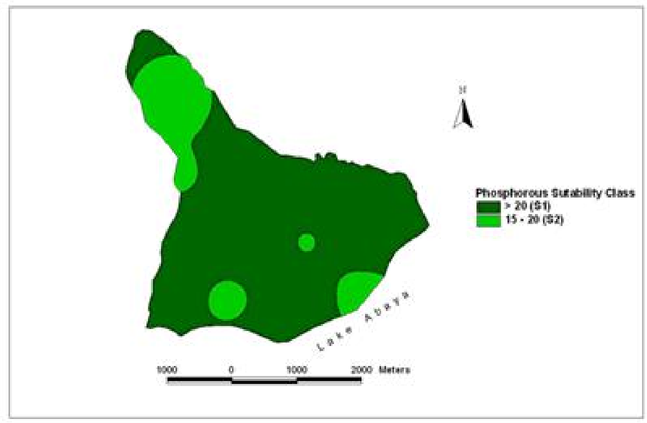


Figure 3.3 Suitability of P for maize Growth **Figure 3.4 Suitability of P for Banana Growth**

Unlike maize, banana requires relatively moderate level of available P. Thus, nearly one-fifth (18.27%) of Lante area was rated "moderately suitable" for banana production. The response to P fertilizer, in general, is unlikely where the available P is > 15 ppm and the soil pH is 7.0 (FAO, 1983; Yerima, 1993; London, 1991). However, the level of adequacy for crops requiring relatively high level of available P, like banana, is > 20 ppm (London, 1991). Upon requirement of available P, Lante area was better suitable for maize growth than that of banana.

3.1.3 Level of Land Suitability for Maize vs., Banana upon Exchangeable Potassium (K) Supply

High to very high exchangeable K characterizes soils of Lante alluvial fan. The exchangeable K was "very high" in 3/4th (75.02%) of the area where its supply was 1.44 – 3.59 me/100g; and it was "high to very high" (0.72 - 1.44 me/100g) in 24.98% of the area (Table 1, Appendix). The level is "high" if the exchangeable K is 0.4 - 0.8 me/100 g and "very high" if it exceeds 0.8 me/100 g (London, 1991).

Table 3.2 Suitability of Land for Maize and Banana upon Exchangeable K (me/100g) and Soil pH, Lante

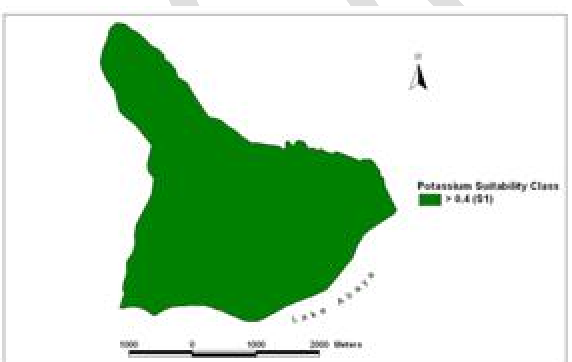
Suitability	Exchangeable K (me/100g)	Soil pH

	Maize		Banana		Maize		Banana	
	Area (ha)	**P (%)**	**Area (ha)**	**P (%)**	**Area (ha)**	**P (%)**	**Area (ha)**	**P (%)**
S1	1107.75	100	1104.30	99.69	0	0.0	281.56	25.42
S2	0	0.0	3.45	0.31	281.56	25.42	809.95	73.12
S3	0	0.0	0	0.0	809.95	73.11	16.25	1.46
N	0	0.0	0	0.0	16.25	1.47	0	0.0
Total	**1107.75**	**100.0**	**1107.75**	**100.0**	**1107.75**	**100.0**	**1107.75**	**100.0**

Source: *Computed by the author, 2016*

It is argued that, compared to the other primary nutrients, exchangeable K supply is high for soils derived from volcanic materials. Moreover, since K, as a basic cation, is soluble in water, its supply should inevitably be very high in low-lying areas like Lante Alluvial Fan. The tendency for K fixation is minimal where vermiculite and illite clay minerals are limited (Olaitan et al., 1984). Maize requires moderate to high level of potassium but the requirement level of banana on this primary nutrient is high. While 100% of the land was "highly suitable" for maize production, about 99.69% and 0.31% of the area was "highly suitable" and "moderately suitable" for banana farming, respectively (Table 3.2).

Maize requires medium to high level of exchangeable K. Based on exchangeable K requirement, the whole Lante area was rated "highly suitable" for maize cropping (Figure 3.5). I.e., the area has no significant limitation in terms of K supply to reduce the productivity of maize. The minimum level of exchangeable K, in the alluvial fan, was 0.72 me/100 g (sample #11, 3rd transect). FAO (1984) suggested that a land unit should be rated "highly suitable" for maize if supply of exchangeable K exceeds 0.4 me/100 g. Besides, upon experience from Ethiopian soils, it was suggested that maize requires no potassium fertilizer if the available form of the nutrient is > 30 ppm (Yerima, 1993). This value is by far < the minimum level of exchangeable K in the study area, which was 285.52 ppm/100 g.



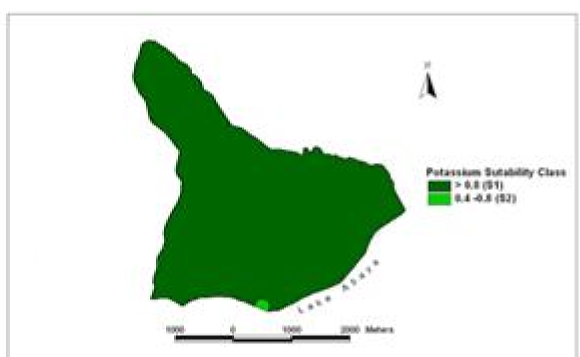
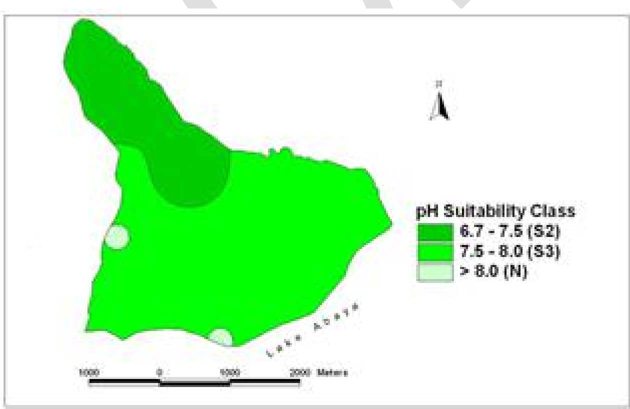


Figure 3.5 Suitability of K for Maize Growth **Figure 3.6 Suitability of K for Banana Growth**

Compared to maize, banana requires higher exchangeable K in the soil. The lion's share of the study site was rated "highly suitable" for banana farming upon exchangeable K supply (Figure 3.6). The spatial distribution of exchangeable K, to a lesser extent, matches with that of total nitrogen, where it decreases from the west and north to the southeast direction. That is why insignificant proportion of the area (0.31%), nearby the coast of Lake Abaya, was rated "moderately suitable" for banana farming (Figure 3.6). London (1991) explained that banana needs high exchangeable K with adequacy level of 300 ppm, which is approximately 0.8 me/100 g. In general, result of the study revealed that, even if the variation was insignificant, the alluvial fan was better suitable for maize farming than banana.

3.1.4 Level of Land Suitability for Maize vs., Banana upon Soil pH

Soil pH is a measure of the acidity and alkalinity of soil (Glendenning, 2000). It describes the extent to which H^+ and OH^- ions are concentrated in the soil. Lante alluvial fan is characterized by slightly alkaline soils. Soil pH of the alluvial fan ranges within 7.06 - 8.06. In the broad classification by Glendenning (2000), soil pH in the study area fall almost within the "neutral" to "slightly alkaline" category (i.e. 7.0 - 8.0). About 27.94% of the land was endowed with neutral soils (i.e. pH = 6.5 – 7.5) (Tables 2 & 3, Appendix). That is, other things being equal, the pH shows the degree of availability or unavailability of essential plant nutrients in the soil. One of the main attributes of soil toxicity is the status of aluminum ion concentration in the exchangeable complex at low pH (FAO, 1984). Neutral soils are dominant in the northern part of Lante. Land nearby Abaya Lake and western edge of the area was characterized by slightly alkaline soils (pH = 7.81 - 8.06), which constituted 16.22% of the area. Alkalinity increases from the northwest to the southeast direction of the study area.



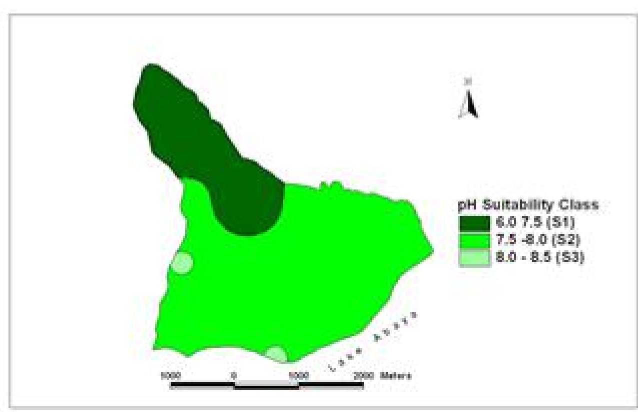


Figure 3.7 Suitability of pH for Maize Growth. Figure 3.8 Suitability of pH for Banana Farming

Based on the pH requirement of maize, while 25.42% of the land was rated "moderately suitable," about 73.11% was graded "marginally suitable" for maize cultivation. In the analysis, only insignificant proportion of the land fell under the "not suitable" class (Table 3.2 above). Whereas, about 25.42% and 73.12% of the land of Lante alluvial fan was rated "highly suitable" and "moderately suitable" for banana production, respectively. Soil reaction (pH) is a very important chemical property in influencing the productivity of all crops. That is, it determines soil productivity by controlling "nutrient availability" and "toxicity" (FAO, 1984). At low soil pH, for instance, Fe, Al, Mn, etc., supply becomes very high to the extent of making essential nutrients "unavailable" (e.g. phosphorous) and the soil toxic.

Difference in the pH requirement is the source of variation in the suitability of land between maize and banana. Maize and banana grow well on soils with pH values around neutrality. The difference is that, while the pH for the optimum maize production ranges 6.0 - 7.0, the ideal pH requirement of banana is 6.0 - 7.5 (FAO, 1983; London, 1991). Hence, a quarter (25.4% or 281.56ha) of the study area was rated "highly suitable" for banana. But, none of the area was highly suitable for maize cropping. Besides, the land rated in the "moderately suitable" (i.e. 809.95 ha) class of banana was only "marginally suitable" for the production of maize. Both crops can tolerate pH value ranging within 5.0 - 8.0; but, banana can tolerate pH value up to 8.5 (London, 1991). Therefore, upon status of soil pH, Lante alluvial fan is by far more suitable for the production of banana than maize.

3.1.5 Level of Land Suitability for Maize vs., Banana upon Soil Drainage Condition

Drainage affects crop yield by influencing circulation of moisture and air within the soil. It is measured by depth of mottles (indicators of unavailability of O_2 in the soil), and the Ground Water Table (GWT).

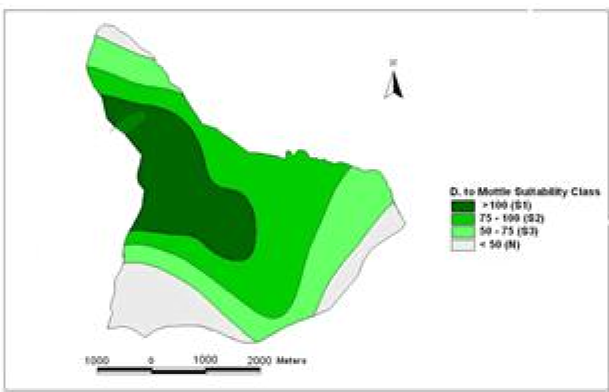
Table 3.3: Suitability of Land for Maize and Banana upon Depth of Mottles (Dm) and GWT

N0	Parameter	Suitability Class	Maize		Banana	
			Area (ha)	P (%)	Area (ha)	P (%)
I	Depth of Mottles	S1	261.63	23.62	147.38	13.27
		S2	391.33	35.33	351.86	31.76
		S3	265.39	23.96	326.24	29.45
		N	189.40	17.09	282.27	25.48

II	GWT	S1	585.44	52.85	585.44	52.85
		S2	151.60	13.69	93.38	8.43
		S3	147.46	13.31	98.57	8.90
		N	223.25	20.15	330.35	29.82

Source: *Computed by the author, 2016*

Poor drainage is a serious land use problem in Lante alluvial fan. 1/3rd of the sample sites (33.33%) revealed occurrence of "occasional mottles" at depth of 40 - 64cm (Table 3, Appendix); and for the same sample sites, the level of GWT was identified to rise to about 48 - 70 cm soil depth. In the rest of the inspection sites, the occurrence of the two attributes, at shallow depth, was insignificant. Upon data of mottles, 23.62%, 35.33%, 23.96% and 17.09% of the area was rated "highly suitable," "moderately suitable," "marginally suitable" and "not suitable" for maize farming, respectively (Table 3.3.).



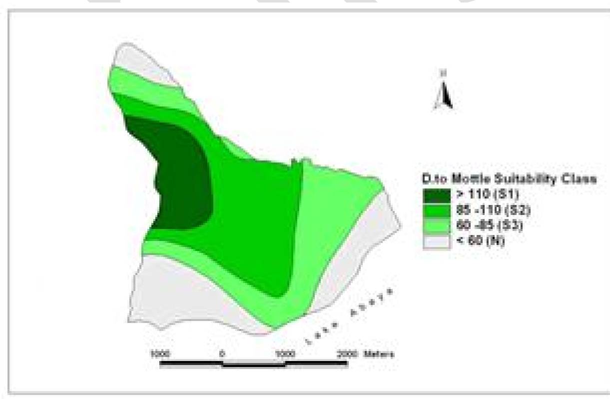
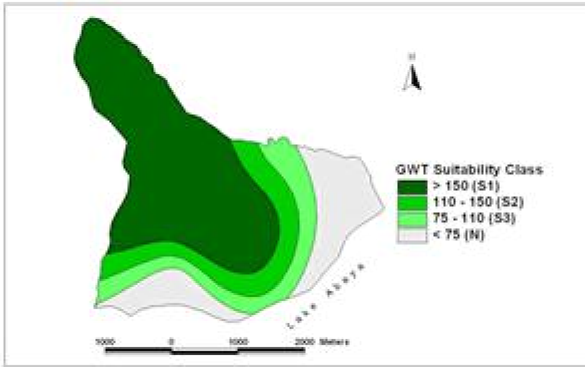


Figure 3.9 Suitability of Dm for Maize Growth: Figure 3.10 Suitability of Dm for Banana Growth

About 13.27% and 31.76% of Lante was "highly suitable" and "moderately suitable," respectively, for banana production; but, 25.48% of the land was "not suitable" for the fruit. Based on GWT requirement, while 20.15% and 29.82% of the area was "not suitable" for maize and banana, respectively, about 52.85% was "highly suitable" for both land uses (Table 3.3; Figures 3.11 & 3.12.). Significant part of Lante (adjacent to Abaya Lake) was hardly suitable for maize and banana farming due to occurrence of mottles and GWT at shallow depth (Figures 3.9, 3.10, 3.11 & 3.12). The optimum productivity of maize and banana requires well drained soils. But, the southern and southeastern part of the area was "marginally suitable" and "not suitable" for both crops due to poor drainage.



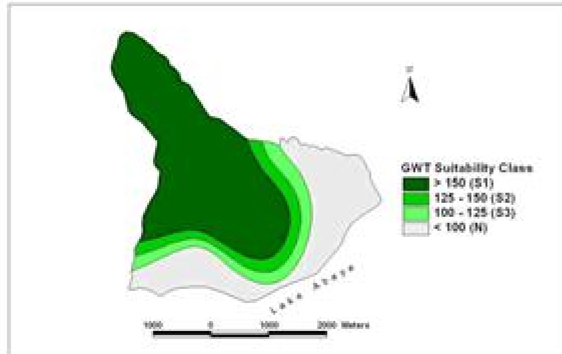


Figure 3.11 Suitability of GWT for Maize Growth. Figure 3.12 Suitability of GWT for Banana Growth

The drainage problem is not due to texture of the soil where it varies from light clay-loam-through loam to sandy-loam. Infiltration rate of these texture classes is 0.2 - 8cm/hour (Olaitan et al., 1984); this shows a medium to low level of moisture retention of soil with respect to texture. The key source of drainage problem, rather, is raise of GWT owning to land's proximity to Abaya Lake. This was also proved by HH (77.78%), who were victims of waterlogging problem in the area (Abren and Daniel, 2007).

3.2 The Overall Suitability of Land for Maize and Banana Production in Lante Area

All land attributes were overlaid to generate synthesized map and compare the land suitability of maize and banana. Result of the GIS-based land suitability analysis revealed that about 23.62%, 40.12%, 22.77% and 13.49% of Lante area was "highly suitable," "moderately suitable," "marginally suitable" and "not suitable" for maize farming, respectively.

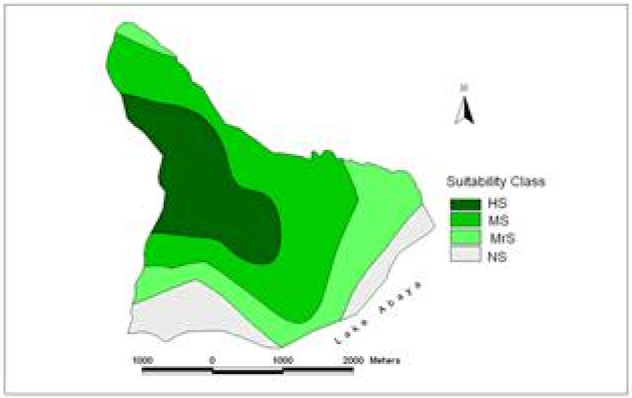
Table 3.4 Status of Land Suitability for Maize Vs., Banana Farming, Lante Area

N0	Suitability Class	Maize		Banana	
		Area (ha)	P (%)	Area (ha)	P (%)
1	HS	261.63	23.62	521.74	47.10
2	MS	444.42	40.12	230.68	20.83
3	MrS	252.23	22.77	315.75	28.50
4	NS	149.46	13.49	39.59	3.57

Source: Computed by the Author, 2016

While about 47.10% was "highly suitable," only about 3.57% was "not suitable" for banana production. Unlike banana, significant proportion of land was "moderately suitable" for maize. I.e., there was a great difference in level of land suitability between maize and banana land uses. Almost half (521.74 ha) of the land is highly suitable for banana, which was almost two fold of the same suitability class of maize.

Significant proportion of Lante Alluvial Fan was “not suitable” for maize cropping. The land in the “not suitable” category of maize was nearly 3.75 times larger than the same suitability class of banana.



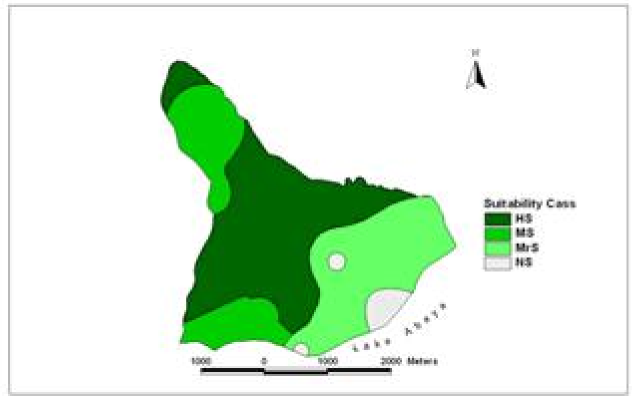


Figure 3.13 Overall Land Suitability for Maize; Figure 3.14 Overall Land Suitability for Banana

Part of the area rated “unsuitable” for both land uses is largely situated nearby Abaya Lake due to poor drainage - which was proved by the depth of mottling and GWT. Nitrogen deficiency is the other attribute hindering the suitability of land for both crops. The central part of Lante area is highly suitable for banana cropping. In general, the suitability of land for the cereal and the fruit cropping decreases from the northwest to the southeast direction (Figures 3.13 and 3.14). Anyway, the study area was better suitable for optimum production of banana than maize.

4. Conclusion and Management Options

Deficient nitrogen was a feature of the soils in Lante Alluvial Fan. Sluggish organic matter decomposition and redox reaction-induced denitrification were remarkable for depletion of N. Soils of the area were rich in available P and exchangeable K due to the “neutral to slightly alkaline” soils (minimizing fixation) and deposition of these soluble nutrients. Lante area revealed little suitability difference for maize and banana upon total N and exchangeable K requirements. Land is better suitable for maize farming upon the depth of mottles, GWT and status of available P; whereas, it was better suitable for banana production upon the requirement of soil pH, which have contributed the lion’s share of the suitability difference between the land-uses accounted for evaluation.

The southeastern part of Lante is dominated by imperfectly to poorly drained soils. The GWT is the proximate source of the drainage problem, where it is exacerbated by the relative position of the area nearby Abaya Lake. The problem severely threatens the productivity of land for both land uses. But, the impact of poor drainage is remarkably greater on banana than that of maize cropping. The cumulative suitability analysis showed that land is better suitable for the production of banana than maize. Thus, decision of farmers to shift from maize farming to the domestication of banana is appropriate as it coincides with the scientifically generated land use recommendation.

Some land use problems were recognized from findings of the study. Thus, land management options are pinpointed below for surmounting the problems: (a) Farmers should mulch their plots with the residue of banana and other organic matter sources so that the pool for the mineralization of nitrogen would be enriched and, hence, the nutrient supply would be improved. This should be done in all parts of the area even if N deficiency was more serious for plots adjacent to Abaya Lake. (b) It is advisable for farmers to integrate use of organic and inorganic fertilizers for sustainable productivity of land for banana. (c) Farmers, under the coordination of gov't bodies (experts), should drain water logged plots; meaning, gov't bodies have to mobilize households so that construction of draining canals would be feasible through the coordinated efforts of farmers holding adjacent farm-plots.

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Appendix:

Table 1: Share (%) of Land by Level of Total N, Available P and Exchangeable K, Lante Alluvial Fan

Total N (%)			Available P (ppm)			Exchangeable K (me/100g)		
Content	**Area (ha)**	**P (%)**	**Content**	**Area (ha)**	**P (%)**	**Content**	**Area (ha)**	**P (%)**
0.25-0.32	21.00	1.90	31.10-36.20	24.41	2.20	2.87 - 3.59	26.95	2.43
0.19-0.25	67.00	6.05	26.00-31.10	64.40	5.81	2.15 - 2.87	86.01	7.76
0.12-0.19	172.62	15.58	20.90-26.00	681.89	61.56	1.44 - 2.15	718.09	64.83
0.06-0.12	847.13	76.47	15.80-20.90	337.05	30.43	0.72 - 1.44	276.70	24.98
Total	**1107.75**	**100.00**	**Total**	**1107.75**	**100.00**	**Total**	**1107.75**	**100.00**

Source: *Computed by the author*, 2016

Table 2: Share (%) of Land by Depths of Mottles, GWT and pH in the Soil, Lante Alluvial Fan

Depth of Mottles (cm)			Level of GWT (cm)			Status of Soil pH		
Depth	**Area (ha)**	**P (%)**	**Depth**	**Area (ha)**	**P (%)**	**pH Level**	**Area (ha)**	**P (%)**
>150	125.15	11.30	>150	553.89	50.00	7.06 - 7.31	141.47	12.77
100-150	657.50	24.67	100-150	249.50	22.52	7.31 - 7.56	168.06	15.17
50-100	273.28	59.35	50-100	238.68	21.55	7.56 - 7.81	618.58	55.84
<50	51.82	4.68	<50	65.69	5.93	7.81 - 8.06	179.64	16.22
Total	**1107.75**	**100.00**	**Total**	**1107.75**	**100.00**	**Total**	**1107.75**	**100.0**

Source: *Computed by the author, 2016*

Table 3: Data Acquired through Laboratory Test of Soil Samples and Field Measurement

ID	Easting (X)	Northing (Y)	Altitude (m)	TN (%)	Avail. P (ppm)	Exch. K (me/100g)	Soil pH	Depth (cm)	
								Dm	**GWT**
1	350996	679004	1200	0.11	20.40	1.95	7.60	90	120
2	351910	678090	1174	0.09	24.40	0.81	7.93	64	70
3	348977	680023	1225	0.11	18.20	1.49	7.08	100	200
4	349998	679003	1205	0.11	21.80	1.31	7.06	100	200
5	350998	678002	1194	0.07	19.60	1.87	7.82	90	185
6	349010	678989	1214	0.11	17.60	1.94	7.64	200	200
7	350091	677910	1191	0.10	27.80	2.48	7.67	103	200
8	351008	676994	1181	0.07	25.20	2.09	7.72	80	120
9	348991	678089	1193	0.20	36.20	3.59	8.06	90	200

10	349801	677200	1181	0.32	17.40	0.83	7.67	42	55
11	350449	676615	1178	0.06	21.80	0.72	8.06	43	50
12	351825	677175	1177	0.06	15.80	1.02	7.79	40	48

Source: Own Survey, 2015/16 (Dm = Depth to the occurrence of mottles; GWT = Ground Water Table)

Table 4: Procedures Used for Soil Laboratory Analysis/Test

Attribute	Unit	Laboratory Procedure
Total nitrogen	%	Kjeldahl procedure
Available P	ppm	Olsen's (0.5 mole sodium bi-carbonate, pH 8.5) method
Exchangeable K	me/100 g	One (1) mole ammonium acetate (pH 7)
Soil pH	-	Potentiometer (using H_2O)

Source: Own Design upon London (1991); Glendenning (2000)