DISTRIBUTION OF SOME SELECTED SOIL PROPERTIES UNDER AGROFORESTRY AND AGRICULTURAL CROPS

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Abstract

Field and laboratory investigations were made to study the distribution of some soil properties under agro-forestry (Eucalyptus + wheat) and agricultural crops (wheat). Eighteen soil samples were collected at a regular grid spacing of 15 m x 25 m and 15 m x 20 m from two depths (0-15, 15-45 cm) under agro-forestry and agricultural crops, respectively from D.I.Khan. Soil samples collected were analyzed for soil pH (1:5), electrical conductivity (1:5), organic matter, lime, mineral N, and AB-DTPA extractable P and K. The total number of plants were 410 in agro-forestry field and were about 5 years old. Data collected on soil properties were statistically analyzed. In the field of agro-forestry, the percent co-efficient of variation (% CV) for EC (1:5) and P were 57.4 and 35.2 for surface soil and 49.8 and 72.7% for sub soil, respectively. Based on critical level for soil P, all the soil samples in both the depths were deficient, except one sample which was medium in subsoil. About 83% in the surface soil and 94% in the subsoil of the samples were found low (<1%) in organic matter. Soil K was found in adequate amount with low variability having CV=6.81% and 6.43% in surface and sub-surface soil, respectively. In the field of agricultural crops (wheat) the CV values for EC and P were 34.9 and 49.98% for surface and 32.02 and 29.48% for sub soil, respectively. Based on critical level, soil P was deficient in 27%, medium in 40% in surface soil while deficient in all the sub soil samples. Variation was also observed in mineral N (25.4 and 31.13%) organic matter (22.57 and 25.61%) in both the depths and in subsoil K (21.41%). Twenty eight percent samples were deficient, 72% medium in organic matter in the surface soil and 94% were deficient in the subsoil. In the surface soil, organic matter, mineral N and soil P were significantly ($P<0.01$) lower under agro-forestry than under agricultural crops because eucalyptus is evergreen and shed little leaves and also utilize the soil nutrients. In the subsoil, soil pH, EC, soil P and K significantly differed between the two systems. Geostatistical analysis of data showed that EC and soil P were spatially distributed in the surface soil while only EC in subsoil under agro-forestry. While organic matter and mineral N in the surface soil and EC, organic matter, lime and soil P in the subsoil were spatially distributed under agricultural crops. Maps of soil properties were prepared using geostatistical technique of kriging. Almost all of the maps showed spatial distribution of soil properties.

Introduction

Due to high land pressure because of increased population rate in Pakistan, there is a continuous process of land degradation. Land degradation is the result of

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accelerated soil erosion or salinity/sodicity problem. Quality land has been converted into poor quality land i.e., marginal lands.

The need for agricultural land to feed growing populations makes it unlikely that high quality land will be used for planting trees. There are several options for increasing the production of fuel and fodder - for example improving cultural practices in existing forests, growing forest trees with other crops (agroforestry), range management, and utilizing marginal lands.

Tree plantation activities under Social Forestry Project have been enhanced in various irrigated arid zones. Different plant species have been introduced in these areas. Trees are planted by individual farmers in agroforestry setting along roads or field boundaries, in small areas or with agricultural crops. Trees might have profound effect on soil properties. In forest ecosystems individual trees and different species of trees affect the chemical properties of that soil in the vicinity. Some of the researchers have reported the effects of tree plantations on soil properties. (Varma et al., 1986).

Some tree species like Eucalyptus can also be grown on salt affected soils (Malik and Sheikh, 1983; Muthana et al., 1983). There has been a lot of research on the reclamation and utilization of slat affected soil using different practices including use of gypsum (Bhatti and Nawaz. 1983; Bhatti and Bakhsh, 1995). Eucalyptus trees are reported to have deteriorating effect on soil properties, while Bargali et al. (1993) compared properties of the top 30 cm soil under plantation of 1 to 8 year old *Eucalyptus tereticornis* and in adjacent natural mixed broad leaved forest in the subtropical zone in Uttar Pardesh. Several soil physical properties (water holding capacity, porosity and water content) decreased with increasing age, while bulk density increased; soil chemical properties, notably organic carbon, total N, P and K decreased as a result of reforestation with *Eucalyptus tereticornis* and further decreased with increasing age of the plantation.

Very limited or no research work has been done on analysis of agroforestry systems such as nutrient accumulation, nutrient cycling and other soil chemical properties. Moreover, the economics of agroforestry has not been compared with the other land use systems in addition to their effects on soil properties.

The present project was undertaken to compare the distribution of various soil properties under agroforestry and agricultural crops.

Materials and Methods

Site Selection

To compare the distribution of some soil properties under two farming systems (agro-forestry and agricultural crops), one field each under agro-forestry and agricultural crops was selected at Rodikhel, located 29 km away from Dera Ismail Khan on D.I.Khan-Bannu road. Tree species, *Eucalyptus camaldulensis* was used for these studies. The soil according to soil survey belongs to Tikken upland association (Typic torriorthents).

Soil Sampling

Selected fields were intensively sampled on a regular grid spacing of 15 m x 25 m and 15 m x 20 m under agro-forestry (0.675 ha) and agricultural crops (0.54 ha), respectively depending on the size of the field. Soil samples were collected at two depths i.e. 0-15 cm (surface soil) and 15-45 cm (subsoil) at 18 locations from each field. At each location, three soil cores at each depth were used within a circle of 5 m radius and mixed thoroughly to get a composite sample. Soil samples from both fields were collected after harvesting of wheat crop.

Laboratory procedures

Soil samples collected were brought to the laboratory of Soil and Environmental Sciences Department, NWFP Agricultural University, Peshawar and airdried, crushed, sieved (<2mm) and stored for various soil analysis. The soil samples collected were analysed for soil pH (Mclean, 1982), electrical conductivity (Richards, 1954), lime content by acid neutralization method (Nelson, 1982), organic matter (Nelson and Sommers, 1982), total mineral nitrogen (Keeney and Nelson, 1982) and AB-DTPA extractable P and K (Olsen and Sommers, 1982).

Statistical Procedures

Data collected on different soil properties were subjected to statistical analysis for calculating descriptive statistics for both the land use system and for each depth according to the procedures given by Steel and Torrie (1980).

Soil properties under agro-forestry and crops agricultural were compared with each other using t-test of significance for each depth separately.

Geostatistical analysis

Semivariograms of soil properties (Bhatti et al., 1991). were developed to determine the structure and magnitude of spatial patterns in various measured soil properties. Semivariance, γ(h), as a function of separation distance (lag, h) was computed using the expression:

$$\gamma(h) = \frac{1}{2n(h)} \sum_{i=1}^{n(h)} [Z(x_i) - Z(x_{i+h})]^2 \qquad (1)$$

Where n(h) is the number of samples separated by a distance h, and Z represents the measured value for a soil property, and x is the position of soil samples.

The values of semivariance computed in equation 1 were interpreted by fitting linear model to the data using nonlinear least square method (Mulla, 1988).

Mapping of Soil Properties

Geostatistical technique of Kriging (Bhatti et al., 1991) was used to interpolate the data values of measured soil properties at unsampled locations according to the expression:

$$Z(o) = \sum_{i=1}^{n(h)} \lambda_i Z_i \qquad (2)$$

Where Z(0) is the value which was estimated at unsampled location, λ_i, the weight associated with measured value Zi. These interpolated data values were used to develop maps of soil properties.

Results and Discussion

Variability in soil properties in the field under agro-forestry system.

The data collected on soil properties of the field under agro-forestry at two depths have been summarized in Table 1. These data showed that there was a considerable variation in the measured soil properties in the field. The maximum variation was observed in EC (1:5) which ranged from 0.28 to 1.38 dS m^{-1} with a mean value of 0.46 dS m^{-1} and a coefficient of variation of 57.44% in the surface soil (Table 1). In the subsoil it ranged from 0.34 to 1.55 dS m^{-1} with a mean value of 0.85 dS m^{-1} and a CV of 49.80%. However, the EC in both the depths was in safe limits for crop production. This was followed by available P which ranged from 0.59 to 2.64 mg kg^{-1} having an average value of 1.57 mg kg^{-1} with a CV of 35.25% in the surface soil and 0.53 to 4.55 mg kg^{-1} with a mean value of 1.21 mg kg^{-1} and a CV of 72.65% in the subsoil. Considering the critical level of 3 mg kg^{-1} P (Olsen and Sommers, 1982), all the soil samples in both the depths were considered deficient in phosphorus except one sample as medium in subsoil. Variation was also observed in the organic matter content which ranged from 0.44 to 1.38% having an average value of 0.85% with a CV of 27.44% in the surface soil, and 0.24 to 1.03% with an average value of 0.62% and a CV of 25.06% in the subsoil. As regards organic matter content, 83% of the soils in the surface and 94% of the soils in the subsoil had less than 1% (<1%) organic matter content which can be considered low.

Available N varied from 3.50 to 7.87 mg kg^{-1} with a CV of 21.50% in the surface soil and 3.90 to 7.87 mg kg^{-1} with a CV of 21.47% in the subsoil. Available soil K had a low variability (6.8% and 6.45% CV) and all the soil samples were adequate in K in both the depths (Table 1).

All the soil samples were alkaline and strongly calcareous in nature in both the depths. These soil properties had also low variability in the field (Table 1).

Table 1. Descriptive statistics of soil properties of a field under agro-forestry.

Soil property	Mean	Min.	Max.	CV(%)
	0-15 cm			
Soil pH (1:5)	8.27	8.00	8.42	1.37
EC dS m^{-1} (1:5)	0.46	0.28	1.38	57.44
Organic matter (g/100 g)	0.85	0.44	1.38	27.44
Lime content (g/100 g)	18.49	17.00	19.10	2.90
Mineral N (mg kg^{-1})	5.35	3.50	7.87	21.50
AB-DTPA ext. P (mg kg^{-1})	1.57	0.59	2.64	35.25
AB-DTPA ext. K (mg kg^{-1})	175.0	158.0	202.7	6.81
	15-45 cm			
Soil pH (1:5)	8.00	7.71	8.31	2.31
EC dS m^{-1} (1:5)	0.85	0.34	1.55	49.80
Organic matter (g/100 g)	0.62	0.24	1.03	25.06
Lime content (g/100 g)	19.45	18.85	19.95	1.43
Mineral N (mg kg^{-1})	5.45	3.90	7.87	21.47
AB-DTPA ext. P (mg kg^{-1})	1.21	0.53	4.55	72.65
AB-DTPA ext. K (mg kg^{-1})	156.6	139.3	173.2	6.43

Variability in soil properties in the field under agricultural crops.

The data collected on soil properties of the field under agricultural crops have been summarized in Table 2. These data showed that there was also a considerable variation in the measured soil properties in the agricultural field. The maximum variation was observed in available soil P which ranged from 3.00 to 14.95 mg kg^{-1} having an average value of 7.05 mg kg^{-1} with a CV of 49.98% in the surface soil, while it ranged from 1.31 to 3.85 mg kg^{-1} with a mean value of 2.05 mg kg^{-1} and a CV of 29.48% in the subsoil. Considering the critical level of 3 mg kg^{-1} P (Olsen and Sommers, 1982), 27% samples were considered deficient and 40% medium in the surface soil and all the subsoil samples were deficient in P. This was followed by EC (1:5) which ranged from 0.24 to 0.61 dS m^{-1} with a CV of 34.9% and a mean value of 0.34 dS m^{-1} in the surface soil, and 0.21 to 0.55 dS m^{-1} with a CV of 32.02% and a mean value of 0.35 dS m^{-1} in the subsoil.

Concentrations of available soil N ranged from 3.59 to 8.75 mg kg^{-1} having an average value of 6.18 mg kg^{-1} with CV of 25.40% in the surface soil and 2.71 to 7.88 mg kg^{-1} with a CV of 31.13% and a mean value of 4.74 mg kg^{-1} in the subsoil. Organic matter content ranged from 0.69 to 1.55% with an average value of 1.09% in the surface soil, while in subsoil it ranged from 0.34 to 1.00% having a mean value of 0.69% with a CV of 25.61%. Data showed that organic matter content was low (<1%) in 27 and medium in 72% of the samples in surface soil, and 94% of the samples were low (<1%) in subsoil. In the surface soil available soil K had a low variability, and all the soil samples were medium (90-167 mg kg^{-1}) in K, except two samples which were adequate. While in subsoil it ranged from 97.01 to 180.8 mg kg^{-1} with a CV of 21% and a mean value of 124.2 mg ka^{-1} and 94.4% of the samples were medium in K (Table 2).

All the soil samples were alkaline and strongly calcareous in nature in both the depths. These soil properties had also low variability in the field (Table 2).

Table 2. Descriptive statistics of soil properties of a field under agricultural crops.

Soil property	Mean	Min.	Max.	CV(%)
		0-15 cm		
Soil pH (1:5)	8.22	7.91	8.50	2.57
EC dS m^{-1} (1:5)	0.34	0.24	0.61	34.90
Organic matter (g/100 g)	1.09	0.69	1.55	22.57
Lime content (g/100 g)	18.51	17.67	19.40	2.95
Mineral N (mg kg^{-1})	6.18	3.59	8.75	25.40
AB-DTPA ext. P (mg kg^{-1})	7.05	3.00	14.95	49.98
AB-DTPA ext. K (mg kg^{-1})	136.3	96.81	168.8	14.60
		15-45 cm		
Soil pH (1:5)	8.26	8.00	8.49	1.86
EC dS m^{-1} (1:5)	0.35	0.21	0.55	32.02
Organic matter (g/100 g)	0.69	0.34	1.00	25.61
Lime content (g/100 g)	19.71	18.52	20.37	2.18
Mineral N (mg kg^{-1})	4.74	2.71	7.88	31.13
AB-DTPA ext. P (mg kg^{-1})	2.05	1.31	3.85	29.48
AB-DTPA ext. K (mg kg^{-1})	124.2	97.01	180.8	21.41

Comparison of soil properties under agro-forestry and agricultural crops using t-test of significance:

Soil properties under both the land use systems were compared using t-test of significance and the results have been summarized in Table 3. The results indicated that the differences between the values of soil pH, EC and lime content in the surface soil and that of organic matter, and mineral N in the subsoil of agro-forestry and agricultural system were non-significant (P>0.05) (Table 3). The values of organic matter, mineral N, soil P in top soil and that of pH, lime content and soil P in subsoil were significantly (P<0.01) higher in agricultural soil as compared to agro-forestry (Table 3).

However, subsoil EC and soil K in both depths were significantly (P<0.01) higher under agro-forestry as compared to agricultural crops. The lower mean soil organic matter, mineral N and soil P values observed under agro-forestry system (Eucalyptus trees with wheat crops) than under agricultural crops in top soil is because the Eucalyptus shed little leaves (ever green). Secondly the leaves are resistant to decomposition. It can be concluded that the noticeable low value of soil elements under Eucalyptus trees of 5 years and above when compared with adjacent soil under agricultural crops may be due to mining of nutrients by *Eucalyptus*.

Table 3. Comparison of soil properties under agro-forestry and agricultural crops.

Soil property	Agro-forestry	Agricultural crops
	0-15 cm	
Soil pH (1:5)	8.27 a	8.22 a
EC dS m^{-1} (1:5)	0.46 a	0.34 a
Organic matter (g/100 g)	0.85 b	1.09 a
Lime content (g/100 g)	18.49 a	18.51 a
Mineral N (mg kg^{-1})	5.35 b	6.18 a
AB-DTPA ext. P (mg kg^{-1})	1.57 b	7.05 a
AB-DTPA ext. K (mg kg^{-1})	175.0 a	136.3 b
	15-45cm	
Soil pH (1:5)	8.00 b	8.26 a
EC dS m^{-1} (1:5)	0.85 a	0.35 b
Organic matter (g/100 g)	0.62 a	0.69 a
Lime content (g/100 g)	19.45 b	19.71 a
Mineral N (mg kg^{-1})	5.45 a	4.74 a
AB-DTPA ext. P (mg kg^{-1})	1.21 b	2.05 a
AB-DTPA ext. K (mg kg^{-1})	156.6 a	124.2 b

Means followed by different letter(s) in each row differ significantly from each other at P<0.05.

Spatial variability of soil properties:

Geostatistical technique of semivariogram analysis was applied to soil properties under both the land use systems. It was found that the linear model was the best fit to the data. Parameters of omnidirectional linear model semivariograms were determined and have been given in Table 4 and 5. These results show that

EC and soil P were spatially distributed in the field of agro-forestry in the surface soil, while only EC was spatially distributed in the field of agro-forestry in the subsoil (Table 4).

Table 4. Parameters of omnidirectional semivariogram linear model for various soil properties under agro-forestry.

Soil property	Nugget	Slope	r^2
	0-15 cm		
Soil pH (1:5)	0.0095	0.0001	0.05
EC dS m^{-1} (1:5)	0.00089	0.0021	0.26
Organic matter (g/100 g)	0.0200	0.00053	0.106
Lime content (g/100 g)	0.2946	-0.0012	0.032
Mineral N (mg kg^{-1})	1.4	-0.0015	0.0004
AB-DTPA ext. P (mg kg^{-1})	0.0866	0.0063	0.25
AB-DTPA ext. K (mg kg^{-1})	40.60	2.04	0.23
	15-45 cm		
Soil pH (1:5)	0.0287	-0.00003	0.003
EC dS m^{-1} (1:5)	-0.243	0.0144	0.53
Organic matter (g/100 g)	0.04	0.00009	0.003
Lime content (g/100 g)	0.049	0.0006	0.14
Mineral N (mg kg^{-1})	0.93	0.009	0.06
AB-DTPA ext. P (mg kg^{-1})	1.29	0.005	0.004
AB-DTPA ext. K (mg kg^{-1})	117.35	0.240	0.006

Table 5. Parameters of omnidirectional semivariogram linear model for various soil properties under agricultural crops.

Soil property	Nugget	Slope	r^2
		0-15 cm	
Soil pH (1:5)	0.06	-0.0007	0.25
EC dS m^{-1} (1:5)	0.004	0.0003	0.22
Organic matter (g/100 g)	0.011	0.002	0.93**
Lime content (g/100 g)	0.101	0.0084	0.16
Mineral N (mg kg^{-1})	1.14	0.050	0.74
AB-DTPA ext. P (mg kg^{-1})	11.21	0.093	0.03
AB-DTPA ext. K (mg kg^{-1})	120.16	8.10	0.23
		15-45 cm	
Soil pH (1:5)	0.026	-0.000097	0.13
EC dS m^{-1} (1:5)	0.0038	0.00024	0.46
Organic matter (g/100 g)	0.040	-0.0004	0.40
Lime content (g/100 g)	0.182	-0.002	0.47
Mineral N (mg kg^{-1})	1.76	0.010	0.03
AB-DTPA ext. P (mg kg^{-1})	0.13	0.0050	0.307
AB-DTPA ext. K (mg kg^{-1})	918.63	-2.44	0.03

** Significant at P<0.01

The soil properties in the field under agricultural crops except soil P, lime content were also spatially distributed in the field in the top soil (Table 5). Here the highest r^2 value (r^2=0.93, P<0.01) was observed for organic matter followed by mineral N. The soil properties in the subsoil under agricultural crops (i.e.) EC, organic matter, lime content and soil P also showed spatial patterns in their distribution in the field (Table 5).

Mapping of soil properties under both the systems

Geostatistical techniques of kriging were used to interpolate soil test values of various soil properties at unsampled locations in the fields at a grid spacing of 10 m x 10 m. After interpolation of soil test values of various soil properties, isarithmic field maps of soil properties were developed.

Maps of Agro-forestry

Maps of all the soil propeties were developed. Maps of only plant nutrients are shown here. Map of surface soil pH shows variation in north-south direction having higher values in south. Similarly pH of subsoil varied from north to south being higher in the south and lower in the north.

EC in the surface soil was higher in the north than in the south. In case of subsoil, EC was lower in the middle than on the sides of the field.

Surface soil organic matter varied in west-east direction being higher in the east than in the western side of the field. While organic matter in the subsoil varied in north-south direction being higher in the north than in the south.

Surface lime content was lower in the middle of the field than on the sides while lime content of the subsoil was higher in the west than in the eastern side of the field.

Mineral N in the surface soil was higher in the western and southern side of the field than in the eastern and northern side (Fig-1). Mineral N in the subsoil was lower in the middle of the field than in the sides of the field.

Surface soil P had a different pattern. It varied in a diagonal pattern. It was higher in North-east than in the South-west direction. Subsoil P was lower in the southern side than in the northern side of the field (Fig-2).

Surface soil K was higher in the north-east of the field (Fig-3). Subsoil potassium was higher in the middle of the field to Northern side than in the sides of the field.

Maps of Agricultural Crops

Map of surface soil pH showed that there were no strong directional patterns in surface soil pH. In case of subsoil pH, though the directional patterns were not strong, but soil pH was higher in the southern and western sides of the field than the other areas.

EC in the surface soil showed higher values on the western side than in the eastern side of the field variability being in east-west direction. Similar were the trends in subsoil EC.

Surface organic matter showed directional patterns in a diagonal pattern being higher in the north-west direction than in the south-east direction. However, it was lower in the south side of the field. In case of subsoil organic matter, variation was in west-east direction being higher in the west than in the east.

Variation in surface lime was in south-north direction. Lime content was higher in the south than in the northern side of the field. Diagonal directional pattern was observed in case of subsoil lime. Lime content was low in the north-east and high in the south-west side of the field.

Mineral nitrogen had also diagonal directional pattern (Fig-4). It was low in south-east direction and high in north-west direction. On the other hand, variability in mineral N in subsoil was in the east-west direction being low in east and high in the west.

Soil P in the surface soil was lower in the middle than the sides of the field. Subsoil P was also lower in the middle than in the sides of the field (Fig-5).

Soil K in the surface soil was lower in north-east corner of the field than in the other areas (Fig-6). Subsoil K was lower in the south-west and south-east corner than in the other areas of the field.

Economics of land use systems

The data on the economics of the two land use systems could not be obtained inspite of visits to the Forest Office at D.I.Khan. However, through an interview of the farmer, it was found that the wheat yield under agro-forestry system is 1500 kg ha^{-1} and under the crops (wheat) it is 2000 kg ha^{-1}. So there is a yield reduction of 500 kg ha^{-1} due to agro-forestry. As Eucalyptus takes 5 to 7 years as sellable commodity there will be a total reduction of wheat yield of 2500 to 3500 kg ha^{-1} amounting to an amount of Rs.18750 to 26250 ha^{-1}. Sale of Eucalyptus plants after 5 years would give an income of Rs.24,700/- ha^{-1} which is less than the reduction in income from wheat during a period of 7 years.

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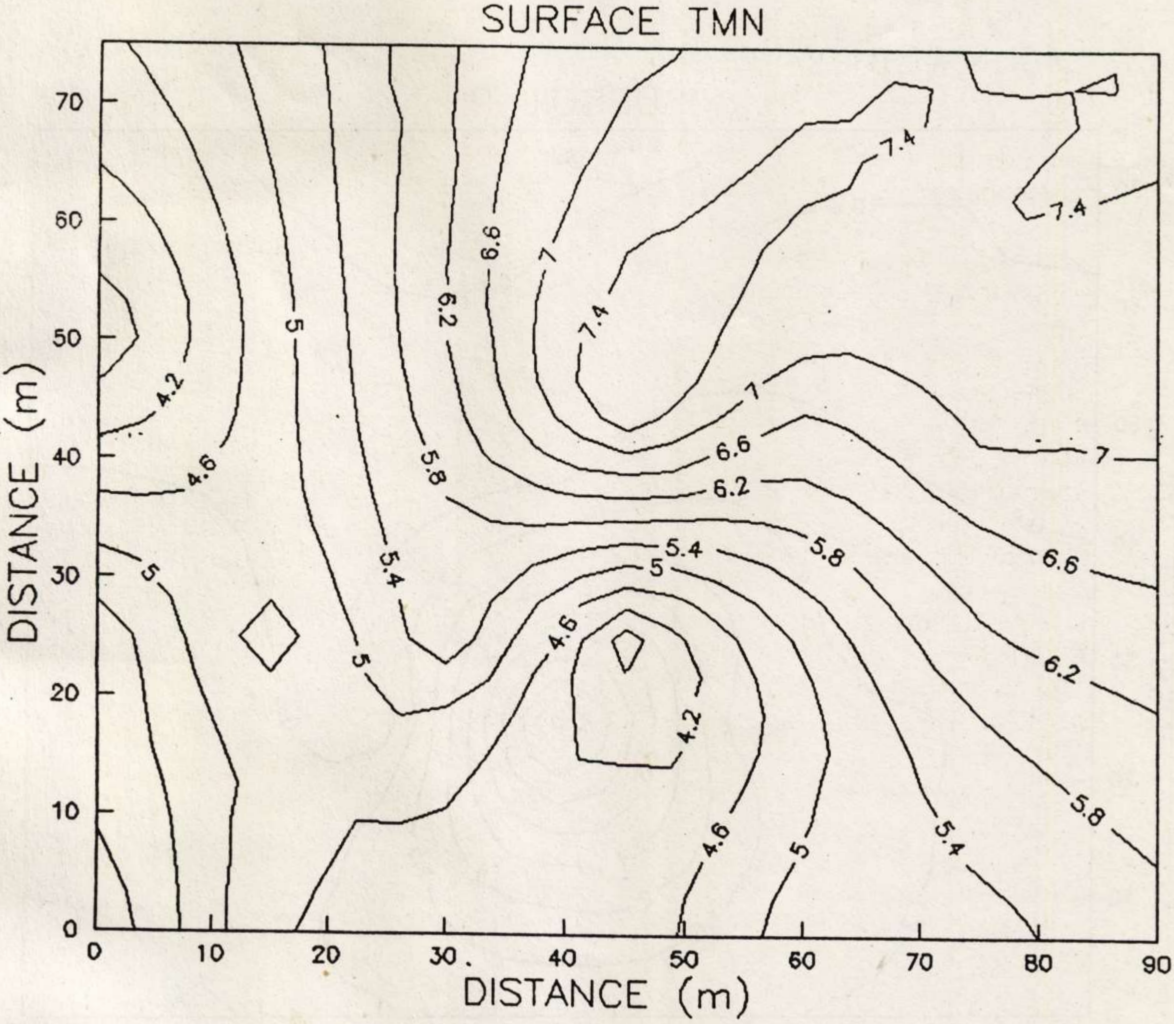

Fig.1. Map showing variation in surface total mineral N ($mg\ kg^{-1}$) under agroforestry

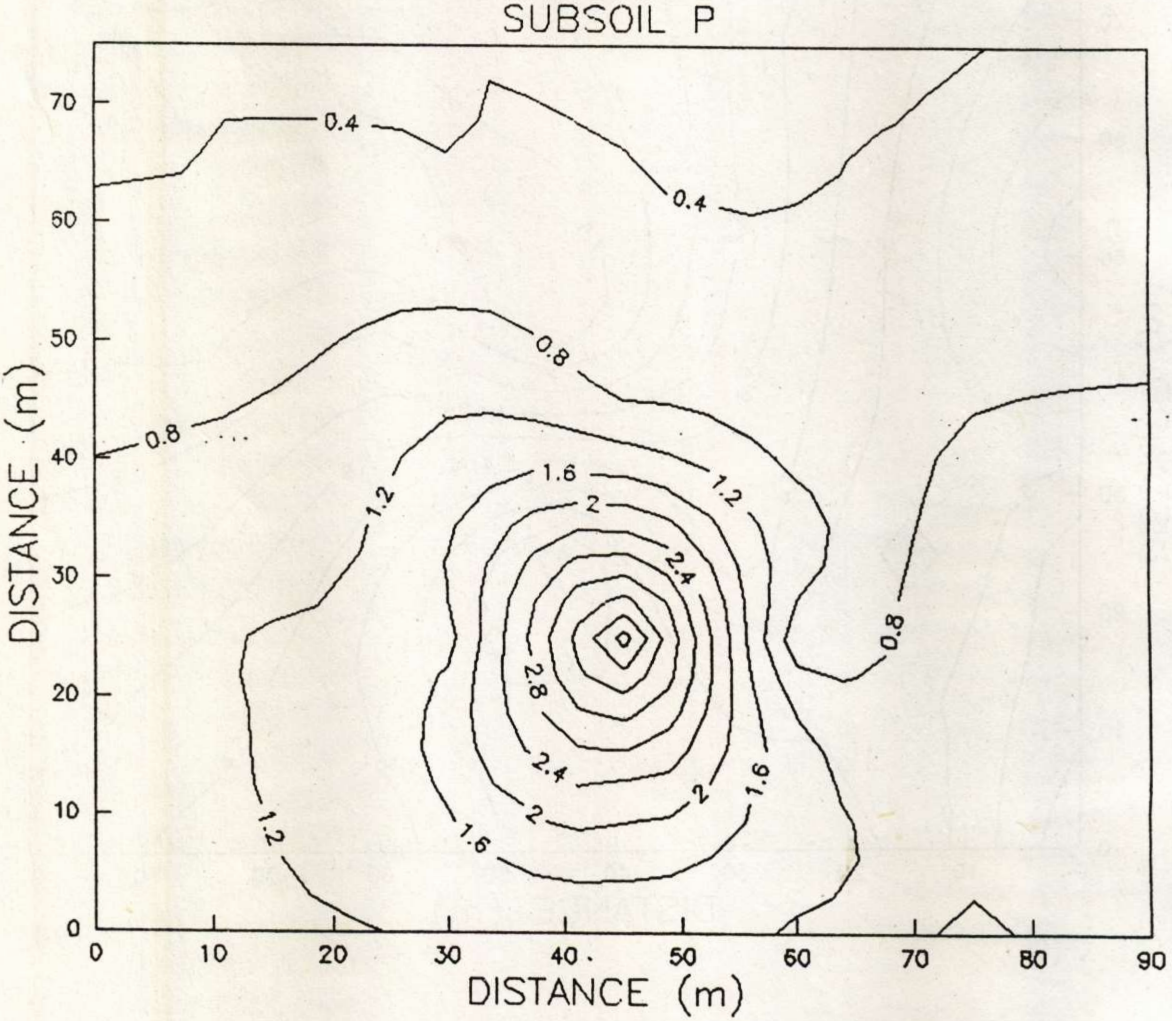

Fig.2. Map showing variation in subsoil P (mg kg^{-1}) under agroforestry

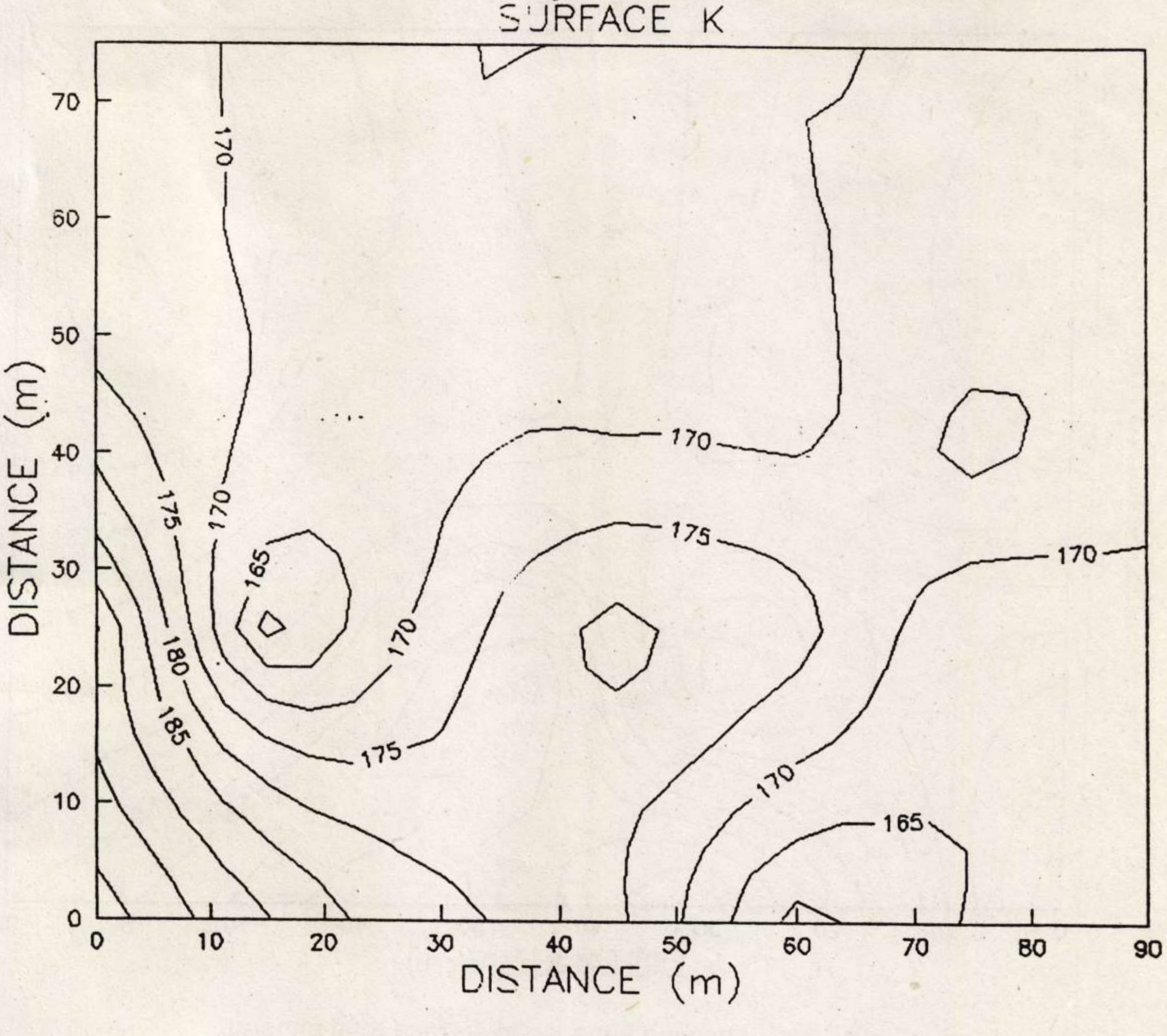

Fig.3. Map showing variation in surface K ($mg\ kg^{-1}$) under agroforestry

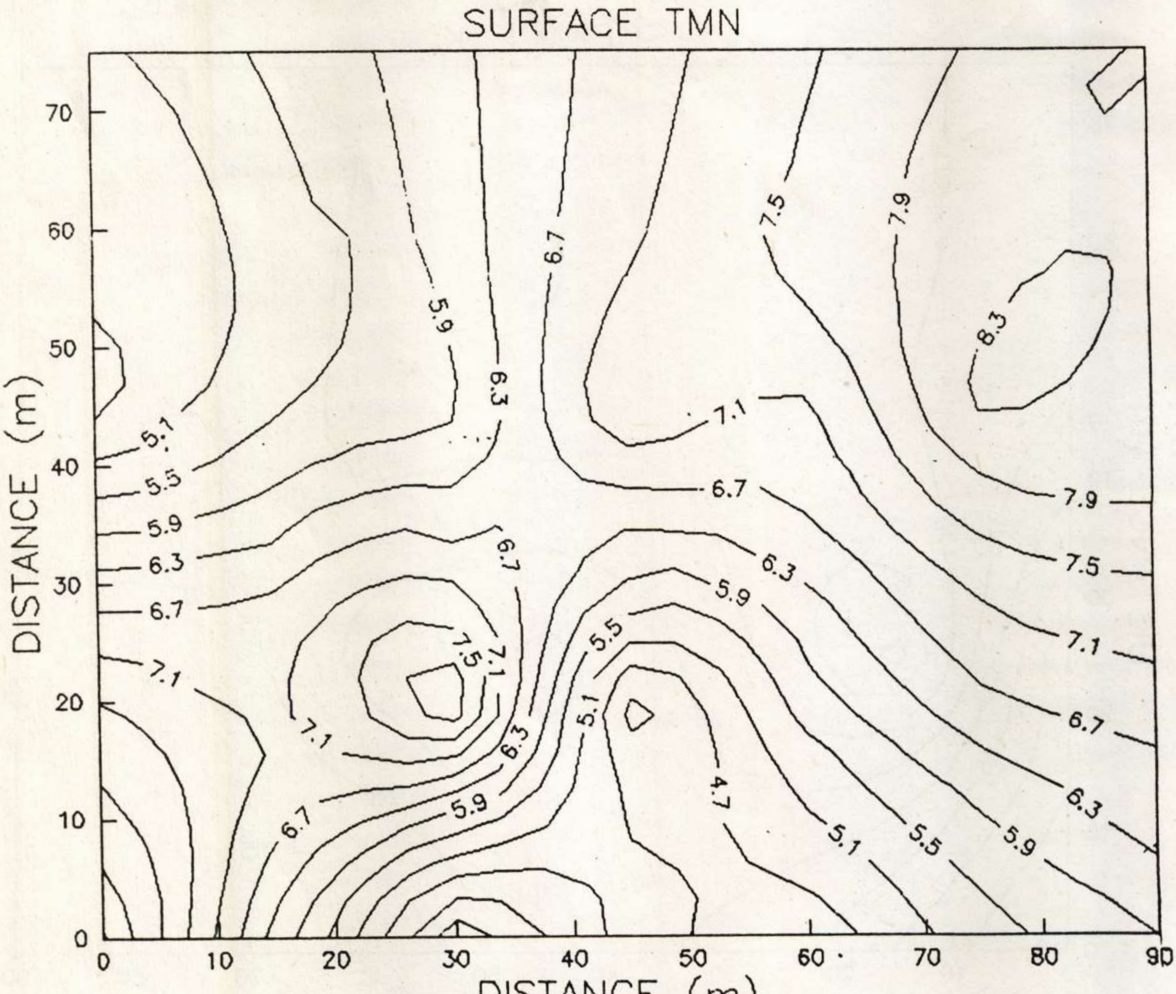

Fig.4. Map showing variation in surface total mineral ($mg\ kg^{-1}$) under wheat crop

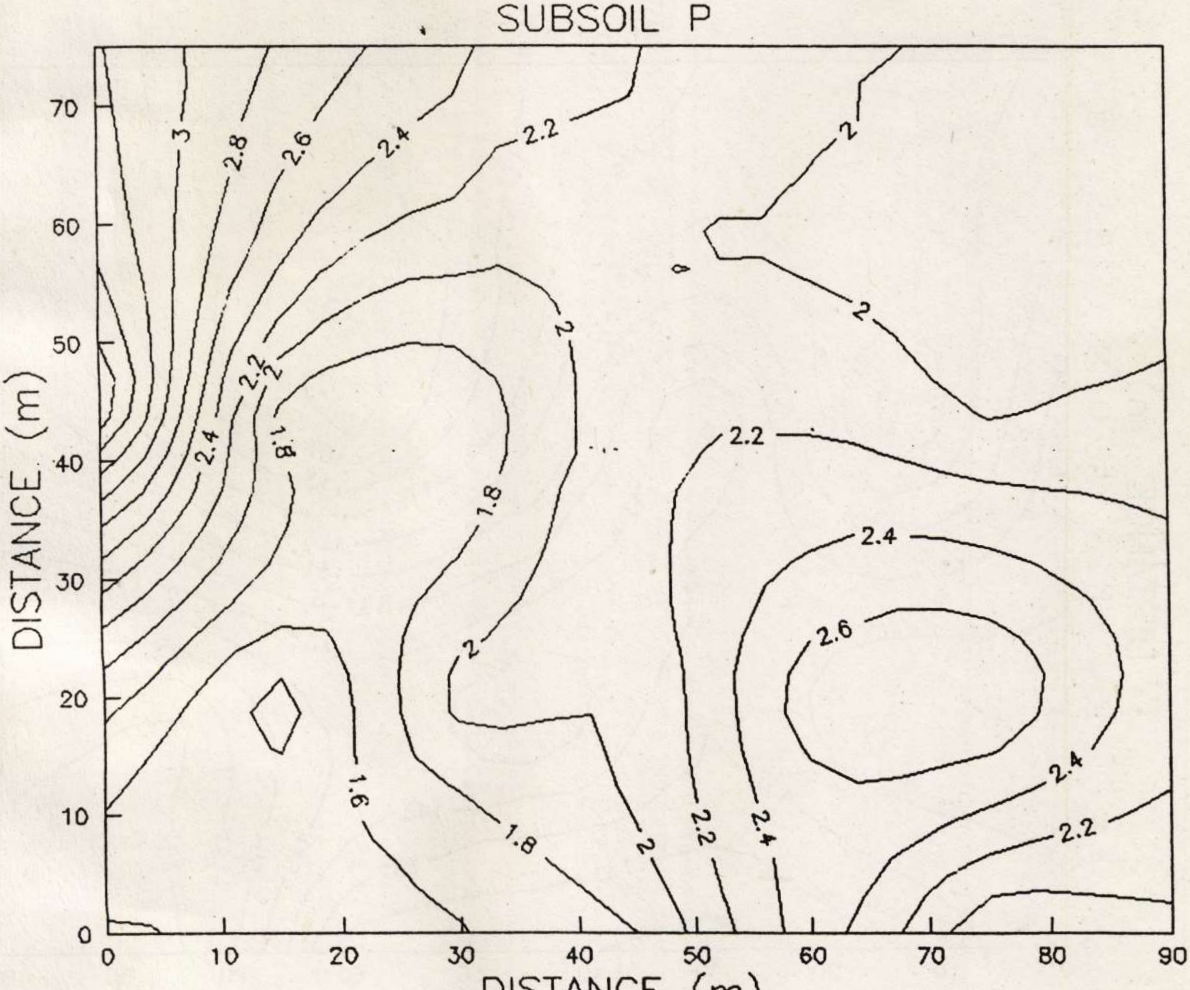

Fig.5. Map showing variation in subsoil P ($mg\ kg^{-1}$) under wheat crop

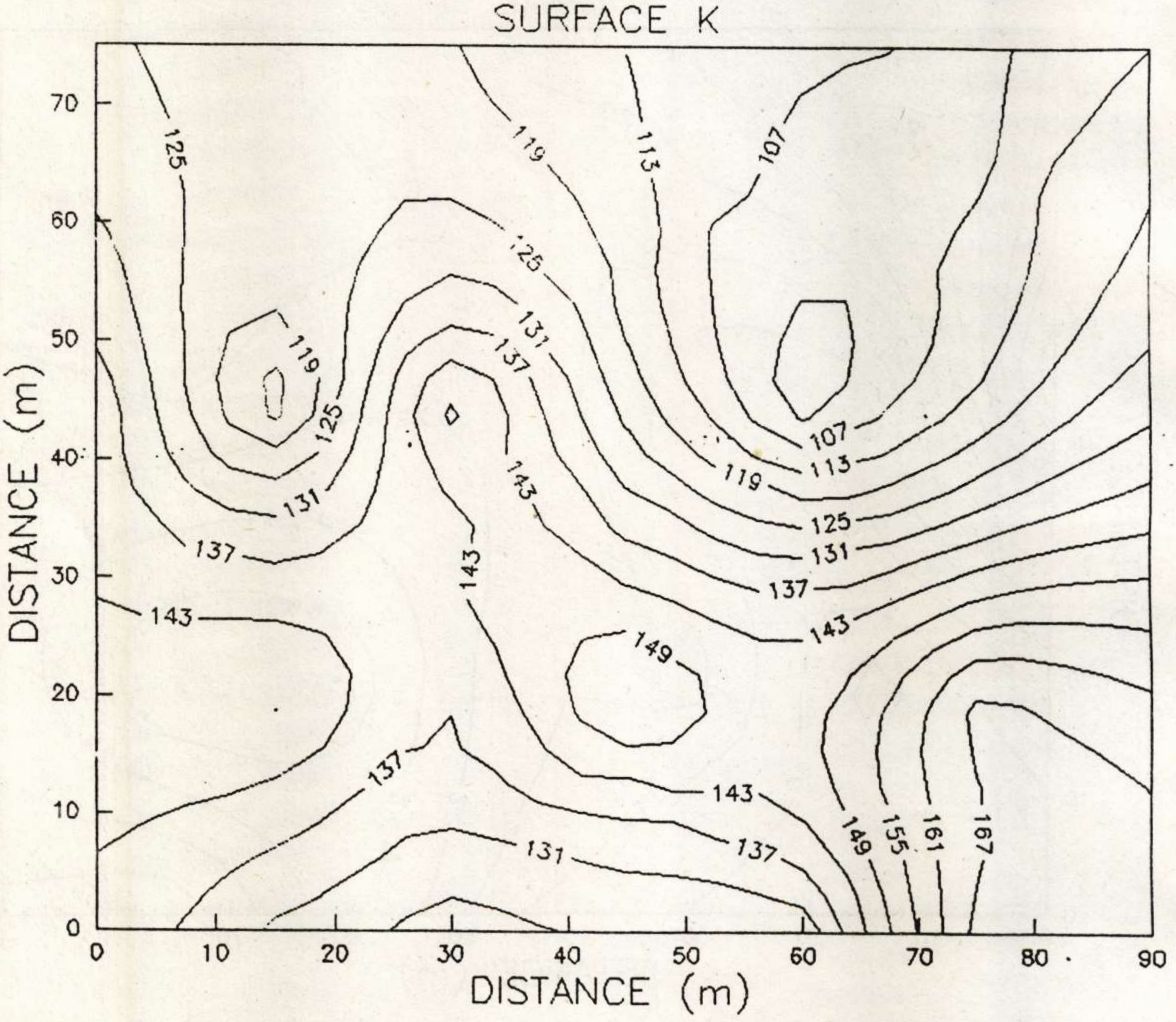

Fig.6 Map showing variation in surface K ($mg\ kg^{-1}$) under wheat crop