

**LONG TERM EFFECT OF WATERSHED DEVELOPMENT ON
CHANGES IN SOIL PROPERTIES OF ALFISOLS AND
PRODUCTIVITY OF FINGER MILLET IN KUTHANAGERE OF
RAMANAGAR DISTRICT, KARNATAKA**

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PAL-0026

**DEPARTMENT OF AGRONOMY
UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU**

2013

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for the award of the degree of

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in

AGRONOMY

BANGALORE

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*Affectionately
Dedicated to
My Beloved Parents
Sri Nagaraju S.
& Smt. Mangala Raj
and Brothers*

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
UNIVERSITY OF AGRICULTURAL SCIENCES,
BENGALURU-560065

CERTIFICATE

This is to certify that the thesis entitled "LONG TERM EFFECT OF WATERSHED DEVELOPMENT ON CHANGES IN SOIL PROPERTIES OF ALFISOLS AND PRODUCTIVITY OF FINGER MILLET IN KUTHANAGERE OF RAMANAGAR DISTRICT, KARNATAKA" submitted by MR. ANILKUMAR, S. N., in partial fulfillment of the requirement for the degree of DOCTOR OF PHILOSOPHY (AGRICULTURE) in AGRONOMY to the College of Agriculture, University of Agricultural Sciences, Bengaluru is a record of research carried out by him during the period of his study in this University, under my guidance and supervision and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

Place: Bengaluru

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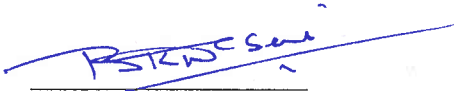
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With ever regardful memories.....

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(ANILKUMAR, S. N.)

LONG TERM EFFECT OF WATERSHED DEVELOPMENT CHANGES ON PRODUCTIVITY OF FINGER MILLET IN KUTHANAGERE WATERSHED

ANILKUMAR, S. N.

ABSTRACT

A field experiment was conducted during the kharif 2011 and 2012 at Kuthanagere watershed of Ramanagar district to study the effect of watershed development on productivity of finger millet. Kuthanagere watershed has 13 soil series of which 9 soil series were selected for taking the experiment based on their suitability along with 2 varieties of finger millet viz., GPU-28 and MR-2. Among 9 soil series, Kuthanagere-1 soil series recorded significantly higher grain yield (31.74 q ha⁻¹) and it was found to be on par with Kuthanagere-3 (29.92 q ha⁻¹) soil series. This was mainly due to higher growth attributing characters like higher number of leaves (8.93 plant⁻¹), more number of tillers (3.46 plant⁻¹) and higher dry matter production (22.80 g plant⁻¹) and its accumulation into different parts of plant and higher yield attributing characters like number of fingers (5.46 ear⁻¹) and number of effective tillers (2.82 plant⁻¹).

Among the two varieties, GPU-28 recorded significantly higher grain yield (25.11 q ha⁻¹) when compared to MR-2 (23.09 q ha⁻¹). However, higher straw yield was noticed in MR-2 (4.24 t ha⁻¹) compared to GPU-28 (3.16 t ha⁻¹). Higher straw yield of MR-2 variety can be mainly attributed to higher plant height compared to GPU-28.

Kuthanagere-1 soil series sown with GPU-28 shown significant interaction (32.55 q ha⁻¹) in pooled analysis followed by Kuthanagere-3 soil series with same variety (21.03 q ha⁻¹).

**Department of Agronomy
UAS, GKVK, Bangalore-65**

Major Advisor

ಕುತ್ತನಗೆರೆ ಜಲಾನಯನದ ದೀರ್ಘಕಾಲ ಅಭಿವೃದ್ಧಿಯ ಪರಿಣಾಮಾದಿಂದಾದ ರಾಗಿ ಉತ್ಪಾದನೆಯ
ಬದಲಾವಣೆಗಳು

ಆನಿಲ್ ಕುಮಾರ್, ಎಸ್. ಎನ್

ಸಾರಾಂಶ

ಜಲಾನಯನ ಅಭಿವೃದ್ಧಿಯ ಪರಿಣಾಮವನ್ನು ರಾಗಿ ಉತ್ಪಾದಕತೆಯ ಒಂದು ಕ್ಷೇತ್ರ ಪ್ರಯೋಗಿಕ
ಅಧ್ಯಯನವನ್ನು ರಾಮನಗರ ಜಿಲ್ಲೆಯ ಕುತ್ತನಗೆರೆ ಜಲಾನಯನ ಪ್ರದೇಶದಲ್ಲಿ ೨೦೧೧ ಮತ್ತು ೨೦೧೨
ವಾರಿನ ಮುಂಗಾರಿನಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಕುತ್ತನಗೆರೆ ಜಲಾನಯನವು ೧೩ ಮಣ್ಣಿನ ಸರಣಿಗಳನ್ನು
ಹೊಂದಿದ್ದು, ಅದರಲ್ಲಿ ಹೊಂದಿಕೆಯಾಗುವ ೯ ಮಣ್ಣಿನ ಸರಣಿಗಳನ್ನು ಮತ್ತು ೨ ರಾಗಿ ತಳಿಗಳಾದ ಜಿ.ಪಿ.ಯು-
೩೦ ಮತ್ತು ಎಮ್.ಆರ್-೨ ಆಧರಿಸಿ ಪ್ರಯೋಗ ತೆಗೆದುಕೊಳ್ಳಲು ಆಯ್ಕೆ ಮಾಡಲಾಯಿತು. ೯ ಮಣ್ಣಿನ
ಪದ್ಧತಿಗಳಲ್ಲಿ, ಕುತ್ತನಗೆರೆ-೧ ಸರಣಿಯು ಗಮನಾರ್ಹವಾಗಿ ಹೆಚ್ಚಿನ ಧಾನ್ಯ ಇಳುವರಿಯನ್ನು (೩೧.೭೪ ಕ್ವಿಂ.
ಪ್ರತಿ ಹೆಕ್ಟರು) ದಾಖಲಿಸಿತ್ತು. ಇದರ ಸರಿ ಸಮಾನವಾಗಿ, ಕುತ್ತನಗೆರೆ-೩ (೨೯.೯೨ ಕ್ವಿಂ. ಪ್ರತಿ ಹೆಕ್ಟರು) ಮಣ್ಣಿನ
ಪದ್ಧತಿಯು ಕಂಡುಬಂದಿತು. ಹೆಚ್ಚಿನ ಎಲೆಗಳು (೮.೯೩), ಅಧಿಕ ತೆಂಡೆಗಳು (೩.೩೬), ಹೆಚ್ಚಿನ ಒಣ ಉತ್ಪನ್ನ
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ಮುಖ್ಯ ಸಲಹೆಗಾರರು

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LIST OF ABBREVIATIONS

Abbreviation	Expansion
N	Nitrogen
P	Phosphorus
K	Potassium
DAS	Days after sowing
ha	Hectare
mg	Miligram
g	Gram
Kg	Kilogram
q	Quintal
t	Ton
ml	Mililitre
mm	Milimeter
cm	Centimeter
m	Meter
%	Per cent
B C	Benefit cost ratio
NS	Non significant
RH	Relative humidity
S. Em	Standard error mean
C.D.	Critical difference
Fig.	Figure

Introduction

INTRODUCTION

Soil is a vital natural resource on which the life supporting system of a country and the socio-economic development of its people depends. Soil provides food, fodder and fuel for meeting the basic needs of human and animal. With the growth in human and animal population, demand for more food production is on the rise. However, the capacity of the soil to produce is limited and limits to production are set by intrinsic characteristics, agro-ecological setting, its use and management. This demands systematic appraisal of our soil resources with respect to their extent, distribution, characteristic, behavior and use potential, which is very important for developing an effective land use system for augmenting agricultural production on sustainable basis (FAO, 1993).

Since soils in general are degrading due to poor management and faulty land use at a rate faster than their natural degeneration, it becomes imperative to protect them from further degradation; as there is a concomitant decline in soil quality to produce healthy crops. In the recent past, productivity of agricultural soils worldwide in general is on the decline. This caused the per capita availability of food grain fall from 510 g per day (1991) to 463 g per day (2004). These declining trends across the world are attributed to ever growing population, raising incomes of populous Asian nations and discovery of new uses such as biofuels, besides weather based abnormalities owing to climate change (Sidhu and Kamal Vatta, 2007). Under these circumstances, to ensure self sufficiency and food security is a challenging task before the populous nations like India.

In India the land resources available for agriculture are shrinking. Our aim of optimizing the utilization of land resources with intensification of agriculture resulted either in the fast depletion of nutrients or occasionally in their accumulation. It is therefore, important to monitor the fertility status of soil from time to time with a view to monitor the soil health.

Soil and water are the two essential resources for the sustained quality of human life and for the foundation of agricultural development. Highly competing demands on soil, vegetation, water and other natural resources from increasing population have resulted in over exploitation and mismanagement of our valuable natural resources. For the sustained development of a region, the resources particularly soil and water needs scientific protection and conservation in harmony with environment (a watershed

approach). These resources should be managed on a sustained manner to meet the needs of development without diminishing the potential for their future use (Kanwar, 1994).

Watershed in British terminology is geographical reference to the highest point from which water is shed on either side into catchment drainage basin, whereas the American use of the term refers to the land and water enclosed within the drainage divide (Jenson, 1996). It is the latter that is used for identifying the drainage divide in watershed approach to land development. The Soil Conservation Society of America (SCSA) defines watershed as a “Geo-hydrological unit comprising of all land and water within the confines of a drainage divide” (Anon., 1982). It further extends the definition to include the eco-system being defined as the interacting system of biological community and its non-living environment. Thus, a watershed comprises people, livestock, vegetation, land, water etc., within the drainage divide.

India, with all its effort and huge investments, could provide irrigation facilities to about 30 per cent of its cultivated area, leaving the rest 70 per cent to be rainfed. Further, augmentation of irrigation facilities in the country is faced with a serious resource crunch apart from being prohibitive cost and ecological concerns. Thus, rainfed farming systems are inextricably linked with the major chunk of the cultivable area. The productivity in these areas is not only low but also highly variable in tune with magnitude and distribution of rainfall.

Karnataka has 19.17 m ha geographical area of which 10.2 m ha is cultivable area, 5.0 m ha could be brought under irrigation. Hence, dryland development demand paramount importance for agricultural development in the state. Scanty rainfall on one hand and high intensity rainfall on the other have been major threats to the dryland agriculture. Improved crop production technologies with the efficient utilization of available rainwater play an important role in increasing the crop yields in drylands.

Concept of watershed based holistic development is one of the potential approaches in rainfed areas, which can lead to higher productivity and sustainability in agricultural production. Different measures are adopted and executed carefully in each of toposequences according to their capability. Hence, a detailed study for characterization and classification of soils is needed to realize the benefits of watershed approach successfully. The National Bureau of Soil Survey and Land Use Planning (NBSS &

LUP), Karnataka State Remote Sensing Application Centre (KSRSAC), All India Soil and Land Use Survey (AISLUS) and other agencies like State Land Use Board are engaged in preparing soil resource maps to delineate areas of potentials and problems (Sehgal, 1990). However, at watershed level, accurate and detailed soil information is needed with maps at scale of 1:20,000 or larger for planning sustainable use as per its capability and suitability.

Studies were carried out on soil resources inventory, capability and crop suitability of arable and non arable lands at Kuthanagere watershed near Bangalore between 1992 and 1999 in south Karnataka, India, provided decisive role in crop planning and management (Krishnappa *et al.*, 2004).

Before development (1992), resource inventory was undertaken on 1:2000 scale to characterize the soil-site of Kuthanagere watershed (IARI, 1971). The total area of the watershed is around 250 ha, out of that 150 ha was arable land with 54 beneficiary farmers holding 1 to 2 ha of land. The non-arable land was afforested and most of which was developed into forest. The drainage lines were treated and arable lands were banded suitably to be brought under improved agriculture system *viz.*, introduction of new varieties, agri-horti systems, agroforestry, contour cultivation, inter cropping, farm pond technology and protective irrigation. Soil survey identified 13 soil series in the watershed, out of which field experiment was conducted in finger millet on 11 soil series to study the yield potential of these soils before the watershed development. Nine of them were found to be suitable at that time for finger millet (Shivaramu *et al.*, 2000).

Finger millet (*Eleusine coracana* L.) is the staple food for millions of people in India and Africa. It ranks third in importance among millets in the country in area (1.3 million ha) and production (1.92 million tones) after sorghum and pearl millet. Karnataka state shares half of the area (0.78million ha) and two third of its production (1.27 million tones) in the country (Anon., 2012). Finger millet is an important dryland crop due to its resilience and ability to withstand aberrant weather condition is generally grown in soils having poor water and nutrient supplying capacity.

In southern Karnataka finger millet is the main dietary component particularly in the districts of Bangalore, Kolar, Tumkur, Mysore, Hassan, Mandya and Chitradurga dryland regions.

The growth and yield of finger millet varies widely depending on soil-site characteristics and crop management practices. These together with weather conditions determine the probable growing period of the crop. Hence after the gap of nearly 20 years of Kuthanagere watershed development, resource inventory of the same watershed and soil-site suitability of finger millet was once again studied with the following objectives.

1. To study the impact of watershed development on soil properties with respect to fertility and productivity of finger millet
2. To study the performance of finger millet at different soil series with respect to the bench mark yield
3. To study the relationship and quantify the limits of soil characters to achieve the potential yield of finger millet
4. To delineate soil suitability map for finger millet.

Review of literature

II. REVIEW OF LITERATURE

An effort has been made in this chapter to compile and present the available literature in relation to watershed development on changes in soil properties and productivity of finger millet. Based on the available information, the literature is reviewed under the following headings.

2.1 Surface soil properties

2.2 Profile properties

2.3 Soil suitability to crops

2.4 Influence of soil-site characters on yield of crops

2.5 Mapping of soils using GIS

2.6 Performance of finger millet genotypes

2.7 Crops and Cropping systems on a watershed approach

2.1 Surface soil properties

2.1.1 Soil chemical properties

Krishnamurthy (1993) studied the properties of 11 red soil pedons from North Karnataka to understand their genesis and to classify them according to U. S. Soil Taxonomy. The pH of soils was acid to mildly alkaline, organic carbon content was high in soils of Dharwad schist. Fe_d and Fe_o content were highest in Bt horizons except in Hunsikatti. Shyadambi pedon was highly weathered due to high rainfall.

2.1.1.1 Soil reaction (pH)

The pH of saline soils was less than 8.5 and that of sodic soils was always more than 8.5 and usually lies between 8.5 to 10.0 (USSL Staff, 1954). However, in saline-sodic soils, the pH depends upon the amount of salts present in them.

Sivasankaran *et al.* (1993) observed that the pH of red soils varied between 3.9 to 7.0 in western ghat of Karnataka and remarked that rainfall was the major factor contributed to the increase in acidity in these soils.

Shivaprasad *et al.* (1998) while characterizing the soils of Karnataka observed that soils derived from granitic-gneiss material were found to be slightly acidic to near neutral in reaction.

Binita *et al.* (2009) while mapping the soil fertility of Ghataprabha left bank canal command area observed that soils was slightly to moderately alkaline (8.02-8.96) as the soils were under arid to semi arid region and hence not subjected to leaching losses of cations.

2.1.1.2 Electrical conductivity

The electrical conductivity of North Gujarat soils increased with depth and the values were 0.19, 1.21, 1.80, 2.10 and 3.00 dS m⁻¹ at 0-20, 20-40, 40-60 and 60-100 cm depth (Barade and Gowaikar, 1965).

Working with red and black soils of Andhra Pradesh, Krishnamurthy and Govinda Rajan (1977) observed that in red soils electrical conductivity values ranged from less than 0.15 to 0.25 dS m⁻¹ and showed increasing trend with depth.

Gundlur (1991) concluded that the electrical conductivity was found to increase with depth in Vertisols in both the irrigated and unirrigated conditions.

The EC values of Ghataprabha left bank canal command area studied by Binita *et al.* (2009) were in normal range (0.11-1.40 ds m⁻¹). Relatively higher values were observed in the study area in the undulating plains and alluvial plains as salts are expected to be higher in lower elements of the landscape.

2.1.1.3 Organic carbon (OC)

Raychaudhari (1941) reported that organic carbon content was low in black soil compared to that of associated red soil. They also reported that the C/N ratio was higher in black soils than that of associated red soils.

While, the organic matter content of arid and semi-arid regions is low under virgin conditions, it commonly increased with the application of irrigation water and cultivation, especially when crop management is good. And this organic matter, apart from being a source of nutrient to plants, also has a favorable effect on soil physical properties (USSL Staff, 1954).

Krishnamurthy and Govinda Rajan (1977) working with black and red soils of Andhra Pradesh noticed higher organic matter in second horizon which later decreased in red soils while in black soils accumulation of organic matter was noticed in fourth horizon due to the downward movement of it along with clay.

A higher content of organic carbon was noticed in the surface layers and with the depth it decreased in salt-affected soils of Purna Command area of Maharashtra (More *et al.*, 1988).

The organic carbon values of Ghataprabha left bank canal command area ranged from 0.34 to 1.33 percent and fall under low, medium and high category. Higher organic carbon content in these soils is owed to its management practices such as addition of crop residues and cropping pattern followed (Binita *et al.*, 2009).

2.1.2 Soil nutrient status

Singh and Ghosh (1995) reported that early establishment of rice and wheat and higher NPK applications increased N, P and K uptake by both crops. Organic carbon and available N, P and K content in soil increased with high fertilizer rates.

Devarajan and Oblisami (1995) recommended effluent irrigation as it significantly increased the available N, P, K, Ca, Mg and micronutrients contents, soil pH, EC and organic matter content in soil.

Shivaprasad *et al.* (1998) mapped seven soils profiles at phase level into 17 mapping units. Available nitrogen was high, available phosphorus was medium to low and available potassium was medium to high.

Ravikumar (2004) characterized and classified the soil resources of 48A Distributary of Malaprabha Right Bank Command for sustainable land use planning and to assess the productivity of the soils. The mapping of available nutrient status by GIS technique indicated that majority of the area was low to medium with respect to available N, P and S. The entire study area was high in K. Among the micronutrients, the majority area was deficient in iron and zinc, whereas manganese and copper status was low to sufficient. The crop cutting experiment revealed that the yields of the crops were in general low as soils were deficient in N, P, S, Zn and Fe.

2.1.2.1 Available nitrogen

The available nitrogen content of the surface ranged from 0.019 to 0.029 per cent, 0.02 to 0.03 per cent and 0.014 to 0.016 per cent in Peelamedu, Periyannayakkanpalyam and Dasarpaty series, respectively and decreased with depth (Parasuraman and Jayaraj, 1982).

Mruthunjaya and Kenchanagowda (1993) while studying some salt affected soils of Cauvery and Vanivilas sagar command areas of Karnataka reported that the available nitrogen in the profiles ranged from 30.71 to 10.51 kg per hectare. Nitrogen content decreased with depth.

In Karnataka about 10.3 per cent of soils fall under low category, 35.8 per cent under medium and 53.9 per cent under high category of available nitrogen status (Shivaprasad *et al.*, 1998).

Soils of Bhanapur microwatershed in northern dry zone of Karnataka was studied for available nitrogen content by Srikanth *et al.* (2008a). The available nitrogen content was low in major portion of the study area (580.42 ha). This might be due to the arid environment and low organic matter content in these soils. Only in about 1.54 ha, available nitrogen was medium due to variation on management practices.

In Ghataprabha left bank canal command area (46029.9 ha) about 58 per cent area was medium in available nitrogen status (26490 ha), while 42 per cent of the area (19540 ha) was low in available nitrogen status (Binita *et al.*, 2009).

2.1.2.2 Available phosphorus

Gangappa (1989) reported that the available phosphorus content of salt affected soils of Chitradurga district (Karnataka), varied from 2.69 to 80.64 kg per ha. In profile samples, it ranged from 2.72 to 41.2 kg per ha. The available phosphorus increased with depth in profile samples.

While characterizing and classifying soils of an irrigated river flood plain in the eastern coastal region. Sahu and Mishra (1997) reported that available phosphorus content varied between 12.76 to 14.00 kg per ha and was in medium level.

The data on the available phosphorus status in the soils of Karnataka showed that about 83 per cent of the soils are low in phosphorus and 17 per cent area is under medium category (Shivaprasad *et al.*, 1998).

The mapping of major nutrient in Bhanapur microwatershed in northern dry zone of Karnataka revealed that the phosphorus content was medium in major portion of the watershed (555.25ha), but it was low in 26.71 ha. The red sandy soils showed low values

of available phosphorus, which may be due to low organic matter content, higher free iron oxide content and acidic soil reaction of less than 6.5 (Srikanth *et al.*, 2008a).

Binita *et al.* (2009) reported that in Ghataprabha left bank canal command area (46029.9ha), about 25 per cent (11354 ha) of the study area was medium in available phosphorus content and rest 75 per cent (34677 ha) of the area was found to be high in P content.

2.1.2.3 Available potassium

The available potassium content of surface soil ranged from 0.082 to 0.03, 0.015 to 0.026 and 0.031 to 0.033 per cent in Peelmedu, Periyankkan palayam and Dasarpatty series, respectively and in general its content decreased with depth (Parasuraman and Jayaraj, 1982).

While characterizing and classifying soils of an irrigated river flood plain in the eastern coastal region Sahu and Mishra (1997) reported that the available potassium content varied from 171.0 to 211.66 kg per ha and was in medium level.

The available potassium is medium to high in most of the soils of the Karnataka state except in lateritic soils of coastal plain and western ghats and in shallow red and black soils where it is low (Shivaprasad *et al.*, 1998).

The available potassium content in major portion of Bhanapur microwatershed was under medium and high category 365.65 and 150.31 ha, respectively. Black soils shown higher values than red soils due to predominance of K rich micaceous feldspar minerals in parent material (Srikanth *et al.*, 2008a).

The available potassium content was found to be high in 88 per cent (40612 ha) of the Ghataprabha left bank canal command area (46029.9ha) while only 12 per cent (5418 ha) had medium available potassium content (Binita *et al.*, 2009).

2.1.2.4 Available sulphur and micronutrients

Sakal *et al.* (1986) reported that the available Zn in the surface soil samples in sub- Himalayan hill and forest region of Bihar ranged from 0.15 to 7.80 ppm.

Badrinath *et al.* (1987) observed that available zinc varied from 0.3 to 1.08 ppm in saline soils of Ankola of coastal Karnataka.

The available Zn in the surface soil samples in old alluvial soils of Bihar ranged from 0.04 to 5.80 ppm with a mean value of 0.66 ppm (Sakal *et al.*, 1988).

Balanagoudar (1989) studied 15 soil bodies representing red, black and lateritic soils in North Karnataka for sulphur status and forms of sulphur. The available sulphur content in different soils in surface in decreasing order was red soils > black soils > lateritic soils.

Katyal and Sharma (1991) reported that available zinc varied from 0.12 and 2.80 mg per kg soil in Indian soils. It was nearly one hundredth of the total zinc in Indian soils. The data on available zinc status and available iron status of soils of Karnataka state indicated that about 79 per cent of area of soils has zinc deficiency.

Ashok (2001) examined 12 soil series representing black, red and coastal soils from different agro-climatic zones of Karnataka and 12 surface soil samples from each series are analyzed for sulphur status and distribution of different forms of sulphur, relationship between sulphur and various soils properties. The CaCl₂ extracted sulphur content in black, red and coastal soils ranged between 5.08 - 59.95 ppm, 8.66 – 27.15 ppm and 7.26 – 20.32 ppm, respectively.

Satyavathi and Suryanarayana Reddy (2004) studied fifty four soil samples from ten pedons of Telangana region, Andhra Pradesh for vertical distribution of DTPA-extractable Zn, Cu, Fe and Mn and their relationship with some soil properties. Soil pH, calcium carbonate, organic carbon and particle size fractions had strong influence on the distribution of these micronutrients. The content of micronutrient increased with the increase in organic carbon and decreased with increase in pH and CaCO₃. There was no definite trend for the distribution of these micronutrients with respect to depth. As per critical limit prescribed for Zn and Fe, 44 and 20 per cent of the soils could be rated as deficient in available zinc and iron respectively. Copper and manganese were found to be adequate.

In view of wide spread micronutrient deficiencies, soils of Bhanapur micro watershed in northern dry zone of Karnataka were studied for their availability by Srikanth *et al.* (2008b). DTPA extractable Fe, Mn, Zn and Cu were found to be adequate in major part of the area. Mapping of available micronutrients status by GIS technique revealed that, out of 581.96 ha area of micro-watershed, 85.46ha was in deficient category, 61.06 ha in sufficient category and 435.44ha in excess category with respect to available Fe status. The entire study area was sufficient in manganese. Major portion of study area (349.94 ha) was under sufficient rating for available zinc status and deficiency of the available Zn was found in 232.02 ha. Available copper content of the study area was under both sufficient (342.34 ha) and deficient (239.62 ha) ratings.

About 27 percent (12420 ha) of the Ghataprabha left bank canal command area (46029.9 ha) was low in sulphur content, 69 percent (31563 ha) was medium and only 4 per cent (2047 ha) was found to be high in sulphur content (Binita *et al.*, 2009).

2.2 Profile Properties

Pradeep Kumar and Verma (2005) characterized and classified seven representative pedons from rice growing soils of Palam valley. Most of the pedons had mottles and sandy loam to silt clay loam in texture with low permeability. In general, the soils were moderately acidic to neutral in reaction, high to very low in organic carbon, mixed in mineralogy and moderately deep to very deep. Bulk density decreased with depth and values ranged from 0.99 to 1.62 Mg per m³. Water retention at 33 kPa and 1500 kPa of soils ranged from 19.9 to 47.2 per cent and 8.1 to 33.2 per cent, respectively. Cation exchange capacity decreased and soil pH, N increased with depth but no definite distribution pattern was observed for P and K. The status of N and P was low to medium and that of K as low to high. Based on soil characteristics, the soils were classified as Typic Hapludalfs and Typic Dystrochrepts.

Based on the properties, the soils of Marpaka watershed are grouped under the orders viz., *Entisols*, *Inceptisols* and *Alfisols* by Santhoshi *et al.* (2011). The pedons 6 and 7 were placed under *Entisols* as they did not exhibit any diagnostic horizon and character as *Orthents*. They were placed under Ustorthents subgroup due to 'ustic' soil moisture

regime. The pedons 1, 2, 4 and 5 were placed under *Inceptisol*. The pedon 3 was placed under *Alfisol*.

2.2.1 Morphological properties

Distinct horizons are not discernible in black soils due to argillo pedoturbation which disturbs the soil horizons and impeded the process of propedanisotropic factor developing an isotropic properties within the soil (Bhattacharjee *et al.*, 1974). In general, presence of subangular blocky to angular blocky structure is commonly noticed in India (Roy and Barade, 1962). A review of soil survey reports on the black soils of Tungabhadra project area revealed that the various soil series described by them consisted of granular blocky in 'Ap' horizon which grades to subangular blocky to angular blocky with slicken sides on their faces in some cases (Murthy *et al.*, 1972).

Esu and Ojanugal (1985) while studying morphological, physical and chemical characteristics of alfisols occurring in Nigeria observed that soil texture varied from sandy loam to gravely clay loam in the sub soil with high silt fractions and relatively low in the surface soil.

Reddy *et al.* (1993) studied morphological and physico-chemical properties of red soils (Alfisols) occurring under irrigated and unirrigated conditions and observed that the texture of soils ranged from sandy loam on the surface to sandy clay loam in the sub soil. Colour of the Bt horizon in all irrigated soils was reddish brown where as in unirrigated soils; it was dark reddish brown.

Alur (1994) studied the morphological, physical and chemical properties of ten red soil pedons from northern dry zone (Zone-3) of Karnataka with the objectives to understand their genesis and to classify them as per U.S. Taxonomy. Among the ten pedons, seven were from granitic area, two from schist and one from sandstone area. Soils derived from a granitic and sand stone rocks exhibited predominantly redder hue (2.5 YR) and soils derived from schist exhibited uniformly yellower hue (5 YR). The structure was weakly to moderately developed and moist consistency ranged from friable to very friable. They were slightly sticky to sticky and non-plastic to plastic when wet. Majority of the pedons were characterized by high gravel content. Sand comprised more

than 50 per cent of the mineral matter. Clay and fine clay contents increased with depth. The texture was sandy loam at the surface and sandy clay loam in Bt horizons of all the pedons.

Sharma *et al.* (1996) observed while characterizing soils in a toposequence over basaltic terrain of southern Rajasthan that the soils at elevated topography were shallow to moderately shallow depth, clayey to loamy skeletal texture and yellowish brown, while at lower topography soils were deep to very deep, fine to fine loamy texture and grayish colour.

Gobin *et al.* (2000) tested the hypothesis that readily observed and easily measured morphological variables can be used to characterize the soils sampled and described in southeastern Nigeria for purposes of land use and management. Field tests were developed for estimating soil texture and amount of ironstone nodules. Two new soil colour indices provided an immediate means of diagnosing the soil drainage regime in case of the colour index (CI) and soil forming processes in tropical soils in case of the redness index (RI). The indices correlated negatively with organic C content ($r = -0.39$) and positively with dithionite extracted Fe_2O_3 (0.44) and Al_2O_3 (0.51). Inexpensive field tests for colour, texture and ironstone can be quantified using colour indices and laboratory measurements. The local soil classification was quantified by means of colour indices (RI, CI) and percentages of ironstone, sand, silt and clay measured in the A horizon. A classification based on soil texture, ironstone and colour was used to define classes for the B horizon. The two first principal components (PC) extracted from soil morphological variables measured on the upper three horizons of 72 pedons explained 64.7 per cent of the total variance.

Santhoshi *et al.* (2011) reported that soil depth of Marpaka watershed varied from shallow to deep. The soils on the valley were deeper compared to the soils of pediplain middle, upper and linear ridges and dolorite dykes. The colour of pedons varied from 2.5 YR to 10YR. Soil structure varies from weak to strong and granular and massive. Pedon 7 had weak structure in the surface layer only. All pedons showed well developed structure in the subsurface indicating moderate to high degree of soil development.

2.2.2 Physical properties

2.2.2.1 Particle size analysis

Roy and Landey (1962) working with red and lateritic soils of Mond watershed area of Raigarh district observed that clay content of soil increased with depth but stabilized at second or third horizon.

Parvathappa (1981) reported that clay content increased with depth mainly because of illuviation in the irrigated soils of Karnataka. Marked change in the particle size distribution of soils in different horizons of soil profile due to irrigation has been reported. The process of eluviation and illuviation were the main factors responsible for bringing out the alterations in the physical and chemical makeup of the soil profile and its development.

Characterizing the red and laterite soils of Northern Plateau Zone of Orissa, formed on highly weathered material, Sahu *et al.* (1990) observed that the content of clay increased with the depth in all the profiles with a simultaneous decrease in sand content indicating well drained condition. Illuviation of clay was evidenced by presence of argillic horizon in the soil.

Sharma *et al.* (1997) studied the physical properties of two soils (Alfisols and Inceptisols) from different command areas of Assam and observed that bulk density was higher in Alfisols than in Inceptisols and it increased with depth in both the soils. The surface layer of both soils contained higher percentage of aggregates less than 0.25 mm when compared to subsurface layers. The clay content was found to be the single most dominant factor influencing the physical attributes of soils in the area.

Gravel and sand contents of Marpaka watershed were higher in the soils of pediplain upper and linear ridges and dolorite dykes, where as silt and clay contents were higher in valley and pediplain lower. Soils of pediplain upper were sandy clay loam in texture and valley were clay loam with high percentage of clay content (Santhoshi *et al.*, 2011).

2.2.2.2 Bulk density, surface area and water holding capacity

Hirekurubar *et al.* (1991) reported about some physical properties of Vertisols derived from different parent materials of Northern parts of Karnataka. Water holding capacity, available water capacity, plasticity index, specific area and total porosity were

higher in the soils derived from chlorite schist and aggregation indices were higher in the soils of shale origin. These physical properties were lower in the soils developed from limestone. Bulk density, macro-porosity and steady state infiltration rate were higher in the soils derived from lime stone.

Gaddi (1995) reported that maximum water holding capacity in the black soils was higher (43.8 to 37.9%) in Agro-climatic Zone-8 of Karnataka.

Rajeev Srivastava *et al.* (1998) studied the water retention characteristics of five swell-shrink soils of Chandrapur district, Maharashtra. The study showed that water retentivity at 33 kPa and 1500 kPa tension was significantly and positively correlated with clay, silt + clay, CEC and $\text{exch. Ca} + \text{Mg}$ and negatively correlated with sand content. The effect of organic carbon content on water retentivity, both at 33 kPa and 1500 kPa tension, was found non-significant due to low and similar content of organic carbon in these soils. The multiple regression equations were also developed to predict water retentivity using clay content and CEC values.

2.2.3 Chemical properties

2.2.3.1 pH

Bhadrapur and Seshagiri Rao (1979) and Patagundi *et al.* (1996) reported an increase in pH with depth in black cotton soil in Tungabhadra project area irrigated for 33 years. The pH values were higher in irrigated soils as compared to unirrigated soils. Higher proportion of exchangeable sodium in the irrigated soils seems to be the reason for higher pH (Gundlur, 1991).

The soils of eastern Himalayas were extremely acidic and surface horizons were having lower pH compared to subsurface horizons (Das *et al.*, 1988).

Sharma and Qaher (1989) working with forest profiles derived from Gneiss and Schist type of parent materials revealed that in most of the soil profiles pH of the soil did not show any specific trend with the depth.

While characterizing and classifying lateritic soils of North Karnataka, Narayana Rao *et al.* (1993) reported that the pH of soil measured in water was slightly less than 6.5

and increased with depth. The pH measured in KCl was slightly lower than that measured in water.

Soils of Bangalore district were found to be acidic to near neutral and showed decreasing trend with the depth (Reddy *et al.*, 1993).

Santhoshi *et al.* (2011) reported that soils are moderately acidic to moderately alkaline in reaction and this wide variation is attributed to the nature of parent material, leaching, presence of calcium carbonate and exchangeable sodium.

2.2.3.2 Electrical conductivity

Electrical conductivity of Northern Karnataka soils ranged from 23.1 to 13.8 dS m⁻¹ and decreased with depth (Bhadrapur and Sheshagiri Rao, 1977).

Sivasankaran *et al.* (1993) while characterizing the soils of Western Ghats in Karnataka observed that the electrical conductivity values ranged from 0.1 to 0.4 dS m⁻¹ indicating no accumulation of salts in the soil.

While characterizing the soils of the Trans-Yamuna Plain, Walia and Rao (1996) reported that the electrical conductivity of these soils were very low ranging from 0.08 to 0.4 dS m⁻¹ and did not show any specific relationship with the depth indicating the low amount of soluble salts in the soil.

According to Pillai and Natarajan (2004) the electrical conductivity of the soils of Garakahalli watershed ranged from 0.02 to 0.20 dS m⁻¹ indicating non-saline nature of the soil. However, these soils did not show any relationship with depth. This may be due to the undulating nature of the terrain coupled with free drainage conditions, which favoured the removal of released bases by the percolating and drainage water. The Inceptisols and Entisols of Shahibi basin in Haryana and Delhi were non-saline with electrolyte concentration ranging from 0.18 to 0.95 dS m⁻¹ (Swarnam *et al.*, 2004).

The soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh showed very low electrical conductivity values ranging from 0.02 to 0.36 dS m⁻¹, suggesting the presence of very low amount of soluble salts (Thangasamy *et al.*, 2005). The forest soils of North Karnataka were non-saline with EC values ranging from 0.01 to 0.07 dS m⁻¹ (Shamsudheen *et al.*, 2005). The Entisols and Inceptisols of Shikohpur

watershed of Gurgaon district, Haryana were non-saline with electrolyte concentration ranging from 1.05 to 1.40 dS m⁻¹ in surface layers and 1.00 to 1.50 dS m⁻¹ in sub-surface layers (Sitanggang *et al.*, 2006).

2.2.3.3 Organic carbon

Walia and Rao (1996) working with red soils of Bundelkhand region of Uttar Pradesh noticed that the organic carbon content of soils (0.5 – 1.5%) decreased with depth, mainly due to the changes in land use.

The organic carbon content of lateritic soils (Bangalore plateau) varied between low to medium and showed decreasing trend regularly down the profile (Shivaprasad *et al.*, 1998).

The organic carbon content in soils of Chandragiri mandal of Chittoor district, Andhra Pradesh varied from 0.6 to 6.3 g kg⁻¹ (plains), 0.8 to 4.1 g kg⁻¹ (uplands) and 3.7 to 6.6 g kg⁻¹ (hill slope). Irrespective of landforms, the organic carbon decreased with depth (Basavaraju *et al.*, 2005). The organic carbon content invariably high in surface horizons and exhibited a declining trend with depth in forest soils as compared to cultivated soils (Sanjeev *et al.*, 2005). The organic carbon content decreased with the depth in soils of Sivgiri micro-watershed in Chittoor district of Andhra Pradesh. This could be due to the addition of plant residues and farm yard manure to surface horizons than in the lower horizons (Thangasamy *et al.*, 2005).

2.2.3.4 Cation exchange capacity and exchangeable cations

Sikka and Dastur (1960) reported the cation exchange capacity (CEC) values of certain cotton growing soils in India. The CEC of Akola and Nanded soils in Maharashtra were 50.0 and 58.6 cmol (p⁺) kg⁻¹ of soil. The CEC values of Kurnool soils in Andhra Pradesh was 50.0 cmol (p⁺) kg⁻¹ of soil. Coimbatore soil in Tamil Nadu showed CEC values of 26.9 cmol (p⁺) kg⁻¹ of soil. The CEC of Dharwad black soil, Raichur black soil and Raichur red soil in Karnataka were 62.0, 51.1 and 16.2 cmol (p⁺) kg⁻¹ of soil, respectively.

Cation exchange capacity in black soils ranged from 34.0 to 54.0 cmol (p⁺) kg⁻¹ of soil. It was high where fine clay fraction was also high. The high cation exchange capacity in these soils is consistent due to high clay content and the presence of smectite group of clay minerals (Landey *et al.*, 1982 and Das and Das, 1966).

Bhadrapur and Seshagiri Rao (1979) reported that exchangeable sodium percentage increased with depth in salt affected soils of Ghataprabha and Malaprabha command areas.

In some salt-affected soils of Purna command area of Maharashtra, the Exchangeable sodium per cent was in the range of 10 to 40 at varying depths, being relatively higher in upper horizons (More *et al.*, 1988).

Sahu *et al.* (1990) while studying soils of Northern plateau zone of Orissa observed that increase in cation exchange capacity increased with depth and was attributed to gradual increase in clay content with the depth of profile.

Gundlur (1991) opined that irrespective of the soil series and irrigated or unirrigated, exchangeable calcium plus magnesium formed the dominant exchangeable cations. The exchangeable calcium and magnesium varied from 47.6 to 48.3 cmol (p⁺) kg⁻¹ and from 49.2 to 52.6 cmol (p⁺) per kg in the unirrigated and irrigated profiles, respectively.

Shrikanth and Bapat (1993) compared the cation exchange capacity of soils formed from different parent materials and observed that cation exchange capacity of soil formed from sand stone ranged from 24.3 to 25.8 cmol (p⁺) kg⁻¹ and slightly increased with depth while that of soil formed on basalt decreased from 53.8 cmol (p⁺) kg⁻¹ in surface to 51.0 cmol (p⁺) kg⁻¹ in subsurface layers. Alluvial soils recorded the cation exchange capacity of 38.1 to 56.7 cmol (p⁺) kg⁻¹. Exchangeable calcium remained constant throughout the depth with the values of 11.0 and 37.8 cmol (p⁺) kg⁻¹ for soil derived from sand stone and basalt respectively whereas exchangeable magnesium recorded the value of 4 cmol (p⁺) kg⁻¹ (sand stone) and 10 to 12 cmol (p⁺) kg⁻¹ (basalt). Exchangeable potassium and sodium ranged from 4 cmol (p⁺) kg⁻¹ and 1.6 to 1.9 cmol (p⁺) kg⁻¹, respectively for sand stone and 0.5 to 0.8 cmol (p⁺) kg⁻¹ and 1.3 to 1.8 cmol (p⁺) kg⁻¹, respectively for basalt.

While characterizing the red soils of Manipur, Sen *et al.* (1993) observed that the cation exchange capacity and base saturation values showed decreasing trends with the depth.

While characterizing the lateritic soils of North Karnataka, Narayana Rao *et al.* (1993) observed that both cation exchange capacity and per cent base saturation values showed regular increasing trend down the profile.

Sen *et al.* (1997) while characterizing some of the soils of Barak valley in Assam observed that cation exchange capacity of the soils was generally low and it varied from 6 to 21 cmol (p⁺) kg⁻¹. The CEC of surface soils were high due to higher organic matter content.

Swarnam *et al.* (2004) stated that the CEC of the soils of Shahibi basin in Haryana and Delhi varied from 3.20 to 10.20 cmol (p⁺) kg⁻¹ soil and decreased with depth. Low CEC of these soils could be attributed to low content of clay and organic carbon. Sharma *et al.* (2004) stated that the CEC in the soils of Neogal watershed in North-West Himalayas ranged from 4.9 to 14.3 cmol (p⁺) kg⁻¹ soil. The difference in CEC between the soils was due to the varied type / content of soil colloids and soil pH values.

The CEC of the Garkahalli watershed soils was found to be low to medium. Maximum CEC was observed in the horizons where illuviation of clay from surface to sub-surface horizon had taken place (Pillai and Natarajan, 2004). CEC of the soils in Dindori district of Madhya Pradesh with smectitic mineralogy was higher (72.0 cmol (p⁺) kg⁻¹) as compared to the soils with mixed mineralogy (28.9 cmol (p⁺) kg⁻¹) (Patil and Jagdish Prasad, 2004).

The CEC values were higher in horizons containing high clay and/or high organic carbon content. Low values of CEC (9.0 to 11.5 cmol (p⁺) kg⁻¹) may be ascribed to the predominance of low CEC minerals, especially illite, in outer Himalayas (Sanjeev *et al.*, 2005). The CEC of the soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh ranged from 1.50 to 45.14 cmol (p⁺) kg⁻¹ soil which corresponds to their clay content in the respective horizons (Thangasamy *et al.*, 2005).

Singh and Agarwal (2005) reported that the CEC values of rice soils of eastern region of Varanasi were low to medium and consistent with clay fractions dominated by the illite and kaolinite minerals. The dominant basic cation was Ca²⁺ which influenced the development of the soils.

The cation exchange capacity of soils varied from 51.16 to 62.98 cmol (p⁺) kg⁻¹ and the soils which had lower amount of clay content had lowest CEC values in a micro-watershed of Vidharbha region in Maharashtra (Gabhane *et al.*, 2006). The CEC varied from 23.00 to 59.00 cmol (p⁺) kg⁻¹ soil with a tendency to decrease with depth but it was found closely associated with clay (r= +0.72) and clay plus organic carbon (r= +0.73) in grape growing soils in Nasik district of Maharashtra (Balpande *et al.*, 2007).

In Marpaka watershed the cation exchange capacity and extractable bases varied considerably among the soils. The cation exchange capacity varied from 13 to 24.8 cmol (p⁺) kg⁻¹. In all the soils, calcium was the predominant cation followed by magnesium and potassium. (Santhoshi *et al.*, 2011).

2.2.3.5 Base saturation

A detailed study of three Vertisols formed under semi-arid climate on deccan trap, limestone and gneiss was done. The soils under study are developed under similar set of factors of soil formation except parent rocks. However, the influence of parent rock is subdued in the solum as evident from the soil properties; they all are clay in texture, have more than 15 per cent exchangeable sodium and are highly calcareous. They contain less free iron and have Ca-P as the dominant P-fraction, indicating mild intensity of weathering (Dasog and Hadimani, 1980).

Gundlur (1991) opined that irrespective of the soil series and irrigated or unirrigated soils, exchangeable calcium plus magnesium forms the dominant exchange cations. The exchangeable calcium plus magnesium forms the dominant exchangeable cations. The exchangeable calcium and magnesium varied from 47.6 to 48.3 cmol (p⁺) kg⁻¹ and from 49.2 to 52.6 cmol (p⁺) kg⁻¹ in the unirrigated and irrigated profiles, respectively.

The per cent base saturation of the soils in upper Maul Khad catchment of Himachal Pradesh ranged from 45 to 62 indicating moderate soil fertility status. Among different cations, Ca²⁺ dominated the exchange complex followed by Mg²⁺, K⁺ and Na⁺ (Sharma and AnilKumar, 2003). According to Pillai and Natarajan (2004) the base

saturation of soils was medium to high due to the low to medium amount of rainfall in Garakahalli watershed of Bangalore rural district.

The base saturation in the soils varied from 31 to 92 per cent and exchangeable bases were in the order of $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ > \text{K}^+$ in soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh (Thangasamy *et al.*, 2005). Soils in watershed area of Sikohpur, Gurgaon district, Haryana were highly base saturated (70 to 93%) indicating low degree of leaching and also showed tendency to increase with depth and followed the distribution pattern of pH (Sitanggang *et al.*, 2006). Ca^{2+} was the dominant cation on the exchange complex followed by Mg^{2+} , Na^+ and K^+ in grape growing soils in Nasik district of Maharashtra (Balpande *et al.*, 2007).

2.2.4 Classification

Any natural object having many variants may not be easy to classify. The multitude of characteristics involved in the variant make the grouping difficult. The soil is a typical example wherein number of variants influencing its origin is large. Therefore, in order to understand differences similarities and relationships among different members, it is necessary that these are grouped in some orderly manner.

Classification is the grouping of objectives in some orderly and logical manner into compartments. It is based on the properties of objects for the purpose of studying, identifying and grouping them. The properties are selected in accordance with the purpose of classification. They are termed as differentiating characteristics and serve to differentiate one class from all others.

A new system of soil classification was presented by soil survey staff of USDA in the year 1975. According to recent edition of keys to Soil Taxonomy (Soil Survey Staff, 2006) this soils are classified into twelve orders based on their properties. Each order is further divided into suborders, great groups, subgroups, families and series.

Classification of red soils of India was initiated by Raychaudhari (1941), Govindarajan and Datta Biswas (1968) classified red loamy soils as Paleustalfs, Rhodustalfs and Haplustalfs and red sandy soils as Rhodustalfs and Haplustalfs.

Zende (1987) classified the soils of Nagaland in relation to physiography. The dominant soils are i) fine loamy, Typic Hapludults on every steep side slopes of high hills ii) loamy skeletal, Typic Udorthents on narrow ridges of high hills iii) loamy skeletal, Typic Hapludults on broad ridges of hills and Paleudults on steep slopes of high hills and very low hills.

The red and lateritic soils of Bangalore district (Karnataka state) were classified as kandic Paleustalfs and Kandic Rhodustalfs by Reddy *et al.* (1993).

Vijay Kumar *et al.* (1994) studied the twelve soils in Northern Telangana of Andhra Pradesh for their genesis and classification. The bulk density, CEC and clay at surface horizons ranged from 1.30 to 1.68 g per cc, 6.2 to 43.0 cmol (p⁺) kg⁻¹ and 17.4 to 54.1 per cent, respectively. Five soils are found with ochric epipedon and qualify for Inceptisols, three with argillic horizons and qualify for Alfisols, three with deep and wide cracks and qualify for Vertisols and one pedon with no profile development classified as Entisol.

Murthy *et al.* (1994) noticed that the Vertisols developed on basaltic parent material showed higher clay content, CEC, WHC and lower pH and EC. Irrespective of parentage, all the pedons were calcareous. Steep reduction in organic carbon was noticed in the basal and granitic – granodiorite parent material soils. Basalt, Granitic-granodiorite and Limestone parentage soils are placed under Calcic Chromusterts while Grey shale and Granodiorite parentage soils were classified as Typic Chromustert and Calcic Pellustert, respectively.

Diwakar and Singh (1994) reported that the fine textured soils of sedimentary and old alluvial origin are characterized by uniform colour (brown to very dark grey), mottles of various shades and intensities, neutral slightly alkaline reaction, low organic carbon and high clay content and high CEC and SiO₂ content. These have developed on varied types of parent materials at different physiographic levels under basic environment and impeded drainage. The sedentary soils have been classified as Udic Chromusterts, old alluvial soils as Udorthentic Chromusterts and chour land soils as Vertic Ustorthents. These soils have an average productivity and good potentiality. The productivity can be raised by 1.8 to 2.0 times by adopting appropriate measures.

Morphology, physical and chemical characteristics and land use plans of basaltic trap representing different landforms in Pratapgarh region of Southern Rajasthan were studied. The soils at elevated topography were shallow to moderately shallow, clayey to loamy skeletal and yellowish brown, while at lower topography were deep to very deep, fine to fine loamy and grayish. The influence of topography had a marked influence on properties like pH, CaCO₃, clay content, vertic properties, cation exchange capacity and exchangeable cations upto pedon 4, thereafter they were subdued by local ephemerals. The soils were classified taxonomically in Lithic/Typic Ustorthents, Typic Haplusterts and Typic Ustifluents sub-groups and lands use plans for the soils associated with each landform are proposed for its better management (Sharma *et al.*, 1996).

Rudramurthy *et al.* (1996) studied the morphological, physical and chemical properties of five pairs of associated red and black pedons to compare their properties and to understand their genesis. These associated red and black pedons were classified, as per the USDA Soil Taxonomy. All the red pedons except Mantagani and Bidar were classified as Alfisols at order level, due to the presence of argillic horizon, whereas Mantagani and Bidar red pedons failed to fulfill the requirements of Alfisols. Hence, they were put under Inceptisols. At suborder level Mantagani and Bidar red pedons were put under tropepts because of isomesic regime and all other red pedons under Ustalfs because of Ustic moisture regime. At great group level, Mantagani and Bidar red pedons were classified as Ustrophepts and the remaining red pedons as Haplustalfs. All the black pedons belonged to the order Vertisols and suborder Usterts. At great group level except Bheemaranagudi all were classified as Haplusterts and the Bheemaranagudi pedon as Calciusterts.

The soils of Karnataka belong to seven orders, 12 suborders, 27 great groups, 47 sub-groups and 96 soil families. Of the total area of Karnataka 27 per cent is covered by Alfisols, 25 per cent by Inceptisols, 16 per cent by Entisols, 15 per cent by Vertisols, 8 per cent by Ultisols, 5 per cent by Aridisols and 1 per cent by Mollisols (Shivaprasad *et al.*, 1998).

Soil characteristics and the taxonomy of the shrink-swell soils in the semi-arid tropical region of India are discussed. A new sub-group of Vertisols, with a mollic

epipedon, is proposed for extensive shrink-swelled soils in Maharashtra (Rajeev Srivastav *et al.*, 1998).

Challa *et al.* (2000) characterized and classified four representative problematic Vertisols occurring on upper and lower Maharashtra plateau distributed in continuously irrigated zone of Ahmed Nagar and Akola districts under semi-arid ecosystem. Khondwad and Kadambhe soils of piedmont plain are dark grayish brown while Amalnar and Valpi soils of flood plain are dark yellowish brown colour. Amalnar and Valpi soils of flood plain showed higher calcium carbonate content than the other soils. Khondwad and Amalnar soils showed high electrical conductivity at 1:2.5 soil water ratio while the other soils Khadambhe and Valpi showed high exchangeable sodium percentage. In all the pedons the sodium adsorption ratios increased with depth and attained maximum in slicken side zone. In general chlorides, sulphates and bicarbonates dominated in soil environment. All the pedons have zone of slicken side. Based on these properties the Khondwad and Amalnar soils are classified as Halic Haplusterts while other soils were grouped under Sodic Haplusterts.

Sahu *et al.* (2001) studied morphological features of four Vertisol pedons in the Western Zone of Orissa and characterized and classified them. The soils are very deep, colour ranges from black to grayish brown in different horizons, crack of 2 to 3 cm wide extends beyond 1 m, slicken sides, wedge shaped aggregates, iron, manganese and concretes were observed in the subsurface horizons of the soils. The soils imperfectly drained, slightly acid to moderately alkaline and the pH value increased with depth. The soils are base rich and high in CEC: clay ratio (0.65 to 0.75) and classified as Typic/Chromic Haplusterts.

2.3 Soil-site suitability for different crops

The most recent evaluation procedure has been introduced since the mid-seventies by FAO. It is a crop specific suitability system that is based on the comparison of plant growth and production requirements with prevailing environmental conditions. Five phases can hereby be distinguished 1) identification of the land utilization type 2) definition of its growth requirements 3) compilation of basic climatic, soils and physiological data of the study area 4) matching of those field data with the crop

requirements and 5) determination of the suitability classes on the basis of the nature and degree of crop growth constraints (Varade *et al.*, 1994).

Giri *et al.* (1994) evaluated soil-site suitability for maize. The area having an annual rainfall of 900 mm, soil depth 100 cm with sandy clay loam to clayey texture (27 - <60% clay) and with a good drainage is most suitable for maize.

The structure of the classification is based on the FAO framework for land evaluation. The classification includes four categories: orders, classes, sub classes and units. There are two orders (S, N), which reflect the kind of suitability (S for suitable and N for unsuitable). There are three classes (S-1 to 3) under the order S and two classes (N-1 and 2) under the order N, reflecting degree of suitability within the order. The appraisal of the classes, within an order is done according to evaluation of land limitations. The sub classes reflect the kinds of limitations or the main kinds of improvement measures required within a class. They are indicated by the symbol, using lower case letters following the Arabic numeral used for the class. The land suitability unit suggests the relative importance of land improvement works. It is indicated by Arabic numerals enclosed in parenthesis following the sub class symbol.

Information of soil and related properties obtained from the soil survey and soil classification can help in better identification of soil and land suitability for irrigation and in efficient irrigation water management. So, depending on the suitability of the mapped agroecological units for a set of crops, optimum cropping patterns have to be suggested taking into consideration the present cropping systems and the socio-economic conditions of the farming community (Sehgal, 1996).

Bhaskar *et al.* (1996) evaluated soil-site suitability for wheat on different soils of Saongi watershed. The effective range of soil depth was from 65 to 100 cm, AWC was from 170 to 200 mm, clay content was from 48 to 56 per cent, CEC was from 43 to 53 cmol (p⁺) kg⁻¹ and organic carbon was from 0.63 to 0.74 per cent. Saongi soils being deep to very deep, well drained, clay loam to silty clay loam in texture, moderate to high in clay, CEC, AWC and organic carbon were found genetically highly suitable.

Chinchmalatpure *et al.* (1998) studied the soil-site suitability of micro-watershed of Wunna catchment. Entisols are the dominant soils on the hill top and erosional

surfaces. These soils are marginally suitable for sorghum crop and unsuitable for pigeonpea. Vertisols are the dominant soils occurring on toe and concave slopes of basaltic transect, where the finer material from hill top and foot slope get deposited. These soils are very suitable for cotton, sorghum and pigeonpea. Inceptisols occur on the toe slopes of sandstone transect and these soils are marginally suitable for sorghum and unsuitable for pigeonpea.

Soils of Mandya (Typic Haplustepts), Bhadravathi (Typic Topaquepts) and Chikodi (Vertic Haplustepts) were moderately suitable for growing sugarcane with moderate limitations of nutrient status and relative humidity. However, the Jamkhandi soils (Typic Haplustults) were marginally suitable for growing sugarcane in Karnataka (Naidu and Hunsigi, 2001). According to Satyavathi and Suryanarayan Reddy (2004b), the soils of Telangana region in Andhra Pradesh were evaluated for crop suitability and reported that Typic Haplustalfs and Typic Rhodustalfs were moderately suitable (S2), Vertic Haplustepts, Typic Haplusterts and Chromic Haplustalfs were marginally suitable (S3) and Typic Ustipsamments were not suitable (N1) for growing groundnut crop.

Soil characteristics such as fine- texture, improper drainage, presence of lime and soluble salts in shrink swell soils and gravelly sub-soils and low fertility in lateritic soils are major constraints in sugarcane growing soils of Karnataka, limiting the cane production (Naidu, 2002).

Tamgadge *et al.* (2002) evaluated the soil suitability for paddy cultivation in Chattisgarh and reported that Udic Haplusterts, Entic Haplusterts, Chromic Haplusterts, Typic Haplusterts and Udic Haplustepts were highly suitable (S1) whereas Vertic Haplustepts and Typic Haplustepts were moderately suitable (S2) for growing paddy. Further, Plinthustalfs, Udic Haplustalfs, Typic Haplustalfs and Typic Rhodustalfs were marginally suitable (S3), Lithic Haplustepts and Typic Ustorthents were not suitable temporarily (N1) and Lithic Ustorthents was not suitable permanently (N2) for growing paddy in Chattisgarh.

The soils of Neogal Watershed in North-West Himalayas are moderately suitable (S2) and marginally suitable (S3) for growing paddy crop (Sharma *et al.*, 2004).

The soil suitability evaluation revealed that the soils of a micro-watershed in Vidarbha region of Maharashtra such as Typic Haplusterts and Vertic Haplustepts were found to be moderately suitable (S2) for growing cotton, sorghum and pigeonpea (Gabhane *et al.*, 2006).

Four typical pedons representing major landforms of Kiar-Nagali micro-watershed, developed from sedimentary rocks, comprising ferromagnesian shale and dolomites/dolomitic limestone and occurring at different elevations under varying land uses were studied by Tripathi *et al.* (2006) for their morphological characteristics and physico-chemical properties and suitability for locally preferred crops. As per Storie's Index the soil productivity potential of the micro-watershed area varies from non-agricultural to good. Nagali-I soils were found to be unfit for cultivation. Nagali-II and Kundla soils had good productivity potential. The land capability classes ranged from II to VIII. The agricultural land belongs to class II and III. The lands had limitations of slope and texture. Kundla and Nagali-II soils were highly suitable for commercial vegetable crops *viz.*, pea and tomato and marginally suitable for growing wheat and maize. The growing of pastures/forest trees/medicinal plants will be more effective/remunerative on Nagali-I soils.

Leelavathi (2007) evaluated soils of Yerpedu mandal of Chittoor district, Andhra Pradesh for soil suitability for six major crops (Groundnut, sorghum, maize, sugarcane, paddy and mango) grown in that area and reported that Ultic Haplustalfs, Typic Haplustepts, Ultic Haplustalfs, Typic Haplustepts and Typic Ustifluvents were moderately suitable (S2) for growing groundnut and sugarcane. Ultic Haplustalfs and Typic Haplustepts were marginally suitable (S3) for growing rice crop, while Ultic Haplustalfs, Typic Ustipsamments, Typic Haplustepts and Typic Ustifluvents were permanently not suitable (N2) for growing paddy.

2.4 Influence of soil-site characters on yield of crops

Soils are first categorized according to their suitability for sustained use based on soil properties. They are then put into land capability classes according to physical factors (topography, drainage and water quality) and socio-economic factors. Separation of land

capability classes is made on specified limits of soil properties and other physical parameters (Anon, 1953).

Among the soil-site characteristics, the major factor responsible for such differences in growth, duration and yield was moisture storage capacity in the profile of each soil. Soil depth and texture are the major characteristics for variation in total plant available water holding capacity. Deeper the soil and finer the texture, greater is the capacity of soil for water retention and supply to plants for better growth and yield (Gajbhiye *et al.*, 1988).

Rao (1991) determined the land capability classes and irrigability classes based on the limitations and potentials of soils. Wani-1, Aniv and Rajapur soils have limitations of slight erosion and are classified as II e lands. A wide range of crops can be grown on these soils. Dhaga and Wani-2 soils with the limitations of erosion and soil depth are rated as III e and III es lands. These soils may be protected by growing cover crops. Nippani soils have limitations of shallow depth and severe erosion and qualify for IVes lands. These soils require proper soil conservation measures and proper vegetation cover should be maintained to prevent soil erosion.

Sehgal (1991) reported the rainfall of about 1000 mm, soil depth of 60-100 cm, and CaCO₃ content of less than 20 per cent to support good crop of cotton. The critical limit of available water holding capacity has been observed to be 100 mm, below which the yields are uneconomical. Rainfed cotton has been observed to give best yield on deep and fine textured soils having good structure.

Productivity indices for 16 soils developed under different agro-climatic regions were calculated by giving the ratings for different limiting soil characteristics. It is seen that for wheat, a well drained, medium textured soils with cambic diagnostic horizons (Vijalpur and Tulewal) are highly productive. It suggested the reliability of soil parameters such as drainage, texture, lime content, fertility status and salinity for soil site suitability evaluation for wheat (Sharma and Sharma, 1991).

Vittal *et al.* (1991) measured effects of variations in topsoil depth on finger millet yield, without and with fertilizer application on alfisol over two seasons. Significant

positive correlation was recorded between the yields and depth of topsoil under varying rainfall and fertilizer condition. The data showed that the rainfall effect was constant while topsoil showed an interaction with fertilizer. Without fertilizer, the rainfall dominates the topsoil effect while with fertilizer, the topsoil dominates the rainfall effect in increasing the yields of the finger millet.

Yield difference of soybean crop among landscape positions have been attributed to soil erosion and difference in plant available water, soil texture, bulk density and surface soil thickness (Brubaker *et al.*, 1993). For the best maize production, the area having annual rainfall of 900 mm, soil depth of 100 cm with sandy clay loam to clayey texture (27 to 60% clay) and with good drainage is most suitable. Soils with very shallow depth having very high clay content, poor drainage or excessive slopes are appeared to be unsuitable (Giri *et al.*, 1994).

The yield influencing factors were evaluated for different crops. The plant available water holding capacity (PAWC) appeared to be the most yield-influencing factor followed by CEC, clay, depth and CaCO₃ content, CEC and clay content for cotton; and clay content followed by PAWC, CEC, depth and CaCO₃ for soybean. The results may be applied for higher production of these crops through proper utilization of similar soils occurring in the same agro-climatic sub-regions under scientific management practices. This confirms the hypothesis of transfer of soil based agrotechnology by way of validation thus facilitating extrapolation of the results to similar soils in the same agro ecological region (Khandse and Gaikawad, 1995).

The productivity behavior of cotton, sorghum and wheat in the soils occurring on particular land form suggests that crop management based on soil and site characteristics will be advantageous for higher production and hence the appropriate crops and levels of management could be selected according to soil scapes for realizing better crop yield (Ravindrachary *et al.*, 1995).

Yadav *et al.* (1995a) derived that soil-cum-climatic parameters viz., PAWC, soil effective rainfall and the length of growing period (LGP) being directly associated with soil depth and clay content, showed significant and positive 'r' value in cotton, pigeon pea, groundnut, sorghum and soybean. Further, lime content also showed significant

contribution towards the yield of pigeon pea and groundnut showed the quadratic relationships of PAWC and effective rainfall with pod yield. Soybean showed quadratic relation with PAWC and linear relationship with effective rainfall.

Statistical models for predicting cotton yields have been developed through relationship amongst different soil site characteristics, input management and the consequent plant growth parameters based on two years study at Khapri watershed. From the study it was concluded that the best prediction of cotton yield could be made with model-1 having ten variables (sand %, clay %, organic carbon %, CaCO₃ content, rainfall, LAI at 60 and 120 DAS, DMA at 30 and 120 DAS and total rainfall) explaining 99 per cent variation in yield (Yadav *et al.*, 1995b).

Shivaramu *et al.* (1997) reported the influence of soil and landscape characteristics under two management levels (low and optimum) on sorghum. Soil erosion and drainage among the site characteristics and soil depth, per cent clay, PAWC, LGP and CEC among the soil parameters being the important yield contributors. Yadav and Shivaramu (1997) reported that the total PAWC was the prominent factor among others influencing the growth and yield of groundnut. When the rainfall was enough and well distributed, other soil characteristics *viz.*, CaCO₃ and sand contents were also favorable for groundnut growth along with total PAWC.

Shivaramu *et al.* (1998) reported that soil characteristics namely per cent slope, depth and per cent silt had significant correlation with grain yield of wheat at low management level, while at optimum level, the depth, PAWC and LGP were found to be important yield contributors.

Yadav *et al.* (1998) reported that up to six per cent slope, there was a steep reduction in the productivity, while it was gradual up to seven per cent and there after it showed no effect. The soils having less than two per cent slope, performed better on an average of three years. The relationship between the effective soil depth and seed cotton yield was more of linear type than that of quadratic nature, within the range of soil depths of 100-160 cm.

Black soils (Vertisols and associated soils) constitute a major group of soils occurring in central and peninsular India. While their high water retentivity and ability to release water over a wide suction range make them suitable for dry land agriculture, their poor internal drainage and high run off potential pose serious problems for sustained crop productivity. Rain water management practices such as planting of crops on beds, use of vegetative hedges, inter-plot water harvesting and run off farming lead to enhancement in crop productivity and sustainability of rainfed production systems (Gupta, 2002).

Strategy to develop a watershed based on soil resources inventory, capability based land use and crop suitability of arable and non arable lands was undertaken at Kuthanagere watershed near Bangalore between 1992 and 1999 in Southern Karnataka, India. Soil resources inventory revealed 13 soil series and 40 mapping units in the watershed. Kuthanagere-1, 2, 3 and 6 soil series were found highly suitable for finger millet and pigeon pea and Kuthanagere-4 and 11 for the latter and Kuthanagere-7, 9 and 11 soil series were highly suitable for groundnut. The yield performances of these crops in different soils have been studied in the light of the variability in land characteristics especially slope, available water holding capacity and the length of growing period (Krishnappa *et al.*, 2004).

Major soils of Telangana region in Andhra Pradesh were evaluated for their suitability for castor, chickpea, cotton, groundnut, maize, and sorghum cultivation using limitation method regarding number and intensity of limitations. The soils belong to Vertisols, Alfisols, Inceptisols and Entisols soil order. Drainage, texture, coarse fragments, soil depth, pH and organic carbon are the limitations for crop growth in all the soils. The limitation levels of the land characteristics varied from crop to crop. (Sathyavathi and Suryanarayana Reddy, 2004).

Vadivelu *et al.* (2004) evaluated the soils of two different areas, one in the Brahmaputra valley and other in the Deccan plateau for commonly cultivated crops, though several characters used for the evaluation, only a few of them decide the suitability class of the land. In the Brahmaputra valley, soil texture, pH, organic carbon and inundation decide the suitability of land for growing rice, potato, cabbage, tomato, French bean, peas and cowpea. In the Deccan plateau, soil depth, slope, erosion, clay

content and organic carbon decide the suitability of the land for growing crops such as cotton, pigeon pea, sorghum and banana.

Tripathi *et al.* (2006) at Solan, Himachal Pradesh reported that Nagali and Kandali-II soils have good productivity potential and belongs to land capability class II and III. These lands have limitations of slope and texture and they were highly suitable for commercial vegetables such as peas and tomato and marginally suitable for growing maize and wheat.

2.5 Mapping of soils using GIS

This pilot study was oriented by David and Judith (1996) towards the characterization of vegetation in the Upper San Pedro River Watershed, southeast Arizona. Change detection necessitates the selection and identification of a number of ground control points located on all of the images and within a map base. These data layers were integrated into a GIS and the subsequent change detection techniques employed. The images depicting change clearly show that most change occurred along the Riparian corridors and the upper Bajadas. This is probably due to increased urbanization, grazing, and to some degree and riparian protection.

A soil loss model was executed by Christopher and Chandra (1998) within a GIS environment to evaluate agricultural management strategies in terms of soil loss on two agricultural watersheds. The GIS provided a fast and efficient means of generating the input data required for the model and allowed for easy assessment of the relative erosion hazard over the watersheds under the different land management options. The model predicted substantial declines in soil loss under conservation-oriented land management compared to current land management for both watersheds. The results of this study indicate that soil loss potential on the Soufriere watershed is approximately four times higher than on the Marquis watershed. This study represents the first attempt in the application of GIS technology to watershed conservation planning for St. Lucia.

A study was undertaken to map the nutrient status of Mirjan village under coastal agro ecosystem of Karnataka by Dhanya *et al.* (2009). The soil analysis showed the deficiency of N, P, K and Zn in the study area. From the soil fertility maps it was

observed that in the study area 247.30ha was low (69.5% of study area, 86.50 ha medium and 22.14 ha high in available nitrogen. An area of 249.30 ha was low (70.0% of the study area), 88.40 ha was medium and 18.32 ha was high in available phosphorus. In the case of potassium 159.15ha was low (44.7% of the study area), 131.71 ha medium and 65.39ha high in available potassium. Zinc deficiency was observed in 201.21 ha (56.5% of the study area).

An investigation was conducted by Binita *et al.* (2009) to study the soil fertility status of Ghataprabha Left Bank canal (GLBC) command area to evaluate the status of major nutrients as affected by the different physiographic units. The fertility maps were prepared for the area using Arc view 3.1 and spatial analyst using spline function for interpolation. The nutrient status was discussed in relation with physiographic position and cropping pattern. Due to intensive irrigated agriculture in the command area, the nutrient status did not follow any distinct trend with respect to physiographic units and crop grown. Based on the overall assessment, the nutrient status in these soils was optimum.

An attempt was made by Ravi kumar *et al.* (2009) to determine the land suitability for different crops of the soils under 48A distributary of Malaprabha Right bank command in Karnataka. The soils were classified at family level as very fine, smectitic, calcareous, isohyperthermic, typic halpusterts. Two soil series viz., Kiresur and Hnchinal were identified in the study area and were mapped into six mapping units.

The digital data from Linear Imaging Self Scanner (LISS)-IV sensor on board IRS-P6 satellite along with survey of India toposheets of the study area were used in the study of natural resources of the watershed. Sample strips were selected for ground truth. Pedons were examined and morphological characteristics, physical and chemical properties were described and soil map was prepared on 1:10000 scales. Soil map was super imposed on physiographic map under GIS environment. The soils are classified under six taxonomic units viz., Typic-Haplustepts, Typic Haplustalfs, Vertic Haplustepts, Typic Ustorthents, Lithic Ustorthents, Lithic Haplustepts. The study showed close relationship between physiography and taxonomic units. (Santhoshi *et al.*, 2011).

The spatial pattern of annual soil erosion rate of forested mountainous sub-watershed in Kerala, India was obtained by integrating geo-environmental variables in a raster based GIS method. GIS data layers including, rainfall erosivity (R), soil erodability (K), slope length and steepness (LS), cover management (C) and conservation practice (P) factors were computed to determine their effects on average annual soil loss in the area. The resultant map of annual soil erosion shows a maximum soil loss of 17.73 t h⁻¹ y⁻¹ with a close relation to grass land areas, degraded forests and deciduous forests on the steep side-slopes (with high LS). The spatial erosion maps generated with RUSLE method and GIS can serve as effective inputs in deriving strategies for land planning and management in the environmentally sensitive mountainous areas (Prasannakumar *et al.*, 2012).

The study has been done by Anil *et al.* (2012) through Remote Sensing and GIS approach using SOI topo sheets, and IRS LISS-III 1998, IRS LISS-III 2010 satellite data. The present study has brought to light that the land use/land cover classes like built-up land has increased from 15.38% to 27.71% during 1998-2010 with a net increase of 12.33%, industrial area has increased from 6.48% to 8.32% with a net increase of 1.84% during the years 1998-2010 and also area under plantations has increased from 10.42% to 10.87% during 1998-2010 with a net increase of 0.45%. But some classes like forest area have decreased from 27.95% to 18.34% with a net decrease of 9.61% during the years 1998-2010.

The study area, Bandu watershed is under the upper catchment of Kasai river, Purulia district is a drought prone district of the West Bengal. In spite of considerable amount of rainfall, due to heavy runoff the main problem of this area is scarcity of water as well as soil erosion. It has been accepted that for sustainable rural livelihood water and soil conservation is a must. The most suitable way to achieve this is micro-watershed development. But there is an acute shortage of technical manpower to handle such a huge volume of survey related work. For that reason, application of Remote Sensing and GIS has become a necessity (Ajoy *et al.*, 2012).

An attempt was made by Reshma *et al.* (2012) to evaluate the drainage morphometrics of Upper South Koel Basin using Remote Sensing and GIS approach.

The stream numbers, orders, lengths and other morphometric parameters like bifurcation ratio, drainage density, stream frequency, shape parameters etc. were measured. The drainage area of Upper South Koel watershed is 942.4 sq km and the drainage pattern is dendritic. The watershed was classified as 6th order drainage basin. The low values of bifurcation ratio and drainage density suggest that the area has not been much affected by structural disturbances.

2.6 Performance of finger millet genotypes

Annapurna had the highest average number of tillers plant⁻¹ (10.8) than purna and Cauvery. The higher yield in Annapurna might be due to the fact that Annapurna had more number of tillers plant⁻¹ (Krishnamurthy, 1971)

Puttaswamy (1973) reported that finger millet produced about 5, 34, 51 and 89 per cent of the final dry matter at tillering, flag leaf stage, heading and grain filling stages respectively. The same study indicated varietal differences in total dry matter production and its distribution to various plant parts. Purna variety produced more dry matter than EC 4840. Similarly, partitioning of dry matter into different plant parts did not differ between varieties in the initial stages but it differed at later stages, particularly grain filling and maturity.

Murthy and Murthy (1977) reported that time taken for panicle initiation was 25 days and panicle initiation to panicle emergence was 40 days in Aruna cultivar and long in PR 202 (45 and 65 days) whereas they were medium (39-55 days) in VZM-1 and Annapurna.

Subramanian (1980) observed genotypic differences with respect to grain yield. Indaf-5 produced highest grain yield (5817 kg ha⁻¹), which was superior over EC 4840 (5289 kg ha⁻¹), Indaf-1 (5007 kg ha⁻¹) and TAH 14-26 (4840 kg ha⁻¹). Higher grain yield in Indaf-5 was attributed to higher grain weight plant⁻¹, moderate ear number plant⁻¹ and moderate grain weight ear⁻¹.

Algarswamy and Bidinger (1985) observed total dry matter, higher grain yield but lower number of productive tillers plant⁻¹ and a lower harvest index from long duration finger millet.

Krishnamurthy (1996) found that variety Indaf-8 recorded higher grain yield (2740 kg ha⁻¹) followed by Indaf-9 (2540 kg ha⁻¹). HR 374 recorded the lowest grain yield (2380 kg ha⁻¹). Highest grain yield in respect of Indaf-8 was attributed to increased values in growth and yield parameters.

Ashoka (1996) reported that pre-released genotypes GPU-26 recorded significantly highest grain yield of 3006 kg ha⁻¹ compared to other pre-releasing genotypes VL 149 (2749 kg ha⁻¹) and ruling PR-202 (2304 kg ha⁻¹) and indaf-8 varieties (2420 kg ha⁻¹). The highest yield in GPU-26 was mainly due to the highest values of yield components.

Mallikarjuna Hosapalya (2005) reported that among the different local finger millet genotypes (*viz.*, *Butti ragi*, *Kulla ragi*, *Unde ragi*, *Pichakaddi ragi* and *Bilimunduga ragi*) *Unde ragi* recorded maximum plant height, tillers plant⁻¹ (20), ear heads plant⁻¹ (49), length of ear head (7cm) and higher grain and straw yield at wider spacing under organic farming.

Sharathbabu *et al.* (2008) reported that the genotypes IE 2303 showed the highest mean grain yield per plant (18.04g) while IE 2995 exhibited the lowest mean grain yield per plant (9.84 g) and the average grain yield per plant. The genotypes namely GPU 28, Dapoli White, IE 2875, IE 2976, IE 2907, IE 2860, and IE 2889 recorded grain yield per plant more than population mean, non significant regression coefficient and non significant deviation from regression revealed their adaptation to all the environments with predictable performance

Rashmi *et al.* (2010) reported that among the 4 genotypes ('GPU 45', 'VR 708', 'VL 149' and Local check) of newly developed finger millet genotypes suitable for western Himalayan hills under rainfed conditions, 'VL 149' produced significantly higher grain and straw yields.

From the above reviews it can be concluded that, genotypes differ in their growth, tillering capacities, dry matter production, days taken to maturity and in yield and yield components.

2.7 Crops and cropping systems on watershed approach

A report from Tamilnadu Agricultural University (Anon., 1981) revealed that it was possible to take up two crops in a year after the implementation of soil and water

conservation measures compared to three crops in two years before the implementation of the Ram Ganga project.

From Central Research Institute for Dryland Agriculture (Anon., 1987) reported that the cropping intensity in 18 model watersheds increased by 30 per cent over a period of three years. The study also reported an increase in area under silvi-pasture with *susbania* and stylo (70 hectares) in Mir watershed and afforestation with *Acasia auriculiformis*, *Leucaina leucacifola* and *Eucalyptus* (227 hectares) in Mittemari watershed.

The impact of watershed programme on adoption and economics of technology and economic conditions of rural people was studied by Reddy and Walker (1987). They reported that 12 per cent area under sole crops in Mittemari watershed area in Karnataka as compared to 16 per cent in non-watershed villages. It was also observed that area under improved varieties was 92 per cent in watershed villages as against 69 per cent in non-watershed villages during the *Kharif* 1986.

Hanumanthaiah and Nataraj (1989) observed a radical change in land use pattern in Chinnatekur watershed area of Kurnool district of Andhra Pradesh pre and post-watershed development periods. The study revealed an increase in dry-cum-wet area, while the dryland area had declined in the post watershed period. The cropping pattern and new crops like redgram occupied larger area after five year period of watershed development.

While analyzing the economics of watershed development programme at Chinnatekur of of Kurnool district of Andhra Pradesh. Nataraj (1989) observed that there was an increase of 38 per cent in cropping intensity on small and marginal farms in watershed project area while the increase was 77.66 per cent on large farms.

Reddy and Walker (1990) revealed that the adoption of intercropping system was higher in watershed areas accounting for 60 per cent of the total cropped area as against 15 per cent in non-watershed area at chevella watershed. Higher area under improved varieties was observed in villages of Mittemari watershed. Further studies on diversification of cropping systems and its economics of the watershed in Chevella and

Mittemari by Hafeez *et al.* (1991) indicated that watershed management made a significant impact on crop diversification and stabilizing the farm returns in addition to minimizing the risk involved in dryland agriculture.

Reddy *et al.* (1990) in their study on impact analysis of dryland development programme on cropping pattern at Yernala and Chandkavate watershed found that the total cropped area increased marginally (0.43 per cent) due to adoption of improved dry farming practices. The area under cereals and fibers showed decline of 10.73 per cent and 9.37 per cent, respectively, while the area under pulses and oil seeds increased by 46.40 per cent and 46.14 per cent, respectively.

In Muchkulla nala watershed increased area under vegetative cover had facilitated higher infiltration rate and was found to have helped in overcoming the hazards of floods in the lower reaches during heavy monsoon (Kallur, 1991).

Narasamma *et al.* (1991) from their survey of Mittemari watershed in Kolar district, Karnataka reported that the area under intercropping system, especially groundnut+pigeonpea had generally increased over a period of three years, while the area under ragi, the food grains declined.

Swarnalatha *et al.* (1994) in their study at Aravali watershed observed a decrease in the watershed area from 5 to 10 ha after the project period, while the rainfed area under double cropping increased from 125 to 601ha.

Krishnappa *et al.* (1994) while documenting the changes in Achalu micro-watershed at Kabbalanala, Karnataka found that agricultural production increased from 15.74 tonnes during pre-project to 48.41 tonnes in the post project from an area of 28.45ha mainly due to change in cropping pattern.

Jaiswal *et al.* (1985) in their study on G. R. Halli watershed in Chitradurga district, reported 10 to 15 per cent increase in crop yields due to adoption of improved dry farming practices, in the watershed area in relation to bench mark yield.

Reddy *et al.* (1985) observed an increase in jowar yield to the extent of 1420 kg from 470 kg ha⁻¹ in jowar belt as a result of adoption of dryland technology in Andhra Pradesh.

Singh (1986) reported that crop yields can be increased from 30 to 40 per cent by sowing across the slope and ridging later in rolling cultivated lands of Telangana region which controls 10 to 20 per cent runoff moisture loss.

Vishnumurthy (1986) identified that adoption of improved land management practice (graded bunds) resulted in 9.06 q as against 8.04 q ha⁻¹ of groundnut yield in relation to traditional method in Hyderabad area.

Reddy and Walker (1987) observed productivity of sole crop and intercrops was significantly higher in Mittermari ORP watershed area as compared to non watershed area. The increased in yield varied from 10 to 40 per cent in different crops.

In Aravalli watershed of Haryana, the yield of various crops had sunstantially increased in a span of three years. In case of wheat, increased in yield was from 40 to 143 per cent, in barley from 107 to 156 per cent, in mustard from 20 to 28 per cent and in gram 91 to 298 per cent as reported by Bharadwaj *et al.* (1989).

Hazra (1989) pointed out an increase in jowar yield by 20 q as against only 5 q ha⁻¹ before the introduction of watershed in Tejpura area near Jhansi. Similar, trend was also observed in respect of peas, sesamum, barley and mustard in the project area.

Hedge and Pandurangaiah (1989) in their study at ORP Mittermari watershed reported significant increase in yield between benchmark and after four years of programme implementation. In case of ragi, the increase in yield was from 650 to 1070 kg ha⁻¹, groundnut from 300 to 865 kg ha⁻¹ and cowpea from 250 to 606 kg ha⁻¹. They implied, one of the key factors for increased yield was farmer's involvement which was ensured through establishment of village resource management society in the watershed.

Chandregowda and Jayaramaiah (1990) while studying Chittravati watershed in Karnataka, found significant increase in yield of ragi with both small and marginal farmers to the extent of 103.34 and 85.6 per cent, respectively after four years of programme implementation when compared to benchmark level. In respect of groundnut, similar pattern was observed, where in small farmers obtained 124.1 per cent and the marginal farmers 90 per cent increase in yield over the benchmark yield.

In the status report of ORP Kabbalanala watershed increased in yield of ragi was more than three times and in groundnut it was two times in relation to benchmark yield

over a period of four years of programme implementation. The yield of ragi+redgram was 1785+305 kg ha⁻¹ in 1989-90 as against 550 kg ha⁻¹ in ragi mixed crop during benchmark year. The yield of groundnut+redgram was 1210+312 kg ha⁻¹ in relation to 550 kg ha⁻¹ of groundnut which was grown as sole crop (Anon., 1996)

The study of Muchkalla nala district watershed by Biradar (1991) showed that soil erosion reduced considerably in the area and the ground water recharge increased after three years of treatment. Uniform soil moisture distribution was also obtained in the fields which helped uniform growth resulting in increase in ragi yield by 80 to 100 per cent which enable the farmer to double income.

Palanisami and Suresh Kumar (2009) observed the changes in both in additional area brought under well irrigation from the fallow lands and in area under rainfed cultivation. The cropping intensity has increased from 120 per cent to 146.88 per cent in Kattampatti watershed and 102.14 per cent to 112.08 per cent in Kodangipalayam watershed.

Palakshappa *et al.* (2010) while studying the impact of watershed development at Itagi watershed observed an increase in the crop growing area from 6517.3 ha during the pre-project period to 3706.6 ha in post-project period over a period of three years. The yield of maize, jowar, groundnut, onion, garlic, sunflower, cotton, vegetables and pulses were 21, 16, 14, 42, 7, 7, 10, 82 and 7 q ha⁻¹, respectively during the pre-project which increased to 30, 20, 18, 60, 9.5, 9, 13, 120 and 10 q ha⁻¹, respectively after project implementation.

Material and methods

III. MATERIAL AND METHODS

Field experiment entitled “Long term effect of watershed development on changes in soil properties of Alfisols and productivity of finger millet in Kuthanagere of Ramanagar district, Karnataka” was conducted under rainfed conditions during *Kharif* seasons of 2011 and 2012. The details of the materials used and techniques adopted in the investigation are described in this chapter.

3.1 General description of study area

The study area falls under Zone-5 (Eastern Dry Zone), which receives most of its annual rainfall during *Kharif* season. The availability of moisture is limiting factor for crop production, which in turn is determined by physiography and soil type. Therefore, characterization of the area is crucial for better agricultural production.

3.2 Location of the study area

The selected watershed lies 60 km away from Bengaluru headquarter on Solur-Kudur road. The selected watershed lies in Magadi taluk of Ramanagar district. The Kuthanagere watershed is located at 13^o 06' N latitude and 77^o 11' E longitude with an average elevation of 869 m above Mean Sea Level (MSL). The location of the watershed is shown in Fig. 1.

3.3 Climatic conditions

The normal weather data as well as weather data prevailing during crop growth period under study with respect to rainfall, maximum and minimum temperature, relative humidity, mean open pan evaporation and mean daily sunshine hours are presented in Table 1 and 2 and depicted in Fig. 2 and Fig. 3. The weather data of the area near Kuthanagere was collected from Karnataka State Natural Disaster Monitoring Cell, Yelahanka, Bangalore.

3.3.1 Normal climatic condition

The normal annual rainfall of the Kuthanagere watershed was 1027.6 mm. The major portion of it is received during April to November with peak during September (201.9 mm). The mean maximum air temperature ranged between 26.2 °C to 33.7 °C and mean minimum air temperature was higher during May (20.5 °C) and lowest in the month of January (13.9 °C).

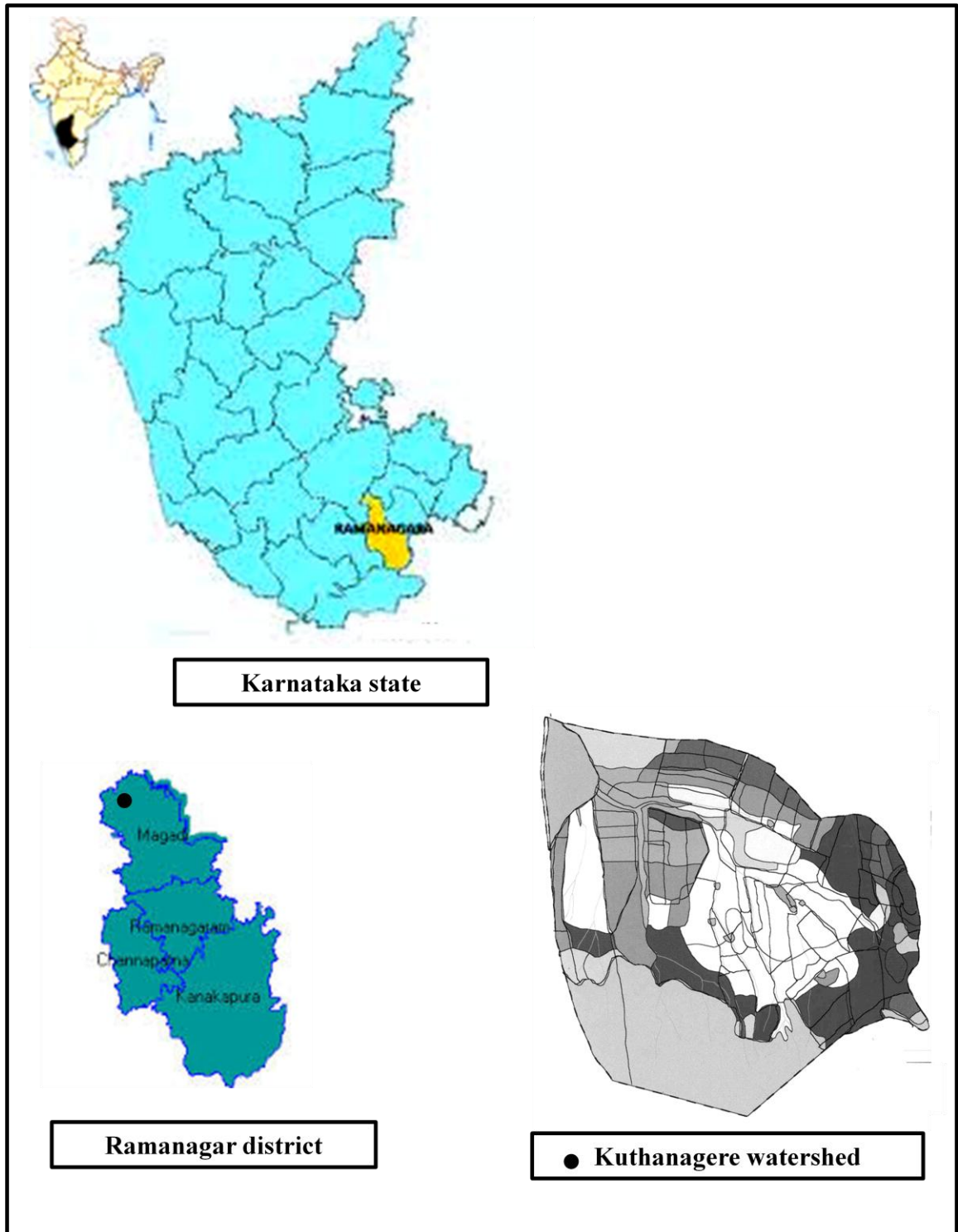


Fig 1: Map depicting the study area of Magadi taluk, Ramanagar district.

Table-1 Normal (mean from 1976-2010) and actual monthly weather data during 2011 at Kuthanagere watershed

Month	Total rainfall (mm)			Mean relative humidity (%)			Mean daily air temperature (°C)						Mean daily open pan evaporation (mm)			Mean daily bright sunshine hours		
							Maximum			Minimum								
	N	A	D	N	A	D	N	A	D	N	A	D	N	A	D	N	A	D
January	1.4	0.1	-1.3	64.0	71.0	7.0	27.3	29.4	2.1	13.9	22.0	8.1	5.1	3.5	-1.6	8.9	9.1	0.2
February	9.9	2.5	-7.4	58.0	71.3	13.3	29.9	28.5	-1.4	15.4	22.1	6.7	6.3	3.4	-2.9	9.6	8.9	-0.7
March	16.9	6.0	-10.9	53.0	73.6	20.6	32.6	30.4	-2.2	17.8	22.9	5.1	7.6	3.4	-4.2	9.6	9.0	-0.5
April	45.9	77.4	31.5	56.0	69.6	13.6	33.7	29.6	-4.1	20.3	22.8	2.5	7.6	4.0	-3.6	9.0	7.3	-1.7
May	98.7	99.5	0.8	60.5	70.3	9.8	33.1	28.7	-4.4	20.5	22.1	1.6	7.2	5.1	-2.1	8.5	7.8	-0.7
June	79.8	84.2	4.4	69.0	68.4	-0.6	29.6	29.3	-0.3	19.5	22.4	2.9	6.0	2.8	-3.2	5.8	6.1	0.3
July	102.9	110.5	7.6	72.0	72.7	0.7	28.2	29.5	1.3	19.0	22.7	3.7	5.3	3.6	-1.7	4.5	4.2	-0.3
August	131.6	197.7	66.1	73.5	67.9	-5.6	27.6	27.7	0.1	18.8	22.5	3.7	4.9	3.7	-1.2	4.7	3.3	-1.4
September	201.9	74.1	-127.8	73.0	70.4	-2.6	28.1	28.0	-0.1	18.8	22.3	3.5	5.0	3.5	-1.5	5.9	5.9	0.0
October	171.0	173.4	2.4	72.0	74.3	2.3	27.7	28.9	1.2	18.2	22.1	3.9	4.7	3.6	-1.1	6.2	5.6	-0.6
November	52.9	26.0	-26.9	72.0	62.8	-9.2	26.6	28.8	2.2	16.6	21.9	5.3	4.5	0.0	-4.5	6.2	6.2	0.0
December	12.9	4.5	-8.4	68.5	74.7	6.2	26.2	28.3	2.1	14.4	22.0	7.6	4.5	0.0	-4.5	7.3	7.3	0.0
Annual	1027.6	855.9	-171.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

N: Normal meteorological data, **A:** Actual meteorological data (year 2011), **D:** Deviation from the Normal (A-N)

Table -2 Normal (mean from 1976-2010) and actual monthly weather data during 2012 at Kuthanagere watershed

Month	Total rainfall (mm)			Mean relative humidity (%)			Mean daily air temperature (°C)						Mean daily open pan evaporation (mm)			Mean daily bright sunshine hours		
							Maximum			Minimum								
	N	A	D	N	A	D	N	A	D	N	A	D	N	A	D	N	A	D
January	1.4	0.5	-0.9	64.0	74.9	10.9	27.3	28.3	1.0	13.9	22.0	8.1	5.1	3.4	-1.7	8.9	9.2	0.3
February	9.9	0	-9.9	58.0	71.9	13.9	29.9	29.6	-0.3	15.4	22.3	6.9	6.3	3.5	-2.8	9.6	9.3	-0.3
March	16.9	1.7	-15.2	53.0	72.3	19.3	32.6	29.2	-3.4	17.8	22.7	4.9	7.6	3.5	-4.1	9.5	8.9	-0.6
April	45.9	87.5	41.6	56.0	72.3	16.3	33.7	28.9	-4.8	20.3	22.2	1.9	7.6	3.5	-4.1	9.0	8.2	-0.8
May	98.7	39.3	-59.4	60.5	71.9	11.4	33.1	29.1	-4.0	20.5	22.2	1.7	7.2	3.5	-3.7	8.4	7.5	-0.9
June	79.8	22.9	-56.9	69.0	71.6	2.6	29.6	29.2	-0.4	19.5	22.2	2.7	6.0	3.5	-2.5	5.8	5.7	-0.1
July	102.9	58.3	-44.6	72.0	71.2	-0.8	28.2	29.0	0.8	19.0	22.0	3.0	5.3	3.5	-1.8	4.5	4.3	-0.2
August	131.6	71.3	-60.3	73.5	72.9	-0.6	27.6	28.9	1.3	18.8	22.0	3.2	4.9	3.6	-1.3	4.7	4.4	-0.3
September	201.9	34.3	-167.6	73.0	71.8	-1.2	28.1	28.9	0.8	18.8	22.5	3.7	5.0	3.6	-1.4	5.9	5.6	-0.3
October	171.0	161.4	-9.6	72.0	73.3	1.3	27.7	28.8	1.1	18.2	22.1	3.9	4.7	3.7	-1.0	6.1	5.7	-0.4
November	52.9	3.3	-49.6	72.0	73.9	1.9	26.6	29.0	2.4	16.6	22.2	5.6	4.5	3.6	-0.9	6.2	7.4	1.2
December	12.9	5.4	-7.5	68.5	76.3	7.8	26.2	28.9	2.7	14.4	22.2	7.8	4.5	3.6	-0.9	7.3	8.0	0.7
Annual	1027.6	485.9	-439.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

N: Normal meteorological data, **A:** Actual meteorological data (year 2012), **D:** Deviation from the Normal (A-N)

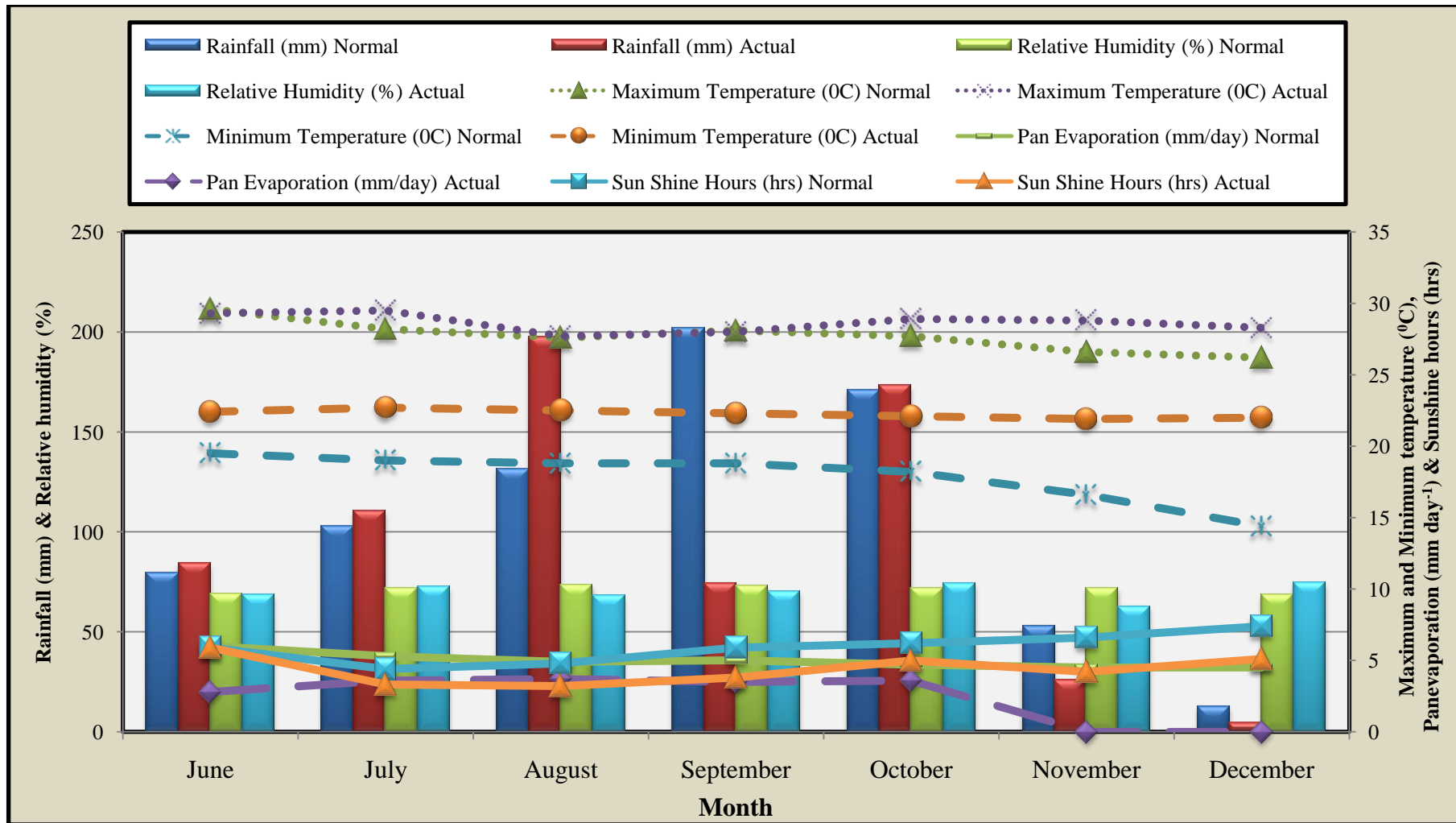


Fig 2: Meteorological data of Kuthanagere watershed during 2011

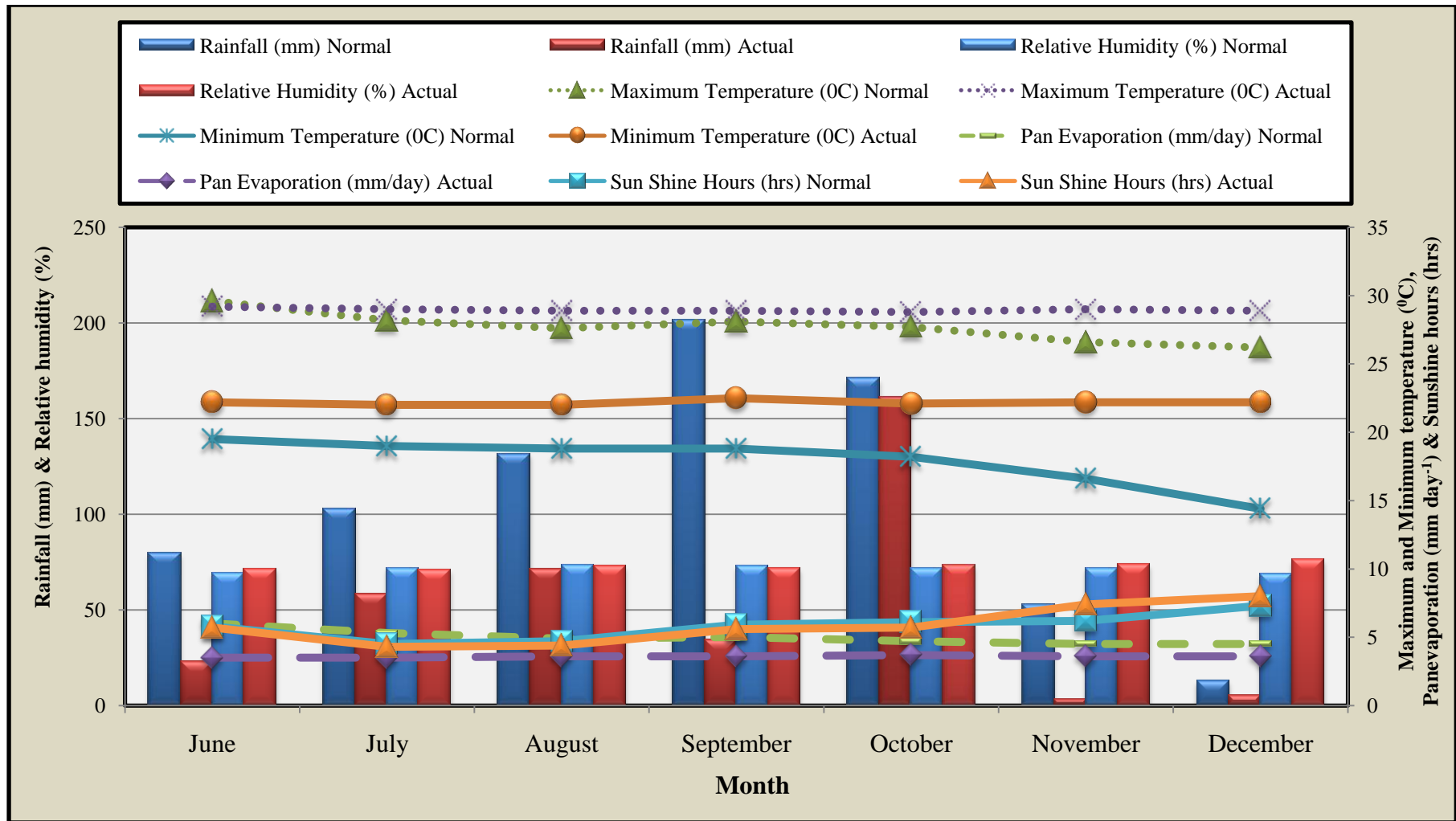


Fig 3: Meteorological data of Kuthanagere watershed during 2012

The mean monthly relative humidity ranged from 53.0% in March to 73.5% in August. The mean open pan evaporation gradually decreased from March to December (7.6 to 4.5 mm day⁻¹). Mean daily sunshine hours ranged from 4.5 hours in June to 9.6 hours in February and March.

3.3.2 Weather condition during the period of experimentation

The total annual rainfall was lower during crop growth period as compared to normal rainfall. The highest monthly rainfall was in August (197.7 mm) during 2011 as against 131.6 mm and October (161.4 mm) in the year 2012 as against 171 mm. During the crop growth period the actual rainfall was lower than the normal rainfall in September and November (-127.8 and -26.9 mm) during 2011 whereas in the year 2012 the actual rainfall was lower in the month of July (-44.6 mm), August (-60.3 mm), September (-167.6mm), October (-9.6mm) and November (-49.6 mm). Actual rainfall was more than the normal in the month of July, August and October (7.6, 66.1 and 2.4 mm, respectively) during 2011. However, during 2012 all the months recorded lower rainfall compared to normal.

The mean maximum air temperature was maximum in the month of July in (29.5 °C) followed by October (28.9 °C) during the crop growth period of 2011. It was also maximum in month of July and November (29 °C) during 2012. The mean minimum temperature was higher than normal temperature in both years of experimentation. Lowest temperature was recorded in month of November (21.9 °C) in 2011 and July (22 °C) during 2012.

The mean monthly relative humidity ranges from 62.8% in November to 74.7% in December in the year 2011, from 71.2% in July to 76.3% in December, 2012. The mean monthly relative humidity was higher than the normal during most of the months except during June, August, September, November in 2011 and July, August and September during the year 2012.

The mean open pan evaporation ranged from 3.5 to 3.7 mm day⁻¹ during both years of crop growth period. Mean daily sunshine hours were lower than the normal in both years. It ranged from 3.3 to 6.2 hours (August and November, respectively) during 2011, from 4.3 to 7.4 hours (July and November, respectively) during the crop growth period of 2012.

The weather conditions were found favorable for crop growth without any adverse effect during 2011, however it was not congenial during 2012 due to less rainfall (-439.9 mm) and intermittent dry spells.

3.3.1 Soil - site characteristics of experimental site

The University of Agricultural Sciences, Bangalore adopted Kuthanagere watershed for demonstration of dry farming technologies on watershed approach. Thirteen (13) soil series and 40 soil phases were identified in the watershed and the characteristics, viz., site characters, physical, chemical and physico-chemical parameters of soils were studied and reported while doing the resource inventory during watershed development programme in 1992-1999, by NBSS and LUP.

3.4 Experimental details

The experiment was laid out in factorial randomized complete block design with 9 treatments replicated thrice.

3.4.1 Treatment details

There were 18 treatment combinations consisting of nine soil series and two varieties of finger millet.

3.4.1.1 First factor

Nine treatments comprising of nine dominant/crucial soil phases one in each soil series was chosen and it is depicted in the Fig. 4.

Suitable soil series

Kuthanagere-1: are very deep (100-130 cm), well drained, yellowish red to reddish brown with sandy loam to sandy clay loam Ap horizon and dark red and clay thick Bt horizon. These soils are occurring on gentle sloping to undulating lands developed on granite gneisses. Soils are members of fine texture, mixed (mineralogy), iso-hyperthermic, Rhodic Plestalfs.

Kuthanagere-2: are very deep (120-150 cm), well drained, dark red to reddish brown sandy loam Ap horizon and dark red to dark reddish brown sandy clay loam with thick Bt horizon. These soils are occurring on gently sloping to undulating lands developed on granite and gneisses. The series is a member of fine-loamy, mixed, iso-hyperthermic, Typic Rhodustalfs.

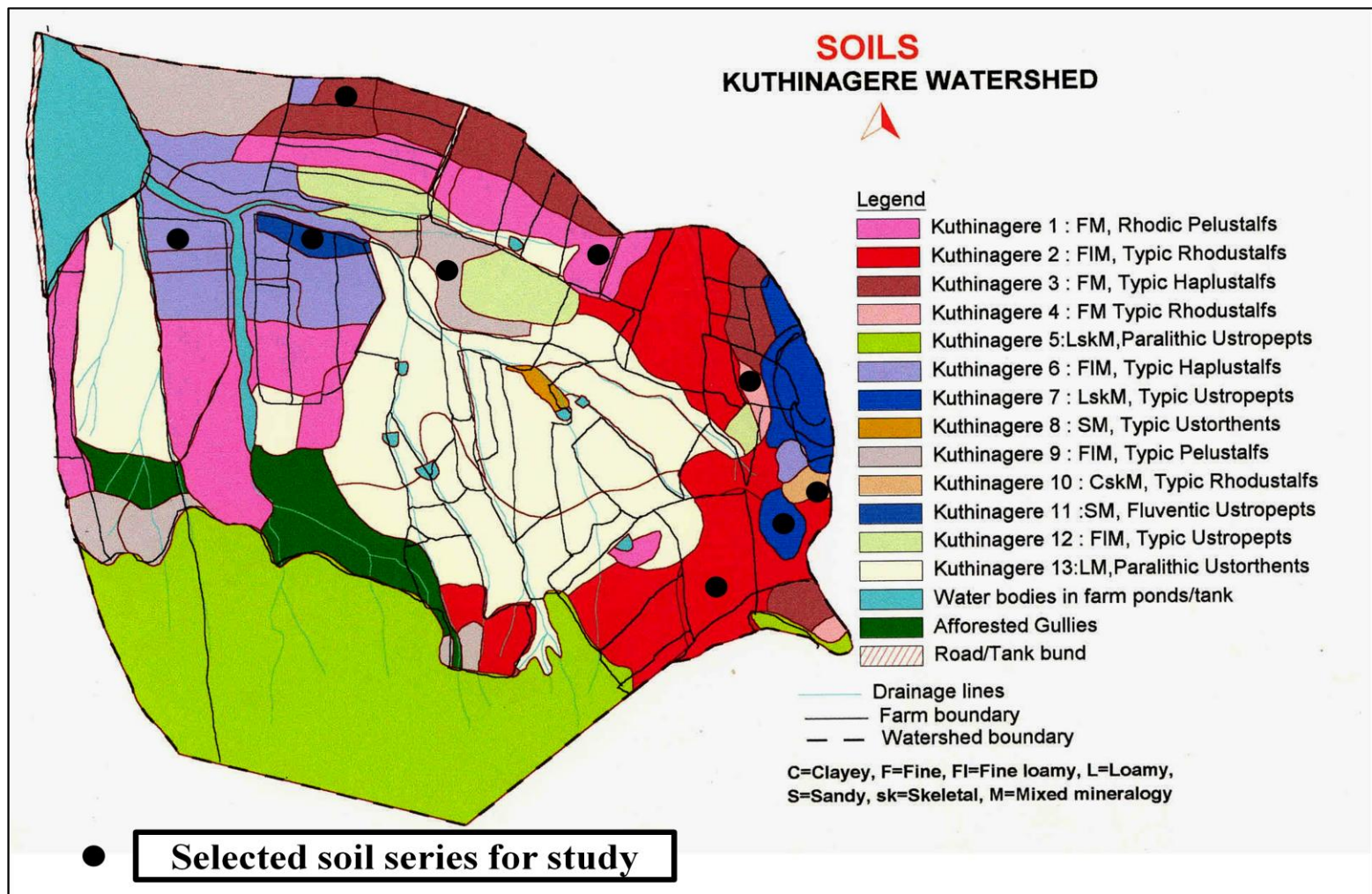


Fig . 4: Kuthanagere soil map depicting the nine soil series in which experiment was taken.

Kuthanagere-3: are very deep (120-150 cm) well drained, dark brown sandy loam Ap horizon and dark red yellowish red sandy clay thick Bt horizon. These soils are developed on gently sloping lands on granite gneiss. The series is a member of fine, mixed, iso-hyperthermic of Typic Haplustalfs.

Kuthanagere-6: are deep (60-90 cm) well drained, dark brown to reddish brown sandy clay loam Ap horizon and reddish brown to dark reddish brown sandy clay thin Bt horizon. These soils are occurring on gently sloping land and developed on granite and granite gneisses. The series is a member of fine-loamy, mixed, iso-hyperthermic of Typic Haplustalfs.

Moderately suitable soil series

Kuthanagere-4: are deep (60-90 cm) well drained, dark red to reddish brown sandy loam Ap horizon and dark red to dark reddish brown sandy clay to clay thin Bt horizon. These soils are occurring on nearly level to gentle sloping lands. These soils are developed on granite and granite gneisses. The series is a member of fine, mixed, iso-hyperthermic of Typic Rhodustalfs.

Kuthanagere-7: are deep (80-90 cm) well drained, dark brown, sandy loam Ap horizon and dark brown to yellowish red sandy clay loam with well developed B horizon. These soils occurring on foot hills and are developed on granite and gneissis. They belong to the soil taxonomy of loamy-skeletal, mixed, iso-hyperthermic family of Typic Ustropepts.

Kuthanagere-9: are very deep (110-150 cm), well drained, dark brown loamy sand, Ap horizon and dark brown to yellowish red, sandy clay loam thick Bt horizon. These soils occurring on foot hills and developed on granite and gneisses and is member of fine-loamy, mixed, iso-hyperthermic family of Typic Rhodustalfs.

Kuthanagere-10: are deep (60-90 cm), well drained, dark red gravely sandy clay loam Ap horizon and dark red, gravely sandy clay thin Bt horizon underlying by thick BC horizon, occurring on foot hills. They are developed on granite and gneisses. It is a member of clayey-skeletal, mixed, iso-hyperthermic of Typic Rhodustalfs.

Kuthanagere-11: are very deep (120-150cm) well drained, dark brown sandy loamy Ap Horizon and reddish brown, yellowish red to red sandy loam subsurfaces horizon occurring on very gently sloping (1-3%) and it is member of sandy, mixed, iso-hyperthermic, Fluventic Ustropepts.

3.4.1.2 Varieties of finger millet

Two varieties of finger millet viz:

V1: GPU 28 and

V2: MR-2

3.4.2 Varietal description

Variety	GPU-28	MR-2
Parentage	Indaf 5 x (Indaf 9 x IE 1012)	Indaf-5 x PR 202
Days to flower	64-68	85-90
Days to maturity	110-115	120-125 days
Grain yield (q/ha)	35-40	25-30
Special features	Blast resistant (neck, finger and leaf blast) Suitable for Kharif and early summer	Resistant to bacterial blight and neck blast Suitable for early kharif

3.4.3 Spacing and seed rate: Spacing: 30 cm x 10 cm

Seed rate: 10 kg ha⁻¹.

3.4.4 Design & layout: Factorial Randomized Block design with three replications.

3.4.5 Plot size:

Gross plot size- 5.4 m x 3.6 m= 19.44 sq. meter

Net plot size- 4.8m x 3.2 m= 15.36 sq. meter

3.5 Cultural practices

3.5.1 Land preparation

The experimental plot was ploughed twice across the slope and was brought to fine tilth by harrowing. The experiment was laid out in flat beds and the individual plots were prepared and small bunds were raised around each plot.

3.5.2 Fertilizer application

At the time of sowing 50 per cent of the N, complete dose of P₂O₅ and K₂O were applied as per the recommendation. The N, P₂O₅ and K₂O were applied in the form of urea, DAP and MOP. These fertilizers were applied to the crop rows at the time of

sowing using seed cum fertilizer drill. Remaining 50 per cent of the N was top-dressed at around 35th day after sowing which coincides with the final inter-cultivation and rain.

3.5.3 Sowing

The seed drill was used to sow the seeds in lines across slope at the rate of 10 kg per ha and later the seed rows were covered with soil. Care was taken to avoid the direct contact of seeds with fertilizer.

3.5.4 After care

Thinning of excess seedlings was done and two seedlings per hill was retained to maintain optimum plant population. Seedlings were spaced at 10 cm between plants with in a row. Weeding was done by bullock drawn implement in order to keep the plots weed free. Inter-cultivation was done twice inbetween the crop rows to control weed and to provide better aeration to roots and to enhance infiltration of subsequent rainwater.

3.5.5 Harvesting and threshing

All border rows were harvested as bulk by leaving the net plot area. Later the ear head of the net plot area were harvested treatment wise. Similarly, the straw from net plot was harvested to ground level separately and dried for a week before recording the weight.

3.5.6 Collection of experimental data

Observations on growth and yield parameters were recorded on five randomly selected plants from the net plot area. In this area, plants were randomly selected in each treatment. These plants were cut at ground level for recording various observations at the interval of 15 days from date of sowing till the maturity.

3.6 The techniques used and the details of observations recorded are explained in the following paragraphs

3.6.1 Pre-harvest studies

3.6.1.1 Plant height

The plant height (cm) of finger millet was measured from randomly selected five plants i.e. from main shoot from ground level to the base of the fully opened leaf at 15, 30, 45, 60, 75, 90 DAS and at harvest. After emergence of ear head, the height was taken

up to the tip of the ear head on the main shoot. The mean plant height was worked out and expressed in centimeter (cm).

3.6.1.2 Number of leaves per plant

The number of fully opened green leaves in five randomly selected plants was counted at 15, 30, 45, 60, 75, 90 DAS and at harvest and the mean value was taken and expressed as total number of leaves per plant.

3.6.1.3 Tiller production per plant

From the randomly selected five plants, number of tillers per plant was counted at 15, 30, 45, 60, 75, 90 DAS and at harvest and they were pooled and average number of tillers per plant was determined. Number of tillers bearing ear head was counted and effective number of tillers were calculated from the selected five plants.

3.6.1.4 Dry matter accumulation and distribution (g plant^{-1})

Dry matter accumulation at 15, 30, 45, 60, 75, 90 DAS and at harvest was determined only for the above ground portion of the plant. The five plant samples selected were partitioned in to different parts like leaf, stem and ear head (depending on the stage of the crop) and later dried in hot air oven at 65°C till the constant dry weight was obtained. The completely dried samples were weighed separately and weight was recorded in grams for each plant part. This primary data was used to estimate the total dry weight per plant and its distribution in various plant parts at different stages of plant growth.

3.6.2 Post-harvest studies

3.6.2.1 Grain yield

The harvested ear heads from net plot were threshed and grains were dried and then weighed. Using the net plot yield, the yield in q ha^{-1} was computed.

3.6.2.2 Straw yield

From the net plot area, straw was cut at ground level in each treatment and sun dried for 8-10 days, weighed and converted to tons per hectare.

3.6.2.3 Number of fingers per head

From randomly selected five plants number of fingers per ear head were counted and averaged.

3.6.2.4 Finger length (cm)

From randomly selected five plants finger length was measured and averaged to obtain the finger length per ear.

3.6.2.5 Test weight (1000 grain weight)

Thousand grains were counted using “NUMIGRAL” seed counter, which automatically stops after counting 1000 grains. The weight was recorded in grams.

3.6.2.6 Harvest Index (HI)

Harvest index is proportion of total dry matter that is accumulated in economic yield. It was worked out using the following formula suggested by Donald and Humblin (1976).

$$\text{Harvest Index (HI)} = \frac{\text{Grain yield (q ha}^{-1}\text{)}}{\text{Grain yield (q ha}^{-1}\text{)} + \text{Straw yield (q ha}^{-1}\text{)}}$$

3.7 Bench mark survey and site characteristic of typifying pedons

A detailed soil survey on 1:2000 scale was carried out during 1995 by characterizing around 50 soil profiles for their morphometric characters and physical and chemical properties using standard procedures (IARI, 1971). Accordingly, 13 soil series (Fig. 4) were identified in the watershed and further delineated in to 40 phases based on the surface soil texture, depth, slope and erosion.

Besides soil map, the thematic maps of important soil parameters of the watershed viz., soil depth (Fig. 5), texture (Fig. 6), slope (Fig. 7) and erosion status (Fig. 8) were produced. Soil depth showed that nearly 23.5 per cent of watershed area was under shallow depth (7.5 to 22.5 cm), 32.0 percent under moderately deep (22.5 to 45cm), 12.8 percent under deep (45 to 90 cm) and 32.9 per cent of the area under very deep soil. Surface soil texture brought out that 5.2 per cent under loamy sand, 2 percent gravelly sandy loam, 61.5 percent under sandy loam, 15.7 per cent under sandy clay loam, 2.1 per cent sandy clay and 3.8 per cent area under clay soil.

The site characteristics, physical, chemical and physicochemical properties and the nutrient status of the typifying pedons (master profiles) for each series are presented in Tables 3, 4 and 5. Depending on the soil site characters and grain yield of finger millet soil site suitability map of finger millet was developed (Fig. 9).

Table 3: Soil series and their characteristics in Kuthanagere watershed during 1995

Sl. No	Soil series	Mapping unit No.	Pedon No.	Slope (%)	Erosion (rating)	Drainage (rating)	Ground water table (m)	Flooding (rating)
1	Kuthanagere -1	No. 3	P8	2.0	2	2	12.0	1
2	Kuthanagere -2	No. 6	P21	0.5	1	2	12.0	1
3	Kuthanagere -3	No. 9	P4	0.5	1	2	12.0	1
4	Kuthanagere -4	No. 13	P19	5.5	2	2	12.0	1
5	Kuthanagere -5	No. 14	P41	22.5	2	3	>30.0	1
6	Kuthanagere -6	No. 19	P3	5.5	3	3	7.5	1
7	Kuthanagere -7	No. 20	P13	3.5	2	2	20.0	1
8	Kuthanagere -8	No. 23	R6	0.5	1	2	1.0	3
9	Kuthanagere -9	No. 24	R5	2.0	2	2	7.5	1
10	Kuthanagere -10	No. 30	P23	2.0	2	2	12.0	1
11	Kuthanagere -11	No. 31	P33	0.5	2	2	7.5	1
12	Kuthanagere -12	No. 32	P20	0.5	2	2	12.0	1
13	Kuthanagere -13	No. 35	R9	5.5	3	3	7.5	1

Erosion rating: 1=Nil to slight erosion, 2=Moderate erosion, 3=severe erosion

Drainage rating: 1=Poor to imperfectly drained, 2=Moderately well to well drained, 3=Somewhat excessively to excessively drained.

Flood rating: 1=No flooding, 2= Occasional flooding, 3= Moderate flooding

Table 4: Physical and chemical properties of typifying pedons (master profiles) of each soil series of Kuthanagere watershed

Sl. No.	Soil series	Horizon	Depth (cm)	C. fragments (%)	Sand (%)	Silt (%)	Clay (%)	O.C (%)	pH	ECe (dsm ⁻¹)	CEC (C mol p ⁺ kg ⁻¹)	BS (%)	Exch. Na (C mol p ⁺ kg ⁻¹)	
1.	Kuthanagere -1	Ap	0-15	0.0	67.3	8.6	24.1	0.40	5.5	0.50	5.90	52.6	1.69	
		Bt ₁	15-43	18.0	43.6	11.9	44.5	0.49	6.4	0.03	8.80	56.8	1.14	
		Bt ₂	43-74	20.0	43.9	13.9	42.2	0.20	6.7	0.03	8.40	66.7	1.19	
		Bt ₃	74-106	10.0	45.0	17.0	38.0	0.20	6.9	0.04	8.70	54.0	1.15	
		C	106-110 ⁺	-	-	-	-	-	-	-	-	-	-	-
		WM	-	13.6	47.4	13.5	39.1	0.30	6.5	0.10	8.20	58.2	1.23	
2.	Kuthanagere -2	Ap	0-12	7.5	70.0	11.6	18.3	0.34	5.4	0.10	4.90	57.1	2.04	
		Bt ₁	12-40	7.5	49.2	15.9	34.9	0.45	5.6	0.10	8.70	68.9	1.15	
		Bt ₂	40-60	19.0	57.2	15.8	27.0	0.26	7.2	0.10	7.40	67.6	1.35	
		Bt ₃	60-113	10.0	57.2	20.0	22.8	0.17	7.8	0.10	6.40	100.0	1.56	
		BC	113-155	25.0	65.2	21.0	13.8	0.04	7.8	0.10	4.70	95.7	2.13	
		C	155 ⁺	-	-	-	-	-	-	-	-	-	-	-
WM	-	14.6	58.9	18.3	22.7	0.21	7.2	0.10	6.37	85.7	1.65			
3.	Kuthanagere -3	Ap	0-12	2.5	80.7	7.5	11.8	0.26	5.3	0.03	2.60	53.8	3.85	
		Bt ₁	12-31	2.5	53.8	14.0	32.2	0.49	6.0	0.04	7.80	56.4	1.28	
		Bt ₂	31-72	2.5	47.6	13.0	39.4	0.21	6.6	0.03	8.30	60.2	1.20	
		Bt ₃	72-105	15.0	49.8	16.3	33.9	0.14	6.8	0.03	7.50	65.3	1.33	
		Bt ₄	105-125	10.0	49.4	21.7	28.9	0.25	7.0	0.04	8.90	76.4	2.25	
		BC	125-140 ⁺	-	-	-	-	-	-	-	-	-	-	-
WM	-	14.4	52.6	14.9	32.5	0.24	6.5	0.03	7.56	62.9	1.67			
4.	Kuthanagere -4	Ap	0-10	7.5	65.2	5.0	29.1	0.76	5.6	0.08	5.39	70.6	3.29	
		B	10-30	7.5	58.1	10.6	30.3	0.62	5.8	0.09	6.35	64.6	1.61	
		B	30-50	22.5	59.1	10.8	30.0	0.54	6.6	0.08	5.96	66.6	1.06	
		BC	50-65	80.0	68.5	7.3	24.1	0.36	6.5	0.09	4.76	77.3	3.77	
		R	65 ⁺	-	-	-	-	-	-	-	-	-	-	-
WM	-	28.8	61.9	9.0	28.6	0.20	6.2	0.08	5.71	69.0	2.20			

5.	Kuthanagere - 5	A	0-10	35.0	72.1	11.9	16.0	0.60	6.1	0.10	4.80	68.0	1.85	
		Bw	10-28	35.0	62.1	15.9	22.0	0.58	6.0	0.10	6.40	73.0	1.69	
		Cr	28-51	-	-	-	-	-	-	-	-	-	-	-
		WM	-	35.0	65.7	14.5	19.8	0.59	6.0	0.10	5.83	71.2	1.75	
6.	Kuthanagere - 6	Ap	0-12	20.0	68.1	11.7	20.2	0.93	5.9	0.10	5.40	68.5	1.85	
		Bt ₁	12-34	17.0	49.7	12.4	37.7	0.55	6.0	0.10	7.60	56.6	1.32	
		Bt ₂	34-60	12.0	50.7	13.6	35.7	1.06	6.2	0.00	7.40	68.9	1.35	
		BC	60-79	20.0	57.7	15.0	27.6	0.03	6.3	0.10	6.90	62.3	1.45	
		C	79-110 ⁺	-	-	-	-	-	-	-	-	-	-	-
		WM	-	16.5	54.7	13.3	31.9	0.65	6.1	0.10	7.00	63.8	1.44	
7.	Kuthanagere - 7	Ap	0-10	50.0	72.0	14.1	13.9	0.58	5.6	0.10	4.00	65.0	2.50	
		B	10-26	52.0	57.8	14.5	27.7	0.78	7.8	0.10	7.30	56.2	1.37	
		B	26-46	50.0	60.7	13.7	26.2	0.48	6.1	0.10	7.50	61.3	1.33	
		B	46-90	46.0	60.2	11.1	28.7	0.25	6.2	0.10	5.90	67.8	1.69	
		C	90-100 ⁺	-	-	-	-	-	-	-	-	-	-	-
		WM	-	48.4	61.2	12.5	26.3	0.41	6.4	0.10	6.30	64.0	1.64	
8.	Kuthanagere - 8	Ap	0-43	10.4	75.1	13.4	11.5	0.61	5.1	0.10	4.60	58.7	6.52	
		AC1	14-38	10.0	79.9	10.1	10.0	0.13	6.8	0.10	3.80	76.3	2.63	
		AC2	38-56	8.0	83.4	8.4	8.2	0.23	7.1	0.04	3.20	90.6	6.25	
		AC3	56-80	12.0	79.5	10.7	9.8	0.10	7.4	0.10	3.60	88.9	5.55	
		AC4	80-93	12.0	76.9	13.0	10.1	0.12	7.1	0.11	5.00	76.0	4.00	
		C	93-120	-	-	-	-	-	-	-	-	-	-	-
		WM	-	10.4	79.3	10.9	9.8	0.22	6.9	0.10	3.92	79.6	4.68	
9.	Kuthanagere - 9	Ap	0-9	7.5	82.1	9.8	8.1	0.25	5.3	0.10	3.20	87.5	3.12	
		B	9-18	7.5	57.1	12.8	30.1	0.29	5.6	0.10	8.80	65.9	1.13	
		B	18-84	7.5	55.8	13.0	31.7	0.41	6.5	0.10	8.80	60.2	1.13	
		B	84-129	7.5	56.6	11.3	32.1	0.22	6.5	0.40	8.50	57.6	4.44	
		BC	129-150 ⁺	7.5	56.2	12.5	31.3	0.10	6.7	0.10	8.70	67.8	1.15	
		WM	-	7.5	57.5	12.2	30.2	0.29	6.5	0.19	8.36	62.5	2.24	

10.	Kuthanagere -10	Ap	0-10	27.5	54.2	13.5	32.3	0.60	6.0	0.10	9.64	63.2	2.10	
		Bt ₁	10-38	40.0	49.1	13.0	37.9	0.72	6.1	0.10	10.82	60.5	1.80	
		Bt ₂	38-68	35.0	43.6	18.9	37.4	0.91	6.2	0.20	12.92	58.3	1.30	
		BC	68-102	65.0	56.8	18.3	38.5	0.98	6.7	0.10	11.56	62.1	1.60	
		C	102-130	-	-	-	-	-	-	-	-	-	-	-
		WM	-	45.6	50.5	16.6	37.4	0.65	6.3	0.13	11.57	60.6	1.60	
11.	Kuthanagere -11	Ap	0-13	0.0	84.6	9.7	5.7	0.31	6.7	0.10	2.50	68.0	4.00	
		Bw	13-32	0.0	78.8	8.1	13.1	0.22	5.3	0.00	4.50	62.2	17.70	
		Bw ₂	32-56	0.0	77.6	9.7	12.7	0.23	5.4	0.10	4.00	57.2	2.50	
		Bw ₃	56-76	0.0	79.8	9.4	10.8	0.12	5.8	0.10	3.70	67.6	5.41	
		Bw ₄	76-92	0.0	81.0	8.3	10.7	0.13	6.1	0.10	3.50	100.0	34.20	
		Bw ₅	92-150 ⁺	0.0	69.3	10.7	20.0	0.23	6.1	0.10	6.80	60.3	1.46	
		WM	-	0.0	75.8	9.7	14.5	0.21	5.9	0.10	4.92	66.0	7.92	
12.	Kuthanagere -12	Ap	0-16	10.0	75.8	13.6	10.6	0.32	6.6	0.10	3.10	80.6	3.22	
		A13	16-35	10.0	72.6	15.9	11.5	0.33	6.1	0.10	3.80	100.0	2.63	
		Bw	35-50	10.0	61.6	17.2	21.2	0.34	6.4	0.10	5.20	84.6	1.92	
		BC	50-77	70.0	58.6	23.3	18.1	0.12	6.9	0.10	5.40	90.7	1.85	
		C	77 ⁺	-	-	-	-	-	-	-	-	-	-	-
		WM	-	30.8	64.3	20.5	15.2	0.25	6.4	0.10	4.39	87.1	2.27	
13.	Kuthanagere -13	Ap	0-13	40.0	64.8	9.5	25.0	0.42	6.8	0.23	5.10	75.1	5.60	
		C	13-43 ⁺	-	-	-	-	-	-	-	-	-	-	-
Note: WM: weighted mean of all the horizon; C.fragments:coarse fragments; O.C: organic carbon														

Table 5: Nutrient status of typifying pedons (master profiles) of each soil series of Kuthanagere watershed

Sl. No	Soil series	Horizon	Depth (cm)	Avail. N (ppm)	Avail. P ₂ O ₅ (ppm)	Exch. K (C mol p ⁺ kg ⁻¹)	Exch. Ca (C mol p ⁺ kg ⁻¹)	Exch. Mg (C mol p ⁺ kg ⁻¹)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	
1.	Kuthanagere - 1	Ap	0-15	140.6	17.2	0.2	1.7	1.1	2.95	0.38	0.52	9.62	
		Bt ₁	15-43	129.7	9.2	0.1	3.4	1.4	1.90	0.18	0.41	0.82	
		Bt ₂	43-74	89.6	9.3	0.1	4.2	1.2	1.80	1.10	0.19	5.20	
		Bt ₃	74-106	80.7	8.4	0.1	3.2	1.3	0.22	0.05	0.30	0.09	
		C	106-110 ⁺	-	-	-	-	-	-	-	-	-	-
		WM	-	104.7	10.1	0.1	3.3	1.3	1.55	0.14	0.33	3.12	
2.	Kuthanagere - 2	Ap	0-12	143.1	12.6	0.1	1.7	0.9	3.80	0.32	0.36	4.48	
		Bt ₁	12-40	134.3	12.0	0.1	4.3	1.5	1.86	0.15	0.86	2.87	
		Bt ₂	40-60	93.6	8.2	0.1	3.4	1.4	1.10	0.12	0.50	1.72	
		Bt ₃	60-113	89.6	5.2	0.1	4.7	1.5	1.50	0.10	0.29	2.90	
		BC	113-155	62.4	4.2	0.1	3.4	0.9	0.58	0.05	0.86	1.47	
		C	155 ⁺	-	-	-	-	-	-	-	-	-	-
		WM	-	95.0	7.3	0.1	3.9	1.3	1.44	0.11	0.58	2.48	
3.	Kuthanagere - 3	Ap	0-12	125.2	12.0	0.1	0.8	0.4	2.90	0.36	0.39	3.65	
		Bt ₁	12-31	134.2	10.7	0.1	2.7	1.5	1.40	0.25	0.89	4.62	
		Bt ₂	31-72	112.0	11.4	0.1	3.0	1.8	1.00	0.20	0.29	0.92	
		Bt ₃	72-105	99.3	8.2	0.1	3.3	1.4	0.40	0.20	1.00	2.12	
		Bt ₄	105-125	94.1	6.6	0.1	5.0	1.5	0.50	0.20	0.59	0.62	
		BC	125-140 ⁺	-	-	-	-	-	-	-	-	-	-
		WM	-	10.8.8	9.7	0.1	3.1	1.5	1.00	0.22	0.63	2.01	
4.	Kuthanagere - 4	Ap	0-10	142.5	22.5	0.3	2.8	0.5	2.90	0.42	0.56	28.2	
		B	10-30	98.4	16.3	0.2	3.2	0.6	2.34	0.21	0.36	3.95	
		B	30-50	90.6	5.1	0.1	2.5	1.3	0.95	0.17	0.40	3.38	
		BC	50-65	80.3	5.1	0.1	2.0	1.4	0.93	0.16	0.37	2.80	
		R	65 ⁺	-	-	-	-	-	-	-	-	-	-
		WM	-	98.6	11.2	0.2	2.6	1.0	1.67	0.22	0.39	7.24	

5.	Kuthanagere - 5	A	0-10	102.9	8.8	0.2	2.1	1.0	3.30	0.40	1.00	11.85	
		Bw	10-28	89.5	8.9	0.2	3.0	1.4	1.80	0.20	0.82	3.58	
		Cr	28-51	-	-	-	-	-	-	-	-	-	-
		WM	-	94.3	8.9	0.2	2.7	1.3	2.33	0.27	0.88	6.79	
6.	Kuthanagere - 6	Ap	0-12	112.0	10.8	0.4	2.0	1.2	3.10	0.29	0.50	20.3	
		Bt ₁	12-34	97.1	7.9	0.2	2.5	1.5	1.80	0.10	0.80	3.80	
		Bt ₂	34-60	80.8	4.5	0.1	3.3	1.6	1.50	0.16	0.40	4.60	
		BC	60-79	45.0	4.1	0.1	2.6	1.5	1.60	0.08	1.27	1.80	
		C	79-110 ⁺	-	-	-	-	-	-	-	-	-	-
WM	-	81.5	6.3	0.2	2.7	1.5	1.85	0.14	0.20	6.12			
7.	Kuthanagere - 7	Ap	0-10	94.5	4.8	0.3	1.4	0.8	4.80	0.36	0.89	8.80	
		B	10-26	85.2	4.4	0.1	2.5	1.4	1.92	0.10	0.57	9.20	
		B	26-46	67.2	4.4	0.1	2.9	1.5	0.82	0.12	0.30	1.80	
		B	46-90	48.3	5.1	0.1	2.8	1.2	0.82	0.10	0.20	1.20	
		C	90-100 ⁺	-	-	-	-	-	-	-	-	-	-
WM	-	64.2	6.3	0.1	2.6	1.3	1.46	0.13	0.36	3.60			
8.	Kuthanagere - 8	Ap	0-43	89.5	5.5	0.1	1.8	0.5	4.20	0.20	0.70	8.55	
		AC1	14-38	80.5	4.8	0.1	2.1	0.6	1.80	0.02	0.56	2.13	
		AC2	38-56	85.2	4.1	0.1	2.0	0.6	1.20	0.05	1.00	1.13	
		AC3	56-80	78.4	4.8	0.1	2.2	0.7	1.50	0.06	1.08	2.13	
		AC4	80-93	58.1	3.8	0.1	2.3	1.2	1.00	0.40	0.89	1.90	
		C	93-120	-	-	-	-	-	-	-	-	-	-
WM	-	79.1	4.6	0.1	2.1	0.7	1.86	0.12	0.85	2.87			
9.	Kuthanagere - 9	Ap	0-9	129.7	13.7	0.1	1.2	0.5	2.90	0.40	0.76	20.56	
		B	9-18	111.9	12.8	0.1	3.8	1.8	2.50	0.20	0.85	10.12	
		B	18-84	109.7	11.5	0.1	3.3	1.8	1.20	0.10	0.55	8.20	
		B	84-129	80.7	8.7	0.1	3.2	1.4	1.20	0.20	0.20	2.50	
		BC	129-150 ⁺	49.0	4.8	0.1	4.0	1.6	1.00	0.03	0.30	2.00	
		WM	-	93.8	9.9	0.1	3.3	1.6	1.35	0.14	0.44	6.48	

10.	Kuthanagere -10	Ap	0-10	142.2	18.2	0.1	1.8	0.8	3.50	0.36	0.56	8.90
		Bt ₁	10-38	122.9	12.8	0.1	2.3	1.8	2.10	0.26	0.56	8.00
		Bt ₂	38-68	95.0	5.3	0.1	3.0	1.4	2.00	0.18	0.86	4.80
		BC	68-102	84.5	4.7	0.1	3.8	1.3	1.00	0.08	0.50	1.00
		C	102-130	-	-	-	-	-	-	-	-	-
		WM	-	103.8	8.4	0.1	3.0	1.4	1.84	0.19	0.63	4.81
11.	Kuthanagere -11	Ap	0-13	94.0	13.2	0.2	1.4	0.0	1.98	0.30	0.46	5.60
		Bw	13-32	93.6	8.4	0.1	1.4	0.5	1.00	0.30	0.56	5.86
		Bw ₂	32-56	89.5	8.6	0.1	1.5	0.6	1.06	0.20	0.60	2.92
		Bw ₃	56-76	80.6	9.1	0.1	1.5	0.7	1.05	0.10	0.50	1.56
		Bw ₄	76-92	49.1	7.1	0.1	1.5	0.7	0.80	0.15	0.30	1.60
		Bw ₅	92-150 ⁺	46.8	5.7	0.1	3.6	1.3	0.40	0.10	0.30	1.82
		WM	-	68.4	7.8	0.1	2.3	0.8	0.85	0.16	0.42	2.78
12.	Kuthanagere -12	Ap	0-16	102.4	8.3	0.1	1.7	0.6	2.50	0.32	0.46	19.80
		A13	16-35	91.8	8.3	0.1	2.2	1.4	2.00	0.20	0.56	10.50
		Bw	35-50	80.8	6.0	0.1	3.2	1.0	1.06	0.10	0.80	5.50
		BC	50-77	58.3	5.6	0.1	3.5	1.2	1.02	0.03	0.30	3.50
		C	77 ⁺	-	-	-	-	-	-	-	-	-
		WM	-	77.7	6.7	0.1	2.7	1.1	1.52	0.14	0.48	8.73
13.	Kuthanagere -13	Ap	0-13	77.7	9.6	0.2	2.5	0.8	0.98	0.29	0.87	2.30
		C	13-43 ⁺	-	-	-	-	-	-	-	-	-
Note: WM: Weighted mean; Avail: Available; Exch: Exchangeable												

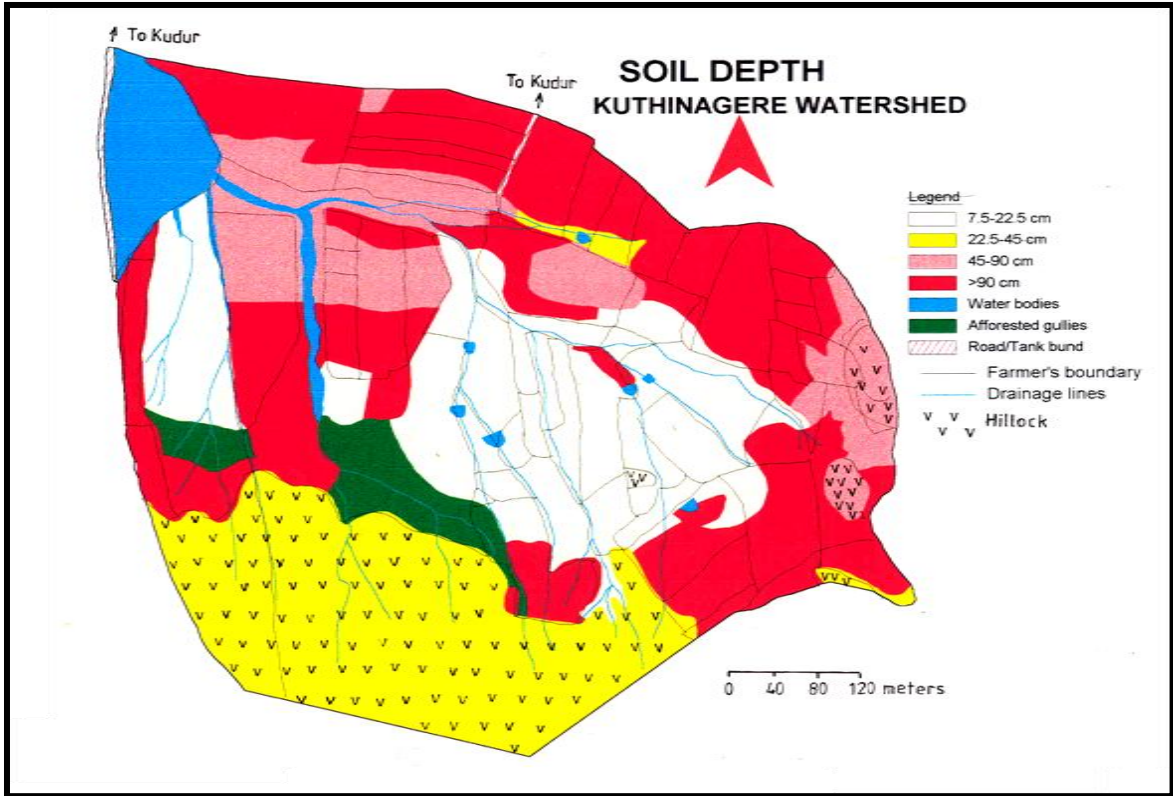


Fig. 5: Soil depth (cm) map of Kuthanagere watershed (1995)

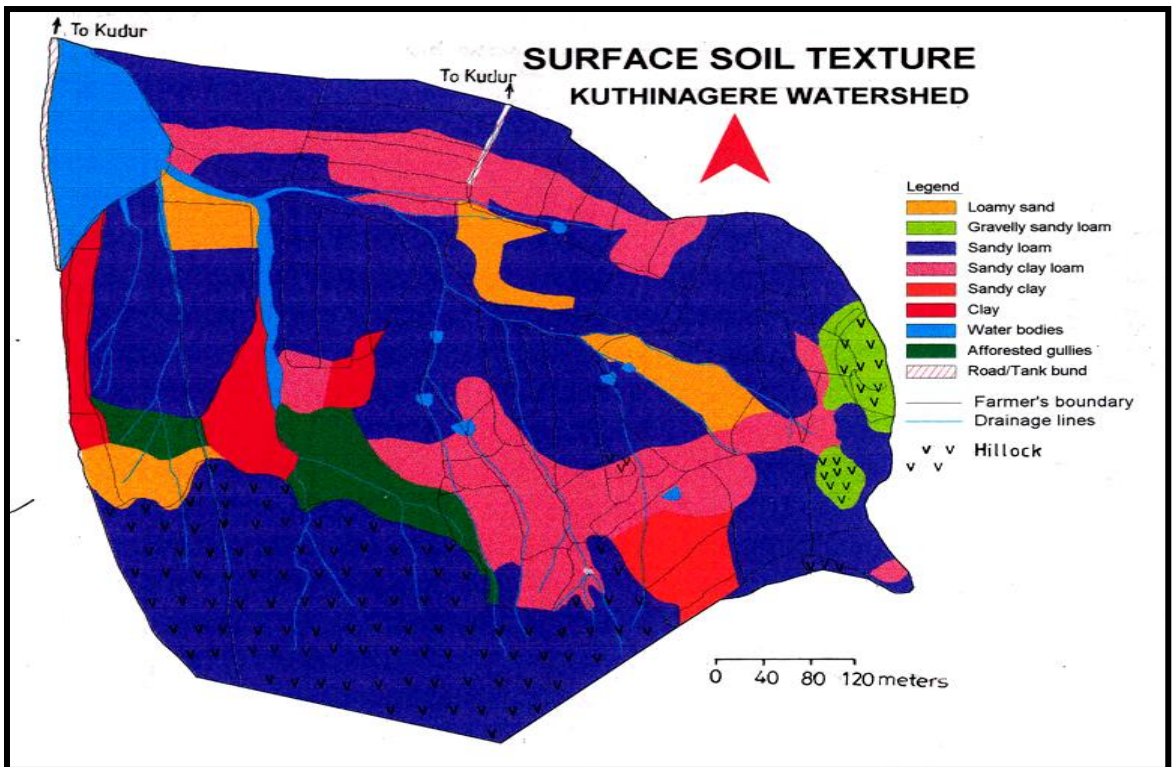


Fig. 6: Soil surface texture map of Kuthanagere watershed (1995)

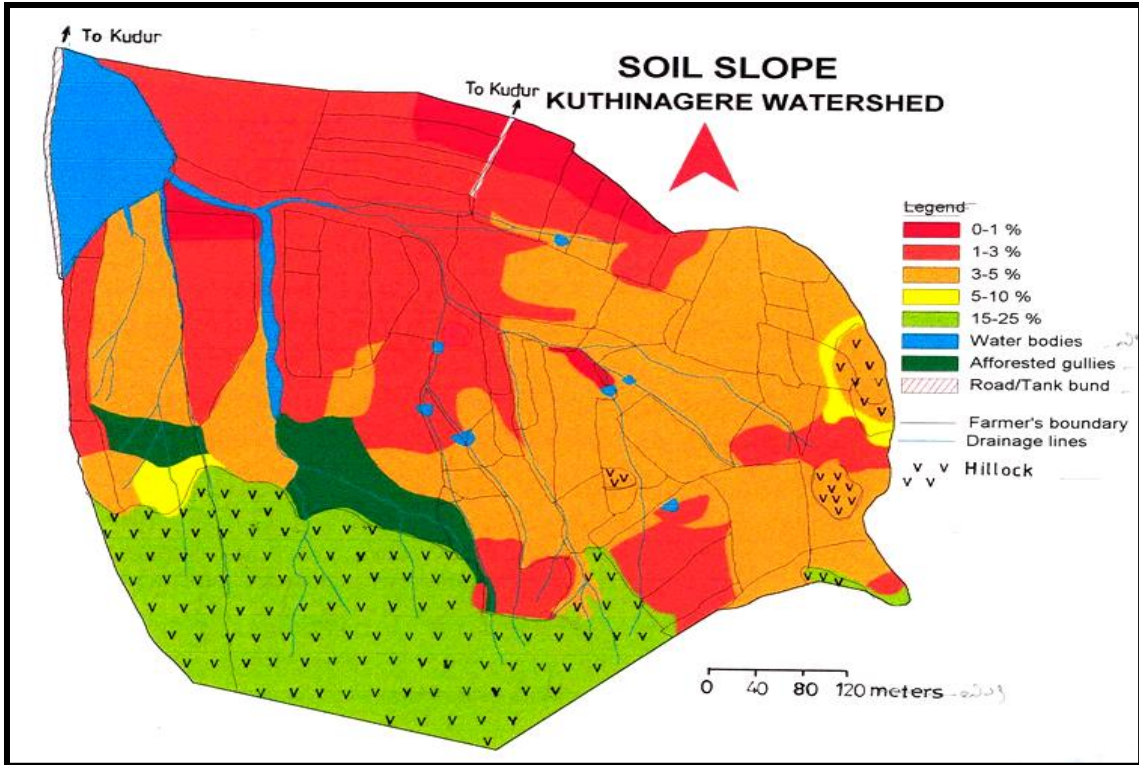


Fig. 7: Soil slope (%) map of Kuthanagere watershed (1995)

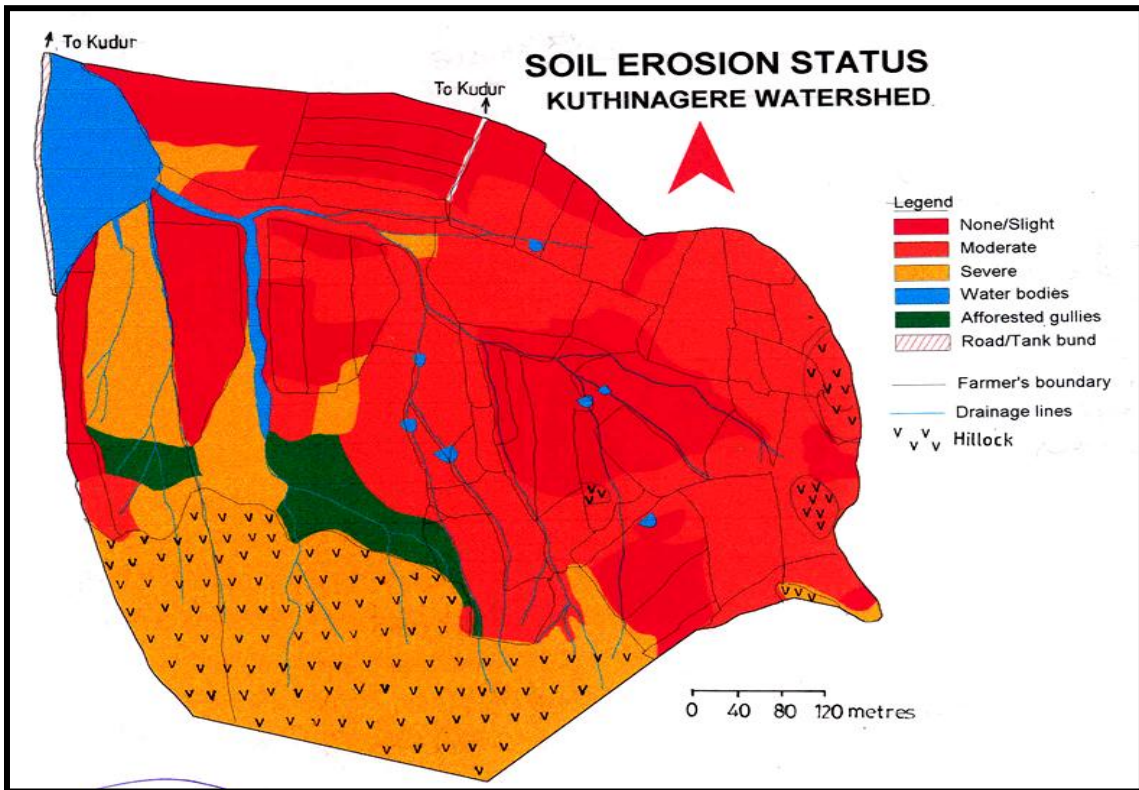


Fig. 8: Soil erosion status map of Kuthanagere watershed (1995)

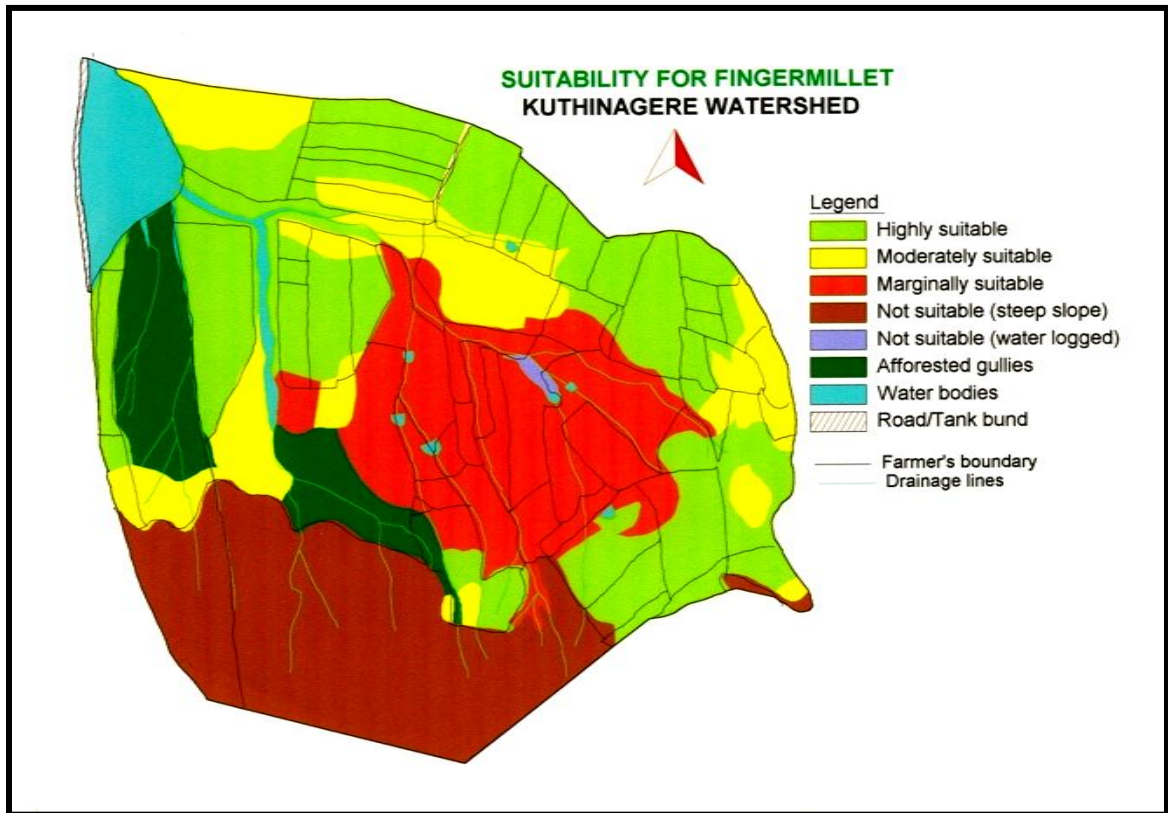


Fig. 9: Soil suitability for finger millet of Kuthanagere watershed (1995)

3.8 Soil sampling

The detailed soil survey of Kuthanagere watershed was carried out using cadastral map of 1:5000 as base map. The survey was carried out by the standard soil survey procedures as described in the soil survey manual (IARI, 1971). At first instance, traversing of the study area was done to have a resource inventory of physiography, stream lines, geology, vegetation and land use. Based on the bench mark study report master profiles were identified and locations were fixed to study pedons. Thirteen pedons were studied in the field for their morphological features. Soil samples from identified horizons of each pedon was collected for analysis of physico-chemical properties.

3.9 Resource inventory of the watershed (Table 6)

Rational utilization of our “finite” soil resources for sustained productivity needs information on nature and extent of distribution of different kind of soils of an area, problems, potentials, capabilities and their suitability for various uses. All the information could be available through systemic characterization and classification of an area. Hence, in the present study 13 representative pedons (Plate 1 to Plate 12) were selected in the watershed of Kuthanagere, Magadi taluk, Ramanagar district of Karnataka covering different physiographic units. With the help of toposheet, water bodies and drainage lines were identified. The spillway of water body was fixed and traversing was done from right side of this point. While traversing elevated places or originating points of first order drainage lines were marked and finally after traversing round about reached back to the starting point. The line drawn touching all the elevated places was considered as boundary line. After the boundary line marking all the information’s was extracted from the toposheet and base map of Kuthanagere watershed was developed. Soil profile pit with dimensions of 1mx2mx2m was dug out at the same site where bench mark survey was carried out to study the important morphological properties along with soil site characteristics during April and May of 2012. The morphological property of the pedons were described based on the established parameter. Horizon wise samples were analyzed in the laboratory for physical, physico-chemical and also nutrient status of surface samples. Further, the suitability of these soils was evaluated for growing finger millet.

Soil samples were analyzed for defined physical and chemical properties (24 parameters). Soil map and other thematic maps of the watershed were prepared using GIS

Table 6: Morphological features of the pedons under study (2012)

Pedon no.	Location		Mean sea level	Land form	Natural vegetation	Land use	Slope (%)	Erosion	Drainage	Runoff	Ground water depth (m)
	Latitude	Longitude									
P8	13°09814' N	77°18338' E	882	Very gently slopy	Eucalyptus, neem, acacia	Fallow	1-3	1	2	Med	>50
P21	13°09511' N	77°18547' E	878	Gently slopy	Acacia, Lantana	Ragi	1-3	2	2	Med	25-50
P4	13°09958' N	77°18116' E	860	Very gently slopy	Neem, Lantana	Mango	1-3	1	2	Med	>50
P19	13°09589' N	77°18521' E	887	Gently slopy	Neem, Acacia	Ragi, mango	3-5	2	2	Med	>50
P41	13°09376' N	77°17882' E	913	Moderate steep to steep slopy	Pongamia, Acacia	Forest	15-25	2	3	Very rapid	>50
P3	13°09976' N	77°17989' E	850	Gently slopy		Fallow	3-5	2	2	Med	>50
P13	13°09686' N	77°18549' E	879	Undulating	Pongamia, neem	Ragi	3-5	1	2	Med	10-25
R6	13°09662' N	77°18271' E	862	Undulating		Ragi	1-3	1	2	Slow	10-25
R5	13°09792' N	77°18159' E	863	Undulating		Mango	3-5	2	2	Med	10-25
P23	13°09574' N	77°18433' E	877	Gently slopy	Eucalyptus		3-5	2	2	Med	10-25
P33	13°09809' N	77°18025' E	859	Very gently slopy	Neem, Bamboo, Eucalyptus	Mango, Jowar	1-3	1	2	Med	>50
P20	13°09591' N	77°18434' E	890	Gently slopy		Mango	3-5	2	2	Med	>50
R9	13°09684' N	77°18138' E	861	Moderately low land			1-3	2	2	Med	10-25

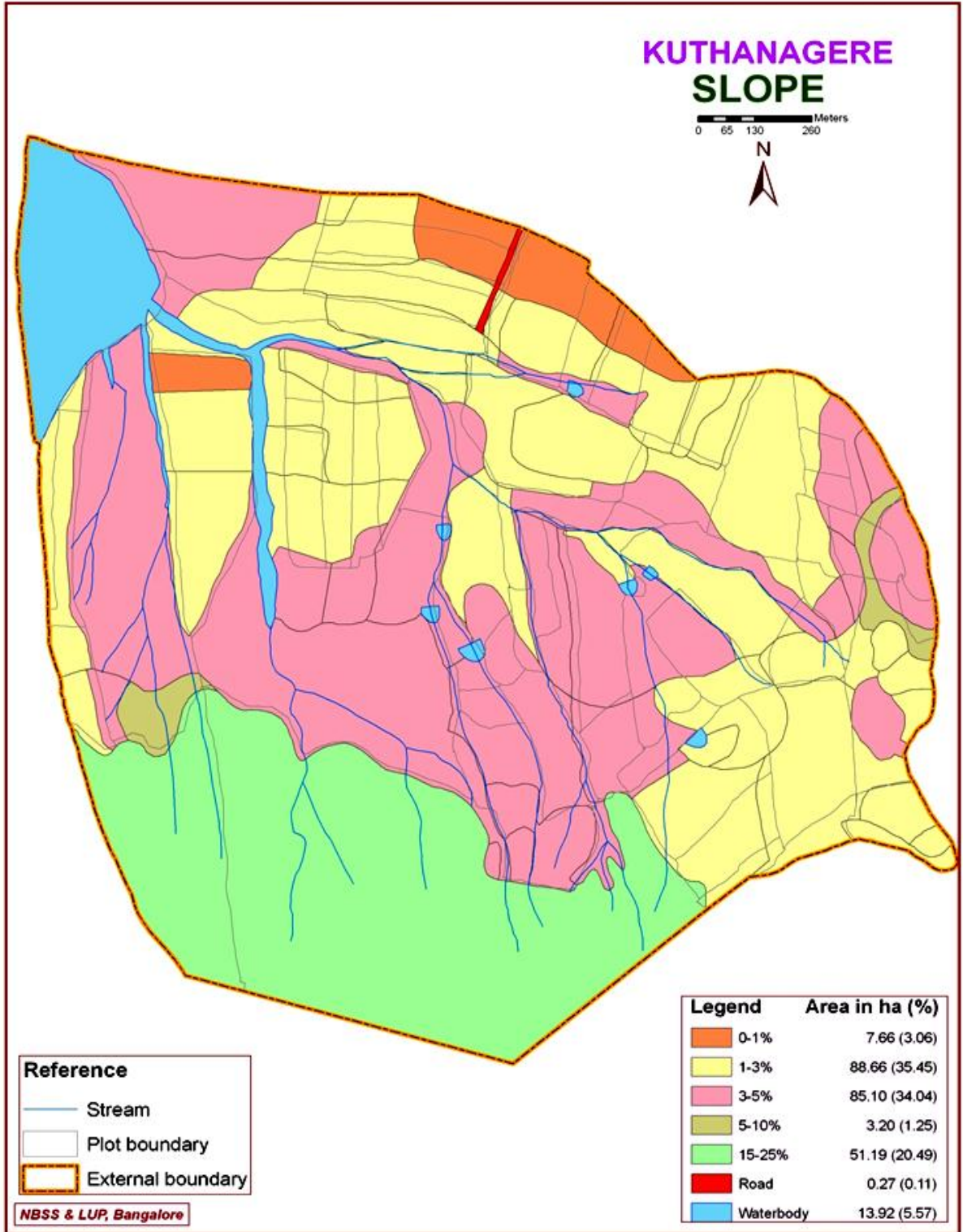


Fig. 10: Slope (%) map of kuthanagere watershed

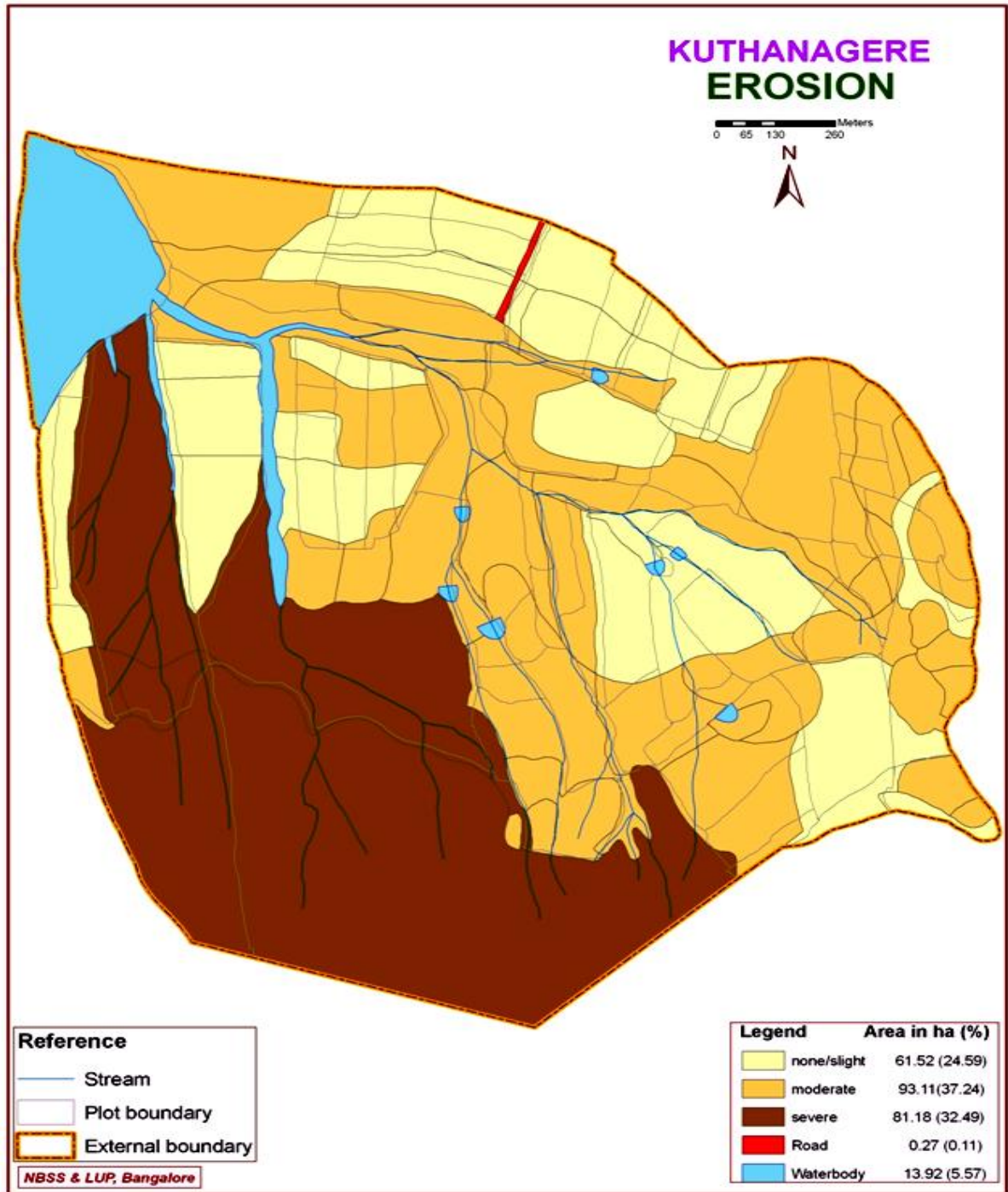


Fig. 11: Erosion map of Kuthanagere watershed

and GPS. Soil suitability map for finger millet was prepared. Comparison of these thematic maps before and after watershed development.

3.10 Preparation of soil samples

Soil samples collected from the each horizon of the profiles were dried in shade. The air-dried samples were ground with a wooden pestle and mortar and passed through 2 mm sieve to separate the coarse fragments (>2 mm). The fine earth samples were stored in separate containers and used for various analyses.

3.11 Methods of soil analysis

3.11.1 Morphological properties

3.11.1.1 Slope (%): Slope is considered important in soil genesis and land use. As such it is considered at the phase level. Slope gradient is the inclination of the surface of the soil from the horizontal. It is generally measured with hand level. The slope classes are given below:

Class	% slope
Level to nearly level	0-1
Very gently sloping	1-3
Gently sloping	3-8
Moderately sloping	8-15
Moderately steeply sloping	15-30

3.11.1.2 Erosion (rating): Soil erosion affects not only genesis and fertility status of the soils but also land use. As such it is important to give the degree and kind of erosions.

The erosion classes are given below:

Class	Rating
Nil to slight erosion	1
Moderate erosion	2
Severe erosion	3

3.11.1.3 Drainage (rating): The drainage condition of an area is of vital importance in determining the crop yields. Its precise determination under field condition is imperative for making soil survey interpretations. It is reflected in soil colour, mottling with low

chromas and the depth of their occurrence in a soil profile. The measurement of subsoil permeability for involving drainage condition is cumbersome and many soil surveyors may not undertake such a task. Moreover, it may not give the true index of drainage conditions because of stratification of sediments, especially in plain areas. The proposed criterion based on field observations not only works well in determining the drainage class but also takes care of separation at the higher category levels. The drainage class is indicated below:

Class	Rating
Poor to imperfectly drained	1
Moderately well to well drained	2
Somewhat excessively to excessively drained	3

3.11.1.4 Ground water table (m): When ground water occurs at shallow depth it saturates the soil modifying their properties and use potentials. Therefore its mention as phase level becomes important in mapping soils. The classes are given below:

Class	Depth of water table below surface
Very shallow	Within 0.50m
Shallow	Between 0.50m and 1m
Moderately shallow	Between 1m and 2 m
Moderately deep	More than 2 m

3.11.2 Physical properties

3.11.2.1 Particle size analysis

Particle size distribution of soil samples was determined by international pipette method as described by Piper (1996) using sodium hydroxide as dispersing agent. From the dispersed suspension an aliquot of clay + silt and clay were pipetted out from specified depth at specific time intervals depending on the suspension temperature. The total sand obtained by repeated decantation of silt and clay was passed through 0.05 mm sieve. The fraction that was finer than 0.05 mm was added to silt determined initially by pipetting to have particle size classes as per USDA systems.

3.11.3 Chemical properties

3.11.3.1 Soil reaction

The soil pH was determined in 1:2.5 soil: water suspension with glass electrode using pH meter (Jackson, 1967).

3.11.3.2 Electrical conductivity

Electrical conductivity was determined in 1:2.5 soil-water extract using conductivity bridge and expressed as dS m^{-1} (Jackson, 1973).

3.11.3.3 Organic carbon

The organic carbon content of a finely ground soil sample was determined by Walkely and Black's Wet Oxidation method as described by Jackson (1967) and expressed in percentage.

3.11.3.4 Exchangeable cations

Exchangeable cations were extracted by neutral normal ammonium acetate. Calcium and magnesium in the extract were determined by Versenate titration and sodium and potassium were determined by flame photometry (Thomas, 1982).

3.11.3.5 Cation exchange capacity

The cation exchange capacity (CEC) of the soil was determined by equilibrating the soil, with neutral normal sodium acetate solution and the excess salts were removed by 95 per cent isopropyl alcohol (NBSS and LUP Staff, 1987). The adsorbed sodium was replaced by equilibrating with neutral normal ammonium acetate solution and the concentration of sodium in the leachate was measured by Flame Photometer and the CEC was calculated.

3.12 Soil analysis for soil fertility evaluation

3.12.1 pH and EC

Soil pH, Electrical conductivity and organic carbon were estimated as described in section 3.11.2.1, 3.11.2.2 and 3.11.2.3.

3.12.2 Available nitrogen: The alkaline permanganate method was adopted to assess the available nitrogen content in soils (Subbiah and Asija, 1956). The easily oxidizable portion of the soil organic matter was oxidized by boiling with alkaline potassium permanganate solution and the liberated ammonia was collected (trapped) in boric acid. Later, the ammonia trapped in boric acid was quantified by titration using standard acid.

3.12.3 Available phosphorus: As the soils were acidic in reaction Bray's P 1 reagents was used for extracting available P content (1:10). The phosphorus content in the soil extract was determined by developing blue color using ascorbic acid-molybdate complex. The color intensity was read at 660 nm using spectrophotometer (Systronics Visiscan 167) (Jackson, 1973).

3.12.4 Available potassium: The available potassium in soil was extracted with neutral normal ammonium acetate. The content of K in the extract was determined by flame photometer (Systronics SYS-128) (Page *et al.*, 1982).

3.12.5 Exchangeable calcium and magnesium: The neutral normal ammonium acetate extract was used to determine exchangeable calcium and magnesium content. The exchangeable Ca and Mg together (Ca + Mg) and exchangeable Ca alone were determined, by Versenate titration method. EBT and Mureoxide indicators were used by maintaining the pH at 10 and 12 using NH₄Cl-NH₄OH buffer and NaOH respectively (Page *et al.*, 1982).

3.12.6 Exchangeable sodium: The neutral normal ammonium acetate extract was used to determine exchangeable sodium. The ammonium ions exchange with the sodium ions of the soil. The sodium content in the equilibrium solution is estimated with flame photometer. Exchangeable sodium percentage of the soil can be calculated after determining the exchangeable cations of soil (Srinivasamurthy *et al.*, 2010).

$$\text{ESP} = \frac{\text{Exch. Na}^+ \times 100}{\text{CEC}}$$

3.12.7 Available sulphur: The sulphate form of sulphur in soil was extracted using 0.15% CaCl₂ solution. The sulphate in the extract was determined by developing turbidity with BaCl₂ and the light transmitted was measured using Systronics Model Visiscan 167 spectrophotometer (Hesse, 1994).

3.12.8 DTPA extractable micronutrients: The metal ions namely, iron, zinc, manganese and copper were extracted using DTPA solution (pH 7.3). The concentration in the extract was determined by AAS (Gerhardt; GB-20) using appropriate hollow cathode lamps (Lindsay and Norvell, 1978).

3.12.9 Boron: Boron in solution (within a concentration range of 0.5-10.0 ppm) forms a stable colour complex with azomethine-H reagent at pH 5.1. The intensity of the colour, proportional to boron concentration is measured at 420nm wavelength (Srinivasamurthy *et al.*, 2010).

3.12.10 Plant available water content (PAWC): The difference in the moisture holding capacity at 33 and 1500kPa was multiplied by bulk density and soil depth to calculate the plant available water holding capacity of each soil series (Shivaramu and Niranjana, 2010).

3.12.11 Length of growing period (LGP): LGP was calculated based on FAO model of water balance analysis which involves plotting of rainfall and potential evapotranspiration values over time at monthly interval as illustrated in the appendix I (Higgins and Kassam, 1981).

3.13 Preparation of thematic maps by GIS techniques

3.13.1 Soil map

Based on physiography, field survey, laboratory investigation and using Remote Sensing and Geographical Information System, the soil phases map of Kuthanagere watershed was prepared using Cadastral maps (1:5000 scale), as base maps. Arc view 3.2a GIS software was used for mapping.

3.13.2 Suitability of crops

By comparing soil site characteristics and soil site suitability requirements for finger millet, the suitability of the soils of study area for finger millet was identified. A database file (dbf) consisting of these information was created in Arc View 3.2a to prepare thematic maps for crop suitability.

3.13.3 Soil fertility maps

A dbf file consisting of data for X and Y co-ordinates in respect of sampling site location was created. A shape file (Vector data) showing the outline of Kuthanagere watershed was created. The dbf file was opened in the project window and in X-field, X-coordinates were selected and in Y-field, Y-coordinate was selected. The Z field was used for different nutrients. The Kuthanagere watershed shape file was also opened and from the `surface menu` of Arc view spatial analyst “Interpolate grid option” was selected. On the output “grid specification dialogue”, output grid extend chosen was same as Kuthanagere watershed shape and the interpolation method employed was spline. Then map was reclassified based on ratings of respective nutrients.

3.14 Statistical analysis and interpretation of data

The analysis and interpretation of the data were done using the Fisher’s method of analysis and variance technique as given by Panse and Sukhatme (1967). The level of significance used in ‘F’ and ‘t’ test was at 5% probability level and wherever ‘F’ test was found significant, the ‘t’ test was performed to estimate critical differences among various treatments.

3.15 Correlation and regression studies

Correlation matrix was worked out to study the relationship of soil site parameters among themselves and on crop yield. In order to find the optimum range of any given soil parameter (x) for obtaining maximum crop yield (y) under both management levels, a quadratic equation ($y = a+bx+cx^2$) was fitted where ‘a’ is an intercept and ‘b’ and ‘c’ are the regression coefficients. Further, the statistical relationship between the soil site characteristics (x_1 to x_n) altogether and the seed yield were established by multi linear regression (MLR) equations ($y = a + b_1x_1 + b_2 x_2+.....+b_n x_n$). Where ‘a’ is an intercept and ‘b₁’ to ‘b_n’ are the partial regression coefficients of ‘x₁’ to ‘x_n’, respectively. The R² value obtained was tested at or below 5 per cent level of significance. Using the step down regression analysis by least square technique (Barrie *et al.*, 1986), the less important soil parameters were dropped one after another and the MLR models with seed yield were developed keeping the remaining important ones. Among the number of

models so developed, the best models were chosen based on the following criteria: (a) R^2 value should be higher and significant at or below 5 per cent level of significance, (b) more number of independent variables in the model should also be significant at or below 5 per cent level of significance and (c) the SE of 'a' and SE of 'y' estimate and index of multi-collinearity should be comparatively low (d) the intercept 'a' should also be significant at or below 5 per cent.

Experimental results

IV. EXPERIMENTAL RESULTS

An investigation was undertaken to study the long term effect of watershed development on changes in soil properties of Alfisols and productivity of finger millet in Kuthanagere of Ramanagar district, Karnataka during *Kharif* 2011 and 2012. The surface and subsurface soil samples were characterized for various physical and chemical properties to study the suitability of soil for finger millet. Field experiments were carried out in different soil series of Kuthanagere watershed to study the performance of finger millet with respect to bench mark yield. The results of field experiments, surface and subsurface soil analysis are presented in this chapter under the following headings.

4.1 Performance of finger millet in different soil series.

4.2 Characterization of profile samples for various physical and chemical properties

4.3 Characterization of surface soil samples for various chemical properties.

4.4 Correlation and regression relationship with grain yield

4.5 Comparison between benchmark survey data with the results of the experiment conducted during 2011 and 2012

4.1 Performance of finger millet at different soil series with respect to bench mark yield

4.1.1 Growth components of finger millet

The data on growth parameters viz., plant height, number of leaves per plant, number of tillers per plant, dry matter accumulation and its distribution in to leaf, stem and ear head at various stages of crop growth are presented in Table 7 to 13.

4.1.1.1 Plant height

The data on plant height (cm) of finger millet at different stages of crop are presented in the Table 7

Soil series of Kuthanagere had significant influence on the plant height at different growth stages. At 15 DAS, Kuthanagere-1 recorded higher plant height (4.39, 4.10 and 4.20 cm) during 2011, 2012 and in pooled analysis, respectively and it was

Table 7: Plant height (cm) at different growth stages of finger millet as influenced by different soil series of Kuthanagere and varieties

Treatments	15 DAS			30 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	4.39	4.01	4.20	9.75	8.99	9.37
Kuthanagere-2	4.25	3.86	4.05	9.33	8.56	8.94
Kuthanagere-3	4.32	3.94	4.13	9.52	8.76	9.14
Kuthanagere-4	3.84	3.46	3.65	8.48	7.72	8.10
Kuthanagere-6	4.19	3.81	4.00	9.19	8.43	8.81
Kuthanagere-7	4.08	3.69	3.88	8.84	8.08	8.46
Kuthanagere-9	3.95	3.56	3.75	8.61	7.85	8.23
Kuthanagere-10	4.14	3.76	3.95	9.01	8.23	8.62
Kuthanagere-11	4.01	3.63	3.82	8.71	7.96	8.34
S. Em.±	0.11	0.12	0.08	0.22	0.25	0.16
CD (0.05)	0.32	0.33	0.22	0.63	0.72	0.46
Varieties (V)						
GPU-28 (V ₁)	3.80	3.45	3.63	7.93	7.21	7.57
MR-2 (V ₂)	4.46	4.04	4.25	10.17	9.36	9.77
S. Em.±	0.05	0.05	0.04	0.10	0.12	0.08
CD (0.05)	0.15	0.16	0.11	0.30	0.34	0.22
Interaction (K*V)						
K ₁ V ₁	4.04	3.69	3.87	8.42	7.70	8.06
K ₂ V ₁	4.74	4.32	3.74	11.08	10.27	7.83
K ₃ V ₁	3.91	3.56	3.78	8.19	7.47	8.00
K ₄ V ₁	4.58	4.16	3.41	10.46	9.65	7.12
K ₆ V ₁	3.96	3.61	3.68	8.36	7.64	7.66
K ₇ V ₁	4.69	4.27	3.58	10.69	9.88	7.35
K ₉ V ₁	3.58	3.23	3.45	7.48	6.76	7.27
K ₁₀ V ₁	4.11	3.69	3.64	9.48	8.67	7.48
K ₁₁ V ₁	3.86	3.51	3.51	8.02	7.30	7.34
K ₁ V ₂	4.52	4.10	4.53	10.36	9.55	10.68
K ₂ V ₂	3.75	3.40	4.37	7.71	6.99	10.06
K ₃ V ₂	4.40	3.98	4.48	9.97	9.16	10.29
K ₄ V ₂	3.62	3.27	3.90	7.63	6.91	9.08
K ₆ V ₂	4.27	3.85	4.31	9.59	8.78	9.95
K ₇ V ₂	3.81	3.46	4.19	7.86	7.11	9.57
K ₉ V ₂	4.48	4.06	4.06	10.16	9.35	9.19
K ₁₀ V ₂	3.68	3.33	4.27	7.69	7.00	9.76
K ₁₁ V ₂	4.35	3.93	4.14	9.74	8.93	9.33
S. Em.±	0.16	0.16	0.11	0.31	0.35	0.23
CD (0.05)	NS	NS	0.32	NS	NS	0.65
CV (%)	6.69	7.53	7.0	5.92	7.37	6.5

Treatments	45 DAS			60 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	24.68	21.73	23.21	38.93	36.98	37.96
Kuthanagere-2	21.13	18.18	19.66	33.98	32.03	33.01
Kuthanagere-3	22.65	19.70	21.18	36.22	34.27	35.24
Kuthanagere-4	15.75	12.80	14.28	25.03	23.08	24.06
Kuthanagere-6	19.98	17.03	18.51	31.48	29.53	30.51
Kuthanagere-7	17.88	14.93	16.41	28.40	26.45	27.43
Kuthanagere-9	16.72	13.77	15.24	25.70	23.75	24.73
Kuthanagere-10	18.92	15.97	17.44	30.65	28.70	29.68
Kuthanagere-11	17.17	14.22	15.69	27.12	25.17	26.14
S. Em.±	0.63	0.57	0.40	1.31	1.28	0.92
CD (0.05)	1.80	1.65	1.14	3.78	3.67	2.58
Varieties (V)						
GPU-28 (V ₁)	18.28	15.46	16.87	29.23	27.34	28.28
MR-2 (V ₂)	20.58	17.50	19.04	32.44	30.43	31.44
S. Em.±	0.29	0.27	0.19	0.62	0.60	0.43
CD (0.05)	0.85	0.78	0.54	1.78	1.73	1.22
Interaction (K*V)						
K ₁ V ₁	23.52	20.70	22.11	37.32	35.43	36.37
K ₂ V ₁	25.85	22.77	18.56	40.55	38.54	31.37
K ₃ V ₁	19.97	17.15	20.24	32.32	30.43	33.61
K ₄ V ₁	22.30	19.22	13.17	35.65	33.64	22.42
K ₆ V ₁	21.65	18.83	17.40	34.55	32.66	28.87
K ₇ V ₁	23.65	20.57	15.31	37.88	35.87	25.79
K ₉ V ₁	14.58	11.76	14.14	23.37	21.48	23.59
K ₁₀ V ₁	16.92	13.84	16.34	26.70	24.69	28.04
K ₁₁ V ₁	18.81	15.99	14.59	29.82	27.93	24.51
K ₁ V ₂	21.15	18.07	24.31	33.15	31.14	39.55
K ₂ V ₂	16.72	13.90	20.76	26.73	24.84	34.65
K ₃ V ₂	19.05	15.97	22.11	30.07	28.06	36.88
K ₄ V ₂	15.55	12.73	15.38	24.53	22.64	25.70
K ₆ V ₂	17.88	14.80	19.61	26.87	24.86	32.15
K ₇ V ₂	17.75	14.93	17.51	28.98	27.09	29.06
K ₉ V ₂	20.08	17.00	16.34	32.32	30.31	25.86
K ₁₀ V ₂	16.00	13.18	18.54	25.45	23.56	31.31
K ₁₁ V ₂	18.33	15.25	16.79	28.78	26.77	27.78
S. Em.±	0.88	0.81	0.57	1.86	1.81	1.29
CD (0.05)	NS	NS	1.61	NS	NS	3.65
CV (%)	7.89	8.53	7.8	10.43	10.84	10.6

Treatments	75DAS			90DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	66.78	64.22	65.50	89.92	87.47	88.69
Kuthanagere-2	60.28	57.72	59.00	83.32	80.87	82.09
Kuthanagere-3	63.35	60.79	62.07	86.23	83.78	85.01
Kuthanagere-4	44.87	42.31	43.59	69.05	66.60	67.83
Kuthanagere-6	58.28	55.72	57.00	80.22	77.77	78.99
Kuthanagere-7	53.00	50.44	51.72	75.50	73.05	74.28
Kuthanagere-9	48.02	45.46	46.74	70.10	67.65	68.88
Kuthanagere-10	55.61	53.05	54.33	71.73	69.28	70.51
Kuthanagere-11	50.30	47.74	49.02	72.42	69.97	71.19
S. Em.±	2.27	2.25	1.58	3.00	2.99	2.09
CD (0.05)	6.54	6.48	4.47	8.61	8.58	5.89
Varieties (V)						
GPU-28 (V ₁)	53.95	51.47	52.71	75.06	72.72	73.89
MR-2 (V ₂)	57.27	54.63	55.95	80.16	77.60	78.88
S. Em.±	1.07	1.06	0.75	1.41	1.41	0.98
CD (0.05)	3.08	3.05	2.11	4.06	4.06	2.78
Interaction (K*V)						
K ₁ V ₁	65.17	62.69	63.93	86.70	84.36	85.53
K ₂ V ₁	68.40	65.76	57.38	93.13	90.57	78.91
K ₃ V ₁	58.62	56.14	60.44	80.08	77.74	81.84
K ₄ V ₁	61.95	59.31	41.96	86.55	83.99	64.70
K ₆ V ₁	61.68	59.20	55.38	83.01	80.67	75.86
K ₇ V ₁	65.02	62.38	50.09	89.45	86.89	71.09
K ₉ V ₁	43.20	40.72	45.11	65.87	63.53	65.71
K ₁₀ V ₁	46.53	43.89	52.71	72.23	69.67	73.35
K ₁₁ V ₁	56.62	54.14	47.39	77.03	74.69	68.03
K ₁ V ₂	59.95	57.31	67.08	83.40	80.84	91.85
K ₂ V ₂	51.33	48.85	60.63	72.26	69.92	85.27
K ₃ V ₂	54.67	52.03	63.70	78.74	76.18	88.17
K ₄ V ₂	46.35	43.87	45.21	66.88	64.54	70.95
K ₆ V ₂	49.68	47.04	58.63	73.32	70.76	82.12
K ₇ V ₂	53.95	51.47	53.35	74.52	72.18	77.46
K ₉ V ₂	57.27	54.63	48.36	68.95	66.39	72.04
K ₁₀ V ₂	48.63	46.15	55.95	69.20	66.86	67.67
K ₁₁ V ₂	51.97	49.33	50.65	75.63	73.07	74.35
S. Em.±	3.22	3.19	2.24	4.24	4.22	2.95
CD (0.05)	9.24	9.16	6.32	12.18	12.14	8.33
CV (%)	10.02	10.41	10.1	9.46	9.73	9.5

Treatments	At harvest		
	2011	2012	Pooled
Soil series (K)			
Kuthanagere-1	95.82	93.32	94.57
Kuthanagere-2	90.63	88.13	89.38
Kuthanagere-3	93.13	90.63	91.88
Kuthanagere-4	76.10	73.60	74.85
Kuthanagere-6	88.22	85.72	86.97
Kuthanagere-7	82.98	80.48	81.73
Kuthanagere-9	78.70	76.20	77.45
Kuthanagere-10	85.43	82.93	84.18
Kuthanagere-11	79.62	77.12	78.37
S. Em.±	2.87	2.82	2.00
CD (0.05)	8.24	8.11	5.63
Varieties (V)			
GPU-28 (V ₁)	83.53	81.14	82.34
MR-2 (V ₂)	87.72	85.11	86.41
S. Em.±	1.35	1.33	0.94
CD (0.05)	3.88	3.82	2.66
Interaction (K*V)			
K ₁ V ₁	93.65	91.26	92.46
K ₂ V ₁	97.98	95.37	87.27
K ₃ V ₁	88.47	86.08	89.77
K ₄ V ₁	92.80	90.19	72.74
K ₆ V ₁	90.97	88.58	84.86
K ₇ V ₁	95.30	92.69	79.62
K ₉ V ₁	73.93	71.54	75.34
K ₁₀ V ₁	78.27	75.66	82.07
K ₁₁ V ₁	86.05	83.66	76.92
K ₁ V ₂	90.38	87.77	96.68
K ₂ V ₂	80.82	78.43	91.50
K ₃ V ₂	85.15	82.54	94.00
K ₄ V ₂	76.53	74.14	76.96
K ₆ V ₂	80.87	78.26	89.08
K ₇ V ₂	83.27	80.88	83.85
K ₉ V ₂	87.60	84.99	79.56
K ₁₀ V ₂	78.12	75.73	86.30
K ₁₁ V ₂	81.12	78.51	79.81
S. Em.±	4.05	3.99	2.83
CD (0.05)	NS	NS	7.97
CV (%)	8.20	8.31	8.2

found to be on par with Kuthanagere-3, 2, and 6. Same trend was observed at 30 DAS. At 45 and 60 DAS, Kuthanagere-1 soil recorded significantly higher plant height when compared to other soil series in both the years of study and in pooled analysis this was followed by Kuthanagere-3. Both these soil series are found to be on par with each other. At 75, 90 DAS and at harvest, Kuthanagere-1, 3, and 2 soil series was found to be on par with each other and differed significantly over other soil series. The lower plant height was recorded with Kuthanagere-4 soil series throughout the crop growth stages during 2011, 2012 and in pooled analysis.

Varietal performance with respect to plant height differed significantly under different soil series. Among the two varieties, MR-2 recorded significantly higher plant height throughout the growth stages compared to GPU-28 during 2011, 2012 and in pooled analysis.

Interaction between soil series and varieties was found insignificant during 2011 and 2012, however it was found significant in pooled analysis. Among the soil series and varieties, MR-2 grown in Kuthanagere-1 combination resulted in higher plant height and it was found to be on par with MR-2 grown in Kuthanagere-2, 3 and 6 throughout the crop growth stages. The lower plant height in the interaction was notice when GPU-28 was grown in Kuthanagere-4 soil series at all the stages of crop growth.

4.1.1.2 Number of leaves

Soil series had a significant influence on the number of leaves at all the stages of finger millet. The data pertaining to the number of leaves are presented in the Table 8.

Throughout the growth stages of finger millet, higher number of leaves was recorded in Kuthanagere-1 soil series in both the years of study and in pooled analysis. At 15, 30 DAS and at harvest Kuthanagere-1 was found to be on par with Kuthanagere-3 soil but it varied significantly compared to other soil series at 45, 60, 75 and 90 DAS. Kuthanagere-2 and Kuthanagere-3 was found to be on par at throughout the growth stages except at 45 DAS whereas Kuthanagere-2 and Kuthanagere-6 was at par throughout the growth stages of finger millet during 2011, 2012 and in pooled analysis.

Table 8: Number of leaves plant⁻¹ at different growth stages of finger millet as influenced by different soil series of Kuthanagere and varieties

Treatments	15 DAS			30 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	2.91	2.68	2.80	11.26	10.90	11.08
Kuthanagere-2	2.75	2.52	2.64	9.72	9.37	9.54
Kuthanagere-3	2.82	2.57	2.69	10.50	10.17	10.33
Kuthanagere-4	2.44	2.21	2.33	8.21	7.87	8.04
Kuthanagere-6	2.69	2.45	2.57	9.27	8.93	9.10
Kuthanagere-7	2.58	2.34	2.46	8.74	8.40	8.57
Kuthanagere-9	2.50	2.27	2.38	8.38	8.04	8.21
Kuthanagere-10	2.65	2.42	2.53	8.99	8.65	8.82
Kuthanagere-11	2.53	2.31	2.42	8.63	8.27	8.45
S. Em.±	0.10	0.10	0.07	0.38	0.36	0.20
CD (0.05)	0.28	0.27	0.19	1.10	1.02	0.57
Varieties (V)						
GPU-28 (V ₁)	2.86	2.62	2.74	9.88	9.54	9.71
MR-2 (V ₂)	2.45	2.21	2.33	8.71	8.37	8.54
S. Em.±	0.05	0.05	0.03	0.18	0.17	0.10
CD (0.05)	0.13	0.13	0.09	0.52	0.48	0.27
Interaction (K*V)						
K ₁ V ₁	3.20	2.96	3.08	11.86	11.50	11.68
K ₂ V ₁	2.62	2.40	2.84	10.66	10.29	10.13
K ₃ V ₁	2.95	2.72	2.91	10.30	9.96	10.91
K ₄ V ₁	2.55	2.32	2.51	9.13	8.78	8.63
K ₆ V ₁	3.04	2.78	2.78	11.08	10.74	9.68
K ₇ V ₁	2.59	2.36	2.62	9.91	9.59	9.16
K ₉ V ₁	2.64	2.39	2.56	8.80	8.47	8.80
K ₁₀ V ₁	2.25	2.03	2.75	7.63	7.28	9.40
K ₁₁ V ₁	2.91	2.66	2.60	9.85	9.51	9.02
K ₁ V ₂	2.47	2.25	2.51	8.68	8.35	10.48
K ₂ V ₂	2.75	2.50	2.44	9.32	8.99	8.96
K ₃ V ₂	2.42	2.18	2.48	8.15	7.81	9.75
K ₄ V ₂	2.67	2.46	2.14	8.97	8.63	7.46
K ₆ V ₂	2.32	2.07	2.36	7.80	7.45	8.52
K ₇ V ₂	2.87	2.62	2.30	9.57	9.24	7.98
K ₉ V ₂	2.44	2.21	2.20	8.40	8.07	7.63
K ₁₀ V ₂	2.71	2.50	2.32	9.21	8.84	8.24
K ₁₁ V ₂	2.35	2.12	2.23	8.04	7.69	7.87
S. Em.±	0.14	0.14	0.10	0.54	0.50	0.29
CD (0.05)	NS	NS	0.27	NS	NS	0.81
CV (%)	8.89	9.69	9.3	10.09	9.75	7.7

Treatments	45 DAS			60 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	16.61	15.53	16.07	22.61	21.39	22.00
Kuthanagere-2	14.27	13.22	13.74	19.55	18.30	18.92
Kuthanagere-3	15.46	14.40	14.93	20.80	19.56	20.18
Kuthanagere-4	12.51	11.46	12.15	17.51	16.40	16.95
Kuthanagere-6	13.77	12.70	13.23	19.10	17.87	18.49
Kuthanagere-7	13.20	12.15	12.68	18.62	17.38	18.00
Kuthanagere-9	12.74	11.69	12.21	18.07	16.83	17.45
Kuthanagere-10	13.43	12.40	12.91	19.06	17.77	18.41
Kuthanagere-11	12.96	11.90	12.43	18.53	17.29	17.91
S. Em.±	0.36	0.34	0.22	0.63	0.62	0.37
CD (0.05)	1.04	0.98	0.61	1.82	1.78	1.06
Varieties (V)						
GPU-28 (V ₁)	14.46	13.40	13.93	19.90	18.69	19.30
MR-2 (V ₂)	13.31	12.25	12.82	18.73	17.48	18.11
S. Em.±	0.17	0.16	0.10	0.30	0.29	0.18
CD (0.05)	0.49	0.46	0.29	0.86	0.84	0.50
Interaction (K*V)						
K ₁ V ₁	17.20	16.09	16.65	23.20	21.97	22.58
K ₂ V ₁	16.03	14.96	14.28	22.03	20.81	19.51
K ₃ V ₁	14.80	13.75	15.51	20.13	18.88	20.77
K ₄ V ₁	13.73	12.68	12.57	18.97	17.71	17.61
K ₆ V ₁	16.05	14.98	13.82	21.38	20.15	19.08
K ₇ V ₁	14.88	13.82	13.26	20.21	18.97	18.58
K ₉ V ₁	13.09	12.04	12.79	18.09	17.12	18.03
K ₁₀ V ₁	11.92	10.88	13.50	16.92	15.67	19.02
K ₁₁ V ₁	14.35	13.29	13.01	19.69	18.48	18.50
K ₁ V ₂	13.19	12.10	15.50	18.52	17.27	21.42
K ₂ V ₂	13.78	12.73	13.21	19.21	17.96	18.34
K ₃ V ₂	12.62	11.57	14.35	18.04	16.80	19.59
K ₄ V ₂	13.32	12.26	11.74	18.65	17.41	16.30
K ₆ V ₂	12.16	11.11	12.65	17.48	16.24	17.90
K ₇ V ₂	14.01	12.98	12.09	19.68	18.36	17.42
K ₉ V ₂	12.85	11.81	11.63	18.43	17.17	16.86
K ₁₀ V ₂	13.54	12.48	12.33	19.12	17.88	17.80
K ₁₁ V ₂	12.37	11.32	11.85	17.95	16.70	17.33
S. Em.±	0.51	0.48	0.30	0.90	0.88	0.53
CD (0.05)	NS	NS	0.86	NS	NS	1.49
CV (%)	6.36	6.54	5.6	8.03	8.41	6.9

Treatments	75 DAS			90 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	24.95	23.82	24.38	23.61	22.58	23.09
Kuthanagere-2	21.88	20.75	21.32	20.55	19.51	20.03
Kuthanagere-3	23.13	22.01	22.57	21.88	20.84	21.36
Kuthanagere-4	19.84	18.70	19.27	18.51	17.47	17.99
Kuthanagere-6	21.44	20.31	20.87	20.10	19.07	19.59
Kuthanagere-7	20.87	19.74	20.30	19.53	18.50	19.02
Kuthanagere-9	20.07	19.01	19.54	18.74	17.70	18.22
Kuthanagere-10	21.10	19.95	20.52	19.76	18.73	19.25
Kuthanagere-11	20.62	19.50	20.06	19.29	18.26	18.78
S. Em.±	0.60	0.59	0.38	0.51	0.50	0.30
CD (0.05)	1.71	1.70	1.06	1.46	1.43	0.83
Varieties (V)						
GPU-28 (V ₁)	22.13	21.00	21.56	20.80	19.76	20.28
MR-2 (V ₂)	20.96	19.84	20.40	19.64	18.60	19.12
S. Em.±	0.28	0.28	0.18	0.24	0.24	0.14
CD (0.05)	0.81	0.80	0.50	0.69	0.68	0.39
Interaction (K*V)						
K ₁ V ₁	25.53	24.39	24.96	24.19	23.15	23.67
K ₂ V ₁	24.36	23.24	21.90	23.03	22.00	20.61
K ₃ V ₁	22.47	21.34	23.15	21.13	20.08	21.94
K ₄ V ₁	21.30	20.16	19.85	19.97	18.93	18.57
K ₆ V ₁	23.71	22.59	21.46	22.46	21.42	20.17
K ₇ V ₁	22.55	21.42	20.88	21.29	20.25	19.60
K ₉ V ₁	20.42	19.27	20.12	19.09	18.05	18.80
K ₁₀ V ₁	19.26	18.12	21.11	17.92	16.89	19.83
K ₁₁ V ₁	22.02	20.90	20.65	20.69	19.66	19.36
K ₁ V ₂	20.85	19.72	23.80	19.52	18.49	22.51
K ₂ V ₂	21.45	20.31	20.73	20.12	19.08	19.45
K ₃ V ₂	20.28	19.16	21.98	18.95	17.92	20.77
K ₄ V ₂	20.66	19.58	18.69	19.32	18.27	17.41
K ₆ V ₂	19.49	18.43	20.29	18.16	17.12	19.01
K ₇ V ₂	21.68	20.53	19.72	20.35	19.31	18.44
K ₉ V ₂	20.51	19.37	18.96	19.18	18.15	17.64
K ₁₀ V ₂	21.21	20.09	19.94	19.87	18.85	18.67
K ₁₁ V ₂	20.04	18.91	19.48	18.71	17.67	18.19
S. Em.±	0.84	0.84	0.53	0.72	0.71	0.42
CD (0.05)	NS	NS	1.50	NS	NS	1.18
CV (%)	6.78	7.08	6.2	6.14	6.37	5.2

Treatments	At harvest		
	2011	2012	Pooled
Soil series (K)			
Kuthanagere-1	9.28	8.56	8.93
Kuthanagere-2	8.05	7.32	7.69
Kuthanagere-3	8.83	8.12	8.47
Kuthanagere-4	6.55	5.84	6.19
Kuthanagere-6	7.57	6.86	7.21
Kuthanagere-7	7.07	6.35	6.71
Kuthanagere-9	6.72	6.01	6.36
Kuthanagere-10	7.32	6.62	6.97
Kuthanagere-11	6.96	6.25	6.60
S. Em.±	0.30	0.30	0.18
CD (0.05)	0.87	0.86	0.51
Varieties (V)			
GPU-28 (V ₁)	8.18	7.46	7.82
MR-2 (V ₂)	7.01	6.30	6.66
S. Em.±	0.14	0.14	0.08
CD (0.05)	0.41	0.41	0.24
Interaction (K*V)			
K ₁ V ₁	9.86	9.13	9.50
K ₂ V ₁	8.70	7.98	8.27
K ₃ V ₁	8.63	7.90	9.05
K ₄ V ₁	7.47	6.74	6.77
K ₆ V ₁	9.41	8.68	7.80
K ₇ V ₁	8.25	7.55	7.29
K ₉ V ₁	7.13	6.41	6.94
K ₁₀ V ₁	5.96	5.26	7.55
K ₁₁ V ₁	8.15	7.45	7.19
K ₁ V ₂	6.98	6.26	8.35
K ₂ V ₂	7.65	6.92	7.10
K ₃ V ₂	6.49	5.77	7.90
K ₄ V ₂	7.30	6.58	5.61
K ₆ V ₂	6.13	5.43	6.62
K ₇ V ₂	7.90	7.19	6.13
K ₉ V ₂	6.74	6.04	5.78
K ₁₀ V ₂	7.54	6.83	6.39
K ₁₁ V ₂	6.37	5.66	6.02
S. Em.±	0.43	0.42	0.25
CD (0.05)	1.23	1.22	0.72
CV (%)	9.79	10.66	8.6

Kuthanagere-4 soil resulted in lower number of leaves compared to all other soil series at all the stages of crop growth in both the years of experimentation.

Among the varieties GPU-28 produced more number of leaves compared to MR-2 throughout the crop growth period during. GPU-28 varied significantly with MR-2 during 2011, 2012 and pooled analysis.

There was no significant difference in interaction between soil series and varieties during 2011 and 2012 at all the growth stage of finger millet however, significant interaction was observed in pooled analysis and at harvest. Among the different treatment combination, GPU-28 grown in Kuthanagere-1 soil resulted in more number of leaves throughout the growth stages compared to all other treatment combinations and it was found to be on par with Kuthanagere-3 at 15 DAS and at harvest. Kuthanagere-3 and Kuthanagere-2 soil series having GPU-28 found to be on par with each other at 15, 30 and 75 DAS whereas Kuthanagere-2 and Kuthanagere-6 with GPU-28 found to be on par throughout the growth stages. Significantly lower number of leaves was observed in MR-2 when grown in Kuthanagere-4 soil series at all the stages of crop growth period.

4.1.1.3 Number of tillers plant⁻¹

The data pertaining to number of tillers per plant of finger millet at different growth stages of crop are presented in Table 9.

With respect to tiller production significant variations were observed between soil series at 30 DAS, more number of tillers per plant was recorded in Kuthanagere-1 (1.31 and 1.07) during 2011 and 2012, which differed significantly when compared to Kuthanagere-6, Kuthanagere-7, Kuthanagere-9, Kuthanagere-10, Kuthanagere-11 and Kuthanagere-4 but it was found to be on par with Kuthanagere-3 and Kuthanagere-2 (1.24, 1.00 and 1.18, 0.94, respectively) during 2011 and 2012. In pooled analysis more number of tillers was observed in Kuthanagere-1 (1.19) which was on par with Kuthanagere-3 (1.12), both the soil series varied significantly compared to other soil series. Same trend was observed at 45, 60, 75, 90 DAS and at harvest. At all the crop growth stages Kuthanagere-2 and Kuthanagere-6 were on par with each other.

Table 9: Number of tillers (plant⁻¹) at different growth stages of finger millet as influenced by different soil series of Kuthanagere and varieties

Treatments	30 DAS			45 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	1.31	1.07	1.19	1.73	1.43	1.58
Kuthanagere-2	1.18	0.94	1.06	1.53	1.23	1.38
Kuthanagere-3	1.24	1.00	1.12	1.62	1.32	1.47
Kuthanagere-4	0.95	0.71	0.83	1.09	0.79	0.94
Kuthanagere-6	1.16	0.92	1.04	1.45	1.15	1.30
Kuthanagere-7	1.07	0.83	0.95	1.30	1.00	1.15
Kuthanagere-9	1.00	0.76	0.88	1.17	0.87	1.02
Kuthanagere-10	1.11	0.87	0.99	1.36	1.06	1.21
Kuthanagere-11	1.04	0.80	0.92	1.23	0.93	1.08
S. Em.±	0.05	0.05	0.03	0.06	0.06	0.04
CD (0.05)	0.14	0.14	0.10	0.18	0.17	0.12
Varieties (V)						
GPU-28 (V ₁)	1.16	0.94	1.05	1.45	1.16	1.31
MR-2 (V ₂)	1.07	0.81	0.94	1.32	1.01	1.16
S. Em.±	0.02	0.02	0.02	0.03	0.03	0.02
CD (0.05)	0.07	0.07	0.05	0.09	0.08	0.06
Interaction (K*V)						
K ₁ V ₁	1.37	1.15	1.26	1.81	1.52	1.66
K ₂ V ₁	1.25	0.99	1.13	1.65	1.34	1.47
K ₃ V ₁	1.24	1.02	1.19	1.62	1.33	1.58
K ₄ V ₁	1.11	0.85	0.89	1.43	1.12	0.98
K ₆ V ₁	1.30	1.08	1.08	1.73	1.44	1.38
K ₇ V ₁	1.17	0.91	1.00	1.52	1.21	1.20
K ₉ V ₁	1.00	0.78	0.93	1.12	0.83	1.07
K ₁₀ V ₁	0.90	0.64	1.03	1.06	0.75	1.28
K ₁₁ V ₁	1.19	0.97	0.97	1.53	1.24	1.14
K ₁ V ₂	1.13	0.87	1.12	1.36	1.05	1.50
K ₂ V ₂	1.11	0.89	0.98	1.34	1.05	1.28
K ₃ V ₂	1.04	0.78	1.04	1.25	0.94	1.36
K ₄ V ₂	1.04	0.82	0.77	1.21	0.92	0.91
K ₆ V ₂	0.95	0.69	1.00	1.12	0.81	1.21
K ₇ V ₂	1.14	0.92	0.91	1.43	1.14	1.09
K ₉ V ₂	1.07	0.81	0.82	1.29	0.98	0.97
K ₁₀ V ₂	1.08	0.86	0.94	1.28	0.99	1.14
K ₁₁ V ₂	1.01	0.75	0.88	1.19	0.88	1.03
S. Em.±	0.07	0.07	0.05	0.09	0.08	0.06
CD (0.05)	NS	NS	0.14	NS	NS	0.18
CV (%)	10.87	13.85	12.0	11.15	13.20	12.3

Treatments	60 DAS			75 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	2.33	1.98	2.15	2.76	2.39	2.57
Kuthanagere-2	2.15	1.80	1.98	2.52	2.15	2.34
Kuthanagere-3	2.23	1.89	2.06	2.66	2.29	2.47
Kuthanagere-4	1.68	1.33	1.50	2.01	1.64	1.83
Kuthanagere-6	2.07	1.72	1.90	2.39	2.02	2.21
Kuthanagere-7	1.90	1.56	1.73	2.25	1.88	2.07
Kuthanagere-9	1.74	1.39	1.57	2.09	1.72	1.90
Kuthanagere-10	2.01	1.66	1.83	2.32	1.95	2.14
Kuthanagere-11	1.82	1.47	1.64	2.17	1.80	1.99
S. Em.±	0.06	0.06	0.03	0.09	0.08	0.05
CD (0.05)	0.16	0.18	0.09	0.25	0.24	0.13
Varieties (V)						
GPU-28 (V ₁)	2.04	1.71	1.88	2.41	2.04	2.23
MR-2 (V ₂)	1.94	1.58	1.76	2.29	1.92	2.11
S. Em.±	0.03	0.03	0.02	0.04	0.04	0.02
CD (0.05)	0.08	0.09	0.04	0.12	0.11	0.06
Interaction (K*V)						
K ₁ V ₁	2.40	1.90	2.23	2.84	2.47	2.65
K ₂ V ₁	2.26	1.87	2.04	2.68	2.31	2.40
K ₃ V ₁	2.20	1.73	2.12	2.59	2.22	2.54
K ₄ V ₁	2.09	1.95	1.56	2.46	2.09	1.88
K ₆ V ₁	2.28	1.82	1.95	2.72	2.35	2.26
K ₇ V ₁	2.18	1.40	1.79	2.59	2.22	2.13
K ₉ V ₁	1.73	1.27	1.62	2.06	1.69	1.96
K ₁₀ V ₁	1.63	1.78	1.88	1.96	1.59	2.20
K ₁₁ V ₁	2.11	1.66	1.69	2.45	2.08	2.05
K ₁ V ₂	2.02	1.62	2.08	2.34	1.97	2.50
K ₂ V ₂	1.95	1.49	1.91	2.31	1.94	2.28
K ₃ V ₂	1.85	1.46	2.00	2.19	1.82	2.41
K ₄ V ₂	1.79	1.33	1.45	2.14	1.77	1.78
K ₆ V ₂	1.69	1.71	1.84	2.03	1.66	2.16
K ₇ V ₂	2.04	1.61	1.67	2.38	2.01	2.01
K ₉ V ₂	1.97	1.53	1.51	2.26	1.89	1.85
K ₁₀ V ₂	1.86	1.42	1.79	2.23	1.86	2.08
K ₁₁ V ₂	1.78	0.09	1.60	2.11	1.74	1.93
S. Em.±	0.08	0.26	0.05	0.12	0.12	0.07
CD (0.05)	NS	NS	0.13	NS	NS	0.19
CV (%)	6.92	1.90	6.3	8.91	10.44	7.4

Treatments	90 DAS			At harvest		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	3.57	3.02	3.30	3.68	3.24	3.46
Kuthanagere-2	3.34	2.79	3.06	3.46	3.02	3.24
Kuthanagere-3	3.47	2.92	3.19	3.57	3.13	3.35
Kuthanagere-4	2.67	2.12	2.39	2.80	2.36	2.58
Kuthanagere-6	3.23	2.68	2.96	3.32	2.88	3.10
Kuthanagere-7	3.01	2.46	2.73	3.11	2.67	2.89
Kuthanagere-9	2.76	2.21	2.48	2.89	2.45	2.67
Kuthanagere-10	3.13	2.58	2.86	3.19	2.75	2.97
Kuthanagere-11	2.86	2.31	2.59	2.98	2.54	2.76
S. Em.±	0.10	0.09	0.07	0.11	0.10	0.08
CD (0.05)	0.30	0.26	0.20	0.33	0.29	0.23
Varieties (V)						
GPU-28 (V ₁)	3.20	2.67	2.93	3.30	2.88	3.09
MR-2 (V ₂)	3.03	2.46	2.75	3.14	2.68	2.91
S. Em.±	0.05	0.04	0.03	0.05	0.05	0.04
CD (0.05)	0.14	0.12	0.10	0.16	0.14	0.11
Interaction (K*V)						
K ₁ V ₁	3.68	3.15	3.42	3.82	3.40	3.61
K ₂ V ₁	3.46	2.88	3.16	3.54	3.08	3.37
K ₃ V ₁	3.42	2.89	3.31	3.58	3.16	3.49
K ₄ V ₁	3.26	2.69	2.47	3.33	2.87	2.65
K ₆ V ₁	3.57	3.04	3.03	3.70	3.28	3.18
K ₇ V ₁	3.37	2.80	2.83	3.45	2.99	2.97
K ₉ V ₁	2.73	2.20	2.56	2.86	2.44	2.73
K ₁₀ V ₁	2.60	2.03	2.94	2.74	2.28	3.03
K ₁₁ V ₁	3.30	2.77	2.68	3.39	2.97	2.83
K ₁ V ₂	3.16	2.59	3.17	3.25	2.79	3.31
K ₂ V ₂	3.09	2.56	2.97	3.18	2.76	3.10
K ₃ V ₂	2.93	2.36	3.08	3.04	2.58	3.22
K ₄ V ₂	2.82	2.29	2.31	2.94	2.52	2.51
K ₆ V ₂	2.69	2.12	2.88	2.83	2.37	3.02
K ₇ V ₂	3.20	2.67	2.64	3.24	2.82	2.81
K ₉ V ₂	3.06	2.49	2.41	3.13	2.67	2.60
K ₁₀ V ₂	2.94	2.41	2.78	3.04	2.62	2.90
K ₁₁ V ₂	2.79	2.22	2.50	2.93	2.47	2.70
S. Em.±	0.15	0.13	0.10	0.16	0.14	0.11
CD (0.05)	NS	NS	0.29	NS	NS	0.32
CV (%)	8.12	8.77	8.8	8.74	8.95	9.2

Significantly lower number of tillers was recorded in Kuthanagere-4 soil series throughout the crop growth stages.

Significant performance of variety was observed in tiller production. Among the two varieties more number of tillers was recorded in GPU-28 and it varied significantly when compared to MR-2 during 2011 and 2012 and in pooled analysis.

Tiller production in different soil series and varieties differed significantly in pooled analysis. More number of tillers per plant was noticed when GPU-28 was grown in Kuthanagere-1 soil series which was followed by Kuthanagere-3 and both these treatment combinations was found to be on par with each other throughout the growth stages of crop. These two treatment combination varied significantly compared to all other treatment combinations. MR-2 variety grown in Kuthanagere-4 recorded significantly lower number of tiller per plant at all the stages of crop growth. The number of tiller produced per plant was found to be insignificant during 2011 and 2012.

4.1.1.4 Dry matter accumulation in leaves plant⁻¹

At different stages of crop growth, dry matter accumulation in leaves (g) as influenced by different soil series and varieties are presented in Table 10.

Higher dry matter accumulation in leaves was noticed in Kuthanagere-1 soil series during 2011, 2012 and in pooled analysis which varied significantly throughout the crop growth stages. At 15 DAS it was found to be on par with Kuthanagere-3 and at later stages of crop growth it was found to be on par with Kuthanagere-2. These three soil series varied significantly over remaining soil series whereas, Kuthanagere-6 soil was on par with Kuthanagere-2 at 15 and 30 DAS and on par with Kuthanagere-3 at 45, 60, 75, 90 DAS and at harvest. Lower dry matter accumulation in leaves was noticed in Kuthanagere-4 soil series throughout the crop growth period in both years of study and in pooled analysis.

Dry matter accumulation in leaves differed significantly between two varieties. Among the two varieties, GPU-28 accumulated higher dry matter in leaves at all the growth stages when compared to MR-2 during 2011, 2012 and in pooled analysis.

Table 10: Dry matter accumulation plant⁻¹ (g) in leaves at different growth stages of finger millet as influenced by different soil series of Kuthanagere and varieties

Treatments	15 DAS			30 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	0.67	0.53	0.60	1.95	1.70	1.82
Kuthanagere-2	0.56	0.43	0.49	1.76	1.51	1.64
Kuthanagere-3	0.61	0.48	0.54	1.84	1.59	1.71
Kuthanagere-4	0.40	0.27	0.33	1.41	1.16	1.29
Kuthanagere-6	0.53	0.39	0.46	1.70	1.45	1.58
Kuthanagere-7	0.46	0.33	0.39	1.59	1.34	1.46
Kuthanagere-9	0.43	0.29	0.36	1.44	1.19	1.32
Kuthanagere-10	0.50	0.36	0.43	1.63	1.38	1.50
Kuthanagere-11	0.44	0.31	0.37	1.49	1.24	1.36
S. Em.±	0.03	0.02	0.02	0.07	0.06	0.05
CD (0.05)	0.08	0.06	0.04	0.20	0.18	0.14
Varieties (V)						
GPU-28 (V ₁)	0.56	0.43	0.50	1.76	1.53	1.64
MR-2 (V ₂)	0.46	0.32	0.39	1.53	1.26	1.40
S. Em.±	0.01	0.01	0.01	0.03	0.03	0.02
CD (0.05)	0.04	0.03	0.02	0.10	0.08	0.07
Interaction (K*V)						
K ₁ V ₁	0.71	0.58	0.64	2.07	1.84	1.96
K ₂ V ₁	0.63	0.49	0.55	1.82	1.55	1.79
K ₃ V ₁	0.62	0.49	0.61	1.90	1.67	1.85
K ₄ V ₁	0.50	0.36	0.39	1.62	1.35	1.37
K ₆ V ₁	0.68	0.55	0.50	1.96	1.73	1.74
K ₇ V ₁	0.54	0.40	0.44	1.71	1.44	1.59
K ₉ V ₁	0.45	0.32	0.42	1.48	1.25	1.41
K ₁₀ V ₁	0.35	0.21	0.47	1.34	1.07	1.65
K ₁₁ V ₁	0.56	0.43	0.43	1.85	1.62	1.46
K ₁ V ₂	0.49	0.35	0.56	1.56	1.29	1.69
K ₂ V ₂	0.51	0.38	0.43	1.71	1.48	1.49
K ₃ V ₂	0.42	0.28	0.48	1.47	1.20	1.58
K ₄ V ₂	0.49	0.36	0.28	1.52	1.29	1.21
K ₆ V ₂	0.36	0.22	0.42	1.37	1.10	1.42
K ₇ V ₂	0.54	0.41	0.35	1.76	1.53	1.33
K ₉ V ₂	0.46	0.32	0.29	1.49	1.22	1.23
K ₁₀ V ₂	0.50	0.37	0.39	1.58	1.35	1.35
K ₁₁ V ₂	0.39	0.25	0.32	1.40	1.13	1.26
S. Em.±	0.04	0.03	0.02	0.10	0.09	0.07
CD (0.05)	NS	NS	0.06	NS	NS	0.20
CV (%)	13.91	14.51	12.2	10.45	10.87	11.1

Treatments	45 DAS			60 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	3.84	3.29	3.56	5.48	4.69	5.09
Kuthanagere-2	3.60	3.06	3.33	5.26	4.47	4.86
Kuthanagere-3	3.72	3.18	3.45	5.39	4.60	5.00
Kuthanagere-4	3.16	2.61	2.88	4.79	4.00	4.39
Kuthanagere-6	3.54	3.00	3.27	5.20	4.41	4.80
Kuthanagere-7	3.39	2.85	3.12	5.06	4.27	4.67
Kuthanagere-9	3.24	2.70	2.97	4.88	4.09	4.49
Kuthanagere-10	3.45	2.90	3.17	5.12	4.33	4.71
Kuthanagere-11	3.32	2.77	3.05	4.97	4.18	4.58
S. Em.±	0.11	0.10	0.08	0.10	0.12	0.10
CD (0.05)	0.31	0.30	0.21	0.29	0.34	0.29
Varieties (V)						
GPU-28 (V ₁)	3.56	3.03	3.30	5.21	4.44	4.82
MR-2 (V ₂)	3.39	2.82	3.11	5.05	4.24	4.64
S. Em.±	0.05	0.05	0.04	0.05	0.06	0.05
CD (0.05)	0.15	0.14	0.10	0.14	0.16	0.14
Interaction (K*V)						
K ₁ V ₁	3.96	3.43	3.70	5.60	4.83	5.22
K ₂ V ₁	3.72	3.14	3.42	5.36	4.55	4.96
K ₃ V ₁	3.69	3.16	3.55	5.35	4.58	5.13
K ₄ V ₁	3.52	2.96	2.97	5.16	4.35	4.43
K ₆ V ₁	3.81	3.28	3.37	5.52	4.75	4.90
K ₇ V ₁	3.63	3.07	3.21	5.27	4.46	4.75
K ₉ V ₁	3.23	2.70	3.06	4.81	4.04	4.55
K ₁₀ V ₁	3.08	2.52	3.26	4.76	3.95	4.82
K ₁₁ V ₁	3.63	3.10	3.13	5.28	4.51	4.63
K ₁ V ₂	3.45	2.89	3.43	5.11	4.30	4.95
K ₂ V ₂	3.47	2.94	3.24	5.13	4.36	4.76
K ₃ V ₂	3.31	2.75	3.35	4.99	4.18	4.87
K ₄ V ₂	3.32	2.79	2.80	4.93	4.16	4.36
K ₆ V ₂	3.16	2.60	3.17	4.83	4.02	4.70
K ₇ V ₂	3.52	2.99	3.03	5.20	4.43	4.59
K ₉ V ₂	3.37	2.81	2.88	5.03	4.22	4.43
K ₁₀ V ₂	3.40	2.87	3.09	5.02	4.25	4.61
K ₁₁ V ₂	3.24	2.68	2.96	4.92	4.11	4.52
S. Em.±	0.15	0.15	0.11	0.14	0.17	0.15
CD (0.05)	NS	NS	0.30	NS	NS	0.42
CV (%)	7.68	8.61	8.2	4.81	6.62	7.7

Treatments	75 DAS			90 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	5.73	4.86	5.29	5.66	4.77	5.21
Kuthanagere-2	5.53	4.66	5.10	5.47	4.63	5.05
Kuthanagere-3	5.60	4.73	5.17	5.53	4.64	5.09
Kuthanagere-4	4.97	4.09	4.53	4.89	4.00	4.45
Kuthanagere-6	5.43	4.55	4.99	5.35	4.46	4.91
Kuthanagere-7	5.24	4.40	4.82	5.18	4.29	4.73
Kuthanagere-9	5.04	4.22	4.63	4.97	4.08	4.53
Kuthanagere-10	5.34	4.47	4.90	5.27	4.38	4.83
Kuthanagere-11	5.13	4.30	4.72	5.10	4.21	4.66
S. Em.±	0.08	0.12	0.11	0.08	0.12	0.12
CD (0.05)	0.22	0.34	0.32	0.22	0.35	0.33
Varieties (V)						
GPU-28 (V ₁)	5.45	4.59	5.02	5.38	4.51	4.94
MR-2 (V ₂)	5.22	4.36	4.79	5.16	4.26	4.71
S. Em.±	0.04	0.06	0.05	0.04	0.06	0.06
CD (0.05)	0.10	0.16	0.15	0.10	0.16	0.16
Interaction (K*V)						
K ₁ V ₁	5.81	4.96	5.39	5.73	4.86	5.30
K ₂ V ₁	5.64	4.75	5.21	5.58	4.67	5.13
K ₃ V ₁	5.64	4.78	5.27	5.56	4.69	5.18
K ₄ V ₁	5.42	4.53	4.64	5.37	4.56	4.56
K ₆ V ₁	5.70	4.84	5.12	5.62	4.75	5.04
K ₇ V ₁	5.51	4.62	4.93	5.45	4.54	4.85
K ₉ V ₁	5.07	4.21	4.75	4.99	4.12	4.66
K ₁₀ V ₁	4.86	3.97	5.03	4.79	3.88	4.95
K ₁₁ V ₁	5.55	4.69	4.81	5.47	4.60	4.83
K ₁ V ₂	5.30	4.41	5.19	5.23	4.32	5.13
K ₂ V ₂	5.36	4.50	4.98	5.28	4.41	4.97
K ₃ V ₂	5.12	4.29	5.07	5.07	4.16	5.00
K ₄ V ₂	5.18	4.32	4.42	5.10	4.23	4.34
K ₆ V ₂	4.91	4.11	4.86	4.85	3.94	4.78
K ₇ V ₂	5.46	4.60	4.71	5.38	4.51	4.62
K ₉ V ₂	5.22	4.33	4.51	5.16	4.25	4.40
K ₁₀ V ₂	5.24	4.38	4.78	5.26	4.39	4.71
K ₁₁ V ₂	5.02	4.22	4.62	4.94	4.03	4.49
S. Em.±	0.11	0.17	0.16	0.11	0.17	0.17
CD (0.05)	NS	NS	0.45	NS	NS	0.47
CV (%)	3.50	6.49	8.0	3.50	6.75	8.4

Treatments	At harvest		
	2011	2012	Pooled
Soil series (K)			
Kuthanagere-1	3.75	3.35	3.57
Kuthanagere-2	3.50	3.10	3.30
Kuthanagere-3	3.60	3.20	3.40
Kuthanagere-4	3.00	2.60	2.80
Kuthanagere-6	3.39	2.99	3.19
Kuthanagere-7	3.25	2.85	3.05
Kuthanagere-9	3.08	2.68	2.88
Kuthanagere-10	3.32	2.92	3.12
Kuthanagere-11	3.15	2.75	2.95
S. Em.±	0.09	0.11	0.08
CD (0.05)	0.25	0.31	0.23
Varieties (V)			
GPU-28 (V ₁)	3.42	3.03	3.22
MR-2 (V ₂)	3.26	2.85	3.06
S. Em.±	0.04	0.05	0.04
CD (0.05)	0.12	0.15	0.11
Interaction (K*V)			
K ₁ V ₁	3.84	3.45	3.65
K ₂ V ₁	3.65	3.24	3.37
K ₃ V ₁	3.57	3.18	3.50
K ₄ V ₁	3.43	3.02	2.89
K ₆ V ₁	3.69	3.30	3.29
K ₇ V ₁	3.51	3.10	3.13
K ₉ V ₁	3.08	2.69	2.96
K ₁₀ V ₁	2.92	2.51	3.22
K ₁₁ V ₁	3.48	3.09	3.01
K ₁ V ₂	3.30	2.89	3.50
K ₂ V ₂	3.32	2.93	3.23
K ₃ V ₂	3.17	2.76	3.31
K ₄ V ₂	3.15	2.76	2.71
K ₆ V ₂	3.01	2.60	3.10
K ₇ V ₂	3.41	3.02	2.97
K ₉ V ₂	3.23	2.82	2.81
K ₁₀ V ₂	3.21	2.82	3.03
K ₁₁ V ₂	3.08	2.67	2.88
S. Em.±	0.12	0.15	0.11
CD (0.05)	NS	NS	0.32
CV (%)	6.37	9.00	8.9

Interaction between soil series and varieties remained non significant during 2011 and 2012 whereas, for pooled analysis interaction had significant influence on the dry matter accumulation in leaves. Among different treatment combinations, higher dry matter accumulation in leaves was noticed when GPU-28 was grown in Kuthanagere-1 soil series it was followed by Kuthanagere-3 soil series with GPU-28, both these treatment combinations were found to be on par with each other throughout the crop growth period. At 60, 75, 90 DAS dry matter accumulation in leaves of GPU-28 grown in Kuthanagere-1, Kuthanagere-2, Kuthanagere-3 and Kuthanagere-6 soil series were found to be on par with each other. Lower dry matter accumulation was noticed when MR-2 was grown in Kuthanagere-4 soil series which was found to be on par with Kuthanagere-9 soil series with same variety throughout the crop growth stages.

4.1.1.5. Dry matter accumulation in stem plant⁻¹

Dry matter accumulation in stem (g) was influenced by soil series as well as varieties at all the stages of crop (Table 11)

At 15 DAS higher dry matter accumulation in stem (0.55, 0.43 and 0.49, respectively) was recorded in Kuthanagere-1 soil series during both years of study and in pooled analysis which differed significantly over other soil series. Kuthanagere-3 (0.48) recorded second higher dry matter accumulation and was found to be on par with Kuthanagere-2 (0.43) during 2011 but varied significantly in 2012 and in pooled analysis. At 30 DAS higher dry matter accumulation was noticed in Kuthanagere-1 during the study and it was found to be on par with Kuthanagere-3. The variations observed at 45 DAS i.e., Kuthanagere-1, Kuthanagere-2 and Kuthanagere-3 soil series was found to be on with each other and it was maintained till harvest in both the years of study and in pooled analysis. Lower dry matter accumulation was noticed in Kuthanagere-4 soil series at all the stages of crop growth.

Varieties showed significant variation for dry matter accumulation in stem. GPU-28 recorded significantly higher dry matter accumulation in stem throughout the crop growth stages when compared to MR-2 variety during 2011, 2012 and in pooled analysis.

Table 11: Dry matter accumulation in stem plant⁻¹ (g) at different growth stages of finger millet as influenced by different soil series of Kuthanagere and varieties

Treatments	15 DAS			30 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	0.55	0.43	0.49	1.73	1.48	1.60
Kuthanagere-2	0.43	0.33	0.38	1.54	1.30	1.42
Kuthanagere-3	0.48	0.39	0.44	1.62	1.37	1.49
Kuthanagere-4	0.27	0.16	0.21	1.19	0.95	1.07
Kuthanagere-6	0.40	0.28	0.34	1.48	1.24	1.36
Kuthanagere-7	0.33	0.22	0.28	1.37	1.12	1.24
Kuthanagere-9	0.31	0.17	0.24	1.22	0.98	1.10
Kuthanagere-10	0.37	0.25	0.31	1.41	1.16	1.28
Kuthanagere-11	0.31	0.20	0.26	1.27	1.02	1.14
S. Em.±	0.02	0.01	0.01	0.06	0.06	0.04
CD (0.05)	0.05	0.04	0.03	0.17	0.16	0.12
Varieties (V)						
GPU-28 (V ₁)	0.44	0.31	0.38	1.54	1.31	1.42
MR-2 (V ₂)	0.32	0.23	0.28	1.31	1.05	1.18
S. Em.±	0.01	0.01	0.00	0.03	0.03	0.02
CD (0.05)	0.02	0.02	0.01	0.08	0.08	0.06
Interaction (K*V)						
K ₁ V ₁	0.59	0.46	0.52	1.85	1.62	1.74
K ₂ V ₁	0.50	0.39	0.43	1.60	1.34	1.57
K ₃ V ₁	0.50	0.37	0.49	1.68	1.45	1.63
K ₄ V ₁	0.36	0.29	0.26	1.40	1.14	1.15
K ₆ V ₁	0.56	0.43	0.38	1.74	1.51	1.52
K ₇ V ₁	0.40	0.35	0.32	1.49	1.23	1.37
K ₉ V ₁	0.33	0.19	0.31	1.26	1.03	1.19
K ₁₀ V ₁	0.21	0.12	0.35	1.12	0.86	1.43
K ₁₁ V ₁	0.44	0.31	0.31	1.63	1.40	1.24
K ₁ V ₂	0.35	0.25	0.45	1.34	1.08	1.47
K ₂ V ₂	0.39	0.26	0.33	1.49	1.26	1.27
K ₃ V ₂	0.28	0.19	0.38	1.25	0.99	1.36
K ₄ V ₂	0.40	0.22	0.17	1.30	1.07	0.99
K ₆ V ₂	0.23	0.12	0.30	1.15	0.89	1.21
K ₇ V ₂	0.42	0.29	0.23	1.54	1.31	1.12
K ₉ V ₂	0.32	0.22	0.17	1.27	1.01	1.02
K ₁₀ V ₂	0.38	0.25	0.27	1.36	1.13	1.14
K ₁₁ V ₂	0.25	0.16	0.20	1.18	0.92	1.05
S. Em.±	0.02	0.02	0.01	0.09	0.08	0.06
CD (0.05)	NS	NS	0.04	NS	NS	0.17
CV (%)	10.82	11.17	11.1	10.46	11.79	11.3

Treatments	45 DAS			60 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	3.48	2.88	3.18	4.85	4.04	4.45
Kuthanagere-2	3.24	2.65	2.94	4.63	3.82	4.22
Kuthanagere-3	3.36	2.77	3.06	4.76	3.95	4.36
Kuthanagere-4	2.76	2.19	2.49	4.16	3.35	3.75
Kuthanagere-6	3.18	2.58	2.88	4.57	3.76	4.16
Kuthanagere-7	3.03	2.43	2.73	4.43	3.61	4.02
Kuthanagere-9	2.88	2.28	2.58	4.25	3.44	3.85
Kuthanagere-10	3.10	2.51	2.80	4.49	3.68	4.08
Kuthanagere-11	2.96	2.36	2.66	4.34	3.53	3.94
S. Em.±	0.09	0.08	0.06	0.12	0.11	0.08
CD (0.05)	0.27	0.24	0.16	0.33	0.31	0.22
Varieties (V)						
GPU-28 (V ₁)	3.17	2.59	2.88	4.59	3.80	4.19
MR-2 (V ₂)	3.04	2.44	2.74	4.41	3.58	3.99
S. Em.±	0.04	0.04	0.03	0.05	0.05	0.04
CD (0.05)	0.13	0.11	0.07	0.16	0.15	0.10
Interaction (K*V)						
K ₁ V ₁	3.58	3.00	3.29	4.98	4.19	4.59
K ₂ V ₁	3.37	2.76	3.01	4.72	3.89	4.33
K ₃ V ₁	3.30	2.72	3.14	4.73	3.94	4.50
K ₄ V ₁	3.18	2.57	2.56	4.52	3.69	3.80
K ₆ V ₁	3.43	2.85	2.96	4.90	4.11	4.27
K ₇ V ₁	3.29	2.68	2.79	4.63	3.80	4.12
K ₉ V ₁	2.85	2.27	2.65	4.19	3.40	3.92
K ₁₀ V ₁	2.66	2.12	2.85	4.12	3.29	4.19
K ₁₁ V ₁	3.25	2.67	2.72	4.66	3.87	4.00
K ₁ V ₂	3.11	2.50	3.07	4.47	3.64	4.30
K ₂ V ₂	3.08	2.49	2.88	4.51	3.72	4.11
K ₃ V ₂	2.97	2.36	2.99	4.35	3.50	4.22
K ₄ V ₂	2.94	2.36	2.43	4.31	3.52	3.71
K ₆ V ₂	2.82	2.21	2.81	4.19	3.36	4.05
K ₇ V ₂	3.14	2.56	2.67	4.58	3.79	3.93
K ₉ V ₂	3.06	2.45	2.51	4.39	3.56	3.78
K ₁₀ V ₂	3.01	2.43	2.76	4.40	3.61	3.97
K ₁₁ V ₂	2.90	2.29	2.60	4.28	3.45	3.87
S. Em.±	0.13	0.12	0.08	0.16	0.15	0.11
CD (0.05)	NS	NS	0.22	NS	NS	0.31
CV (%)	7.39	8.26	6.8	6.34	7.12	6.6

Treatments	75 DAS			90 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	5.31	4.52	4.91	5.86	5.08	5.47
Kuthanagere-2	5.11	4.31	4.71	5.65	4.87	5.26
Kuthanagere-3	5.18	4.38	4.78	5.71	4.93	5.32
Kuthanagere-4	4.55	3.75	4.15	5.09	4.31	4.70
Kuthanagere-6	5.01	4.21	4.61	5.51	4.72	5.11
Kuthanagere-7	4.82	4.02	4.42	5.33	4.55	4.94
Kuthanagere-9	4.61	3.82	4.22	5.15	4.37	4.76
Kuthanagere-10	4.92	4.12	4.52	5.42	4.64	5.03
Kuthanagere-11	4.71	3.91	4.31	5.23	4.45	4.84
S. Em.±	0.13	0.12	0.09	0.13	0.13	0.09
CD (0.05)	0.39	0.35	0.25	0.38	0.36	0.26
Varieties (V)						
GPU-28 (V ₁)	5.03	4.24	4.63	5.53	4.76	5.15
MR-2 (V ₂)	4.80	3.99	4.40	5.34	4.55	4.95
S. Em.±	0.06	0.06	0.04	0.06	0.06	0.04
CD (0.05)	0.18	0.16	0.12	0.18	0.17	0.12
Interaction (K*V)						
K ₁ V ₁	5.39	4.64	5.02	5.95	5.18	5.57
K ₂ V ₁	5.22	4.41	4.83	5.76	4.97	5.36
K ₃ V ₁	5.22	4.43	4.88	5.75	4.98	5.40
K ₄ V ₁	5.00	4.19	4.26	5.55	4.76	4.81
K ₆ V ₁	5.28	4.49	4.74	5.79	5.02	5.22
K ₇ V ₁	5.09	4.28	4.55	5.64	4.85	5.02
K ₉ V ₁	4.65	3.86	4.36	5.20	4.43	4.89
K ₁₀ V ₁	4.44	3.63	4.65	4.97	4.18	5.11
K ₁₁ V ₁	5.13	4.34	4.43	5.60	4.83	4.95
K ₁ V ₂	4.88	4.07	4.81	5.41	4.61	5.37
K ₂ V ₂	4.94	4.15	4.60	5.40	4.63	5.16
K ₃ V ₂	4.70	3.89	4.69	5.25	4.46	5.24
K ₄ V ₂	4.76	3.97	4.04	5.28	4.51	4.58
K ₆ V ₂	4.46	3.68	4.48	5.03	4.24	5.01
K ₇ V ₂	5.04	4.25	4.30	5.49	4.72	4.86
K ₉ V ₂	4.80	3.99	4.07	5.34	4.55	4.64
K ₁₀ V ₂	4.82	4.03	4.40	5.34	4.57	4.95
K ₁₁ V ₂	4.60	3.79	4.20	5.12	4.33	4.73
S. Em.±	0.19	0.17	0.13	0.19	0.18	0.13
CD (0.05)	NS	NS	0.36	NS	NS	0.36
CV (%)	6.73	7.23	6.9	6.03	6.61	6.2

Treatments	At harvest		
	2011	2012	Pooled
Soil series (K)			
Kuthanagere-1	6.73	5.89	6.31
Kuthanagere-2	6.48	5.64	6.06
Kuthanagere-3	6.58	5.74	6.16
Kuthanagere-4	5.98	5.14	5.56
Kuthanagere-6	6.37	5.53	5.95
Kuthanagere-7	6.23	5.39	5.81
Kuthanagere-9	6.06	5.22	5.64
Kuthanagere-10	6.30	5.46	5.88
Kuthanagere-11	6.13	5.28	5.70
S. Em.±	0.12	0.12	0.11
CD (0.05)	0.33	0.35	0.30
Varieties (V)			
GPU-28 (V ₁)	6.40	5.56	5.98
MR-2 (V ₂)	6.24	5.39	5.81
S. Em.±	0.05	0.06	0.05
CD (0.05)	0.16	0.17	0.14
Interaction (K*V)			
K ₁ V ₁	6.82	5.99	6.41
K ₂ V ₁	6.63	5.78	6.13
K ₃ V ₁	6.55	5.71	6.26
K ₄ V ₁	6.41	5.56	5.64
K ₆ V ₁	6.67	5.84	6.05
K ₇ V ₁	6.49	5.64	5.88
K ₉ V ₁	6.06	5.23	5.71
K ₁₀ V ₁	5.90	5.05	5.97
K ₁₁ V ₁	6.46	5.63	5.77
K ₁ V ₂	6.28	5.43	6.21
K ₂ V ₂	6.30	5.47	5.99
K ₃ V ₂	6.15	5.30	6.07
K ₄ V ₂	6.13	5.30	5.47
K ₆ V ₂	5.99	5.14	5.86
K ₇ V ₂	6.39	5.56	5.73
K ₉ V ₂	6.21	5.36	5.57
K ₁₀ V ₂	6.19	5.35	5.79
K ₁₁ V ₂	6.06	5.21	5.64
S. Em.±	0.16	0.17	0.15
CD (0.05)	NS	NS	0.42
CV (%)	4.47	5.50	6.2

Interaction effect was found to be insignificant during 2011 and 2011 throughout the growth stages. However, in pooled analysis significant interaction was noticed. At 15DAS higher dry matter accumulation in stem was noticed when GPU-28 was grown in Kuthanagere-1 soil series (0.52) and it was found to be on par with Kuthanagere-3 (0.49), this trend was maintained till 45 DAS. Kuthanagere-1 sown with GPU-28 resulted in higher dry matter accumulation in stem at 75 DAS and was found to be on par with Kuthanagere-2 and Kuthanagere-3 and also with Kuthanagere-1 sown with MR-2. This trend was maintained till the harvest of the crop. Lower interaction effect was noticed when MR-2 was grown in Kuthanagere-4 soil which was found to be significant compared to other treatments throughout the growth stages.

4.1.1.6 Dry matter accumulation in ear head plant¹

The data pertaining to dry matter accumulation in ear head (g) is presented in Table 12.

Higher dry matter accumulation was noticed in Kuthanagere-1 soil series compared to other soil series throughout the growth stages during 2011, 2012 and in pooled analysis. At 60 DAS dry matter accumulation in Kuthanagere-1 soil series was found to be on par with Kuthanagere-2 and Kuthanagere-3. Similar trend was maintained till harvest of the crop. From 60 DAS till harvest Kuthanagere-2 was on par with Kuthanagere-6 soil. Kuthanagere-4 soil series recorded significantly lower dry matter accumulation in ear head than other soil series throughout the crop stages.

Throughout the crop growth stages GPU-28 excelled significantly over MR-2 with respect to dry matter accumulation in ear head during 2011, 2012 and in pooled analysis.

Dry matter accumulation in ear head did not show significant difference between soil series and varieties during 2011 and 2012, but significant interaction was noticed in pooled analysis. Among the treatment combination higher dry matter accumulation in ear head was recorded when GPU-28 was grown in Kuthanagere-1 soil series throughout the crop growth stages. Kuthanagere-2 with GPU-28 found to be on par with Kuthanagere-1 with GPU-28 at all the stages and it was also found to be on par with Kuthanagere-3 with GPU-28. MR-2 grown in Kuthanagere-1 soil was on par with Kuthanagere-1,

Table 12: Dry matter accumulation in ear head plant⁻¹ (g) at different growth stages of finger millet as influenced by different soil series of Kuthanagere and varieties

Treatments	60 DAS			75 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	5.32	4.53	4.93	8.54	7.59	8.06
Kuthanagere-2	4.91	4.12	4.52	8.13	7.19	7.66
Kuthanagere-3	5.17	4.38	4.77	8.38	7.44	7.91
Kuthanagere-4	4.11	3.32	3.72	7.33	6.39	6.86
Kuthanagere-6	4.78	3.99	4.39	8.00	7.05	7.52
Kuthanagere-7	4.51	3.72	4.12	7.73	6.79	7.26
Kuthanagere-9	4.25	3.46	3.85	7.46	6.52	6.99
Kuthanagere-10	4.65	3.86	4.25	7.86	6.92	7.39
Kuthanagere-11	4.38	3.59	3.99	7.60	6.65	7.12
S. Em.±	0.18	0.16	0.12	0.23	0.23	0.15
CD (0.05)	0.52	0.46	0.33	0.67	0.67	0.41
Varieties (V)						
GPU-28 (V ₁)	4.89	4.12	4.51	8.16	7.23	7.69
MR-2 (V ₂)	4.46	3.65	4.05	7.63	6.67	7.15
S. Em.±	0.08	0.08	0.06	0.11	0.11	0.07
CD (0.05)	0.24	0.22	0.16	0.32	0.31	0.19
Interaction (K*V)						
K ₁ V ₁	5.54	4.77	5.15	8.80	7.87	8.34
K ₂ V ₁	5.10	4.29	4.75	8.27	7.31	7.93
K ₃ V ₁	5.13	4.36	5.00	8.40	7.47	8.19
K ₄ V ₁	4.70	3.89	3.95	7.86	6.90	7.13
K ₆ V ₁	5.38	4.61	4.61	8.65	7.72	7.80
K ₇ V ₁	4.95	4.14	4.35	8.12	7.16	7.53
K ₉ V ₁	4.33	3.56	4.08	7.60	6.67	7.27
K ₁₀ V ₁	3.90	3.09	4.48	7.06	6.10	7.67
K ₁₁ V ₁	5.00	4.23	4.21	8.26	7.33	7.40
K ₁ V ₂	4.56	3.75	4.70	7.73	6.77	7.79
K ₂ V ₂	4.73	3.96	4.29	8.00	7.07	7.38
K ₃ V ₂	4.30	3.49	4.55	7.46	6.50	7.64
K ₄ V ₂	4.46	3.69	3.49	7.73	6.80	6.58
K ₆ V ₂	4.03	3.22	4.16	7.20	6.24	7.25
K ₇ V ₂	4.86	4.09	3.89	8.13	7.20	6.98
K ₉ V ₂	4.43	3.62	3.63	7.60	6.64	6.72
K ₁₀ V ₂	4.60	3.83	4.03	7.86	6.93	7.12
K ₁₁ V ₂	4.16	3.35	3.76	7.33	6.37	6.85
S. Em.±	0.25	0.23	0.17	0.33	0.33	0.21
CD (0.05)	NS	NS	0.47	NS	NS	0.58
CV (%)	9.40	10.05	9.6	7.23	8.18	6.8

Treatments	90 DAS			At harvest		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	11.75	10.50	11.13	13.65	12.24	12.94
Kuthanagere-2	11.35	10.10	10.72	13.24	11.83	12.45
Kuthanagere-3	11.60	10.35	10.98	13.49	12.08	12.79
Kuthanagere-4	10.55	9.30	9.92	12.44	11.03	11.73
Kuthanagere-6	11.21	9.96	10.59	13.11	11.70	12.40
Kuthanagere-7	10.95	9.70	10.32	12.84	11.43	12.13
Kuthanagere-9	10.68	9.43	10.06	12.57	11.16	11.87
Kuthanagere-10	11.08	9.83	10.46	12.97	11.56	12.27
Kuthanagere-11	10.81	9.56	10.19	12.71	11.30	12.00
S. Em.±	0.24	0.25	0.21	0.26	0.26	0.23
CD (0.05)	0.69	0.72	0.59	0.76	0.74	0.64
Varieties (V)						
GPU-28 (V ₁)	11.43	10.19	10.81	13.38	11.99	12.66
MR-2 (V ₂)	10.79	9.53	10.16	12.63	11.20	11.91
S. Em.±	0.11	0.12	0.10	0.12	0.12	0.11
CD (0.05)	0.33	0.34	0.28	0.36	0.35	0.30
Interaction (K*V)						
K ₁ V ₁	12.07	10.83	11.45	14.02	12.63	13.33
K ₂ V ₁	11.44	10.18	11.04	13.27	11.84	12.75
K ₃ V ₁	11.66	10.42	11.30	13.61	12.22	13.17
K ₄ V ₁	11.03	9.77	10.24	12.86	11.43	12.12
K ₆ V ₁	11.92	10.68	10.91	13.87	12.48	12.79
K ₇ V ₁	11.28	10.02	10.64	13.12	11.69	12.52
K ₉ V ₁	10.86	9.62	10.38	12.81	11.42	12.25
K ₁₀ V ₁	10.23	8.97	10.78	12.06	10.63	12.65
K ₁₁ V ₁	11.53	10.29	10.51	13.48	12.09	12.39
K ₁ V ₂	10.90	9.64	10.81	12.73	11.30	12.56
K ₂ V ₂	11.26	10.02	10.40	13.21	11.82	12.15
K ₃ V ₂	10.63	9.37	10.65	12.46	11.03	12.40
K ₄ V ₂	11.00	9.76	9.60	12.95	11.56	11.35
K ₆ V ₂	10.36	9.10	10.27	12.20	10.77	12.02
K ₇ V ₂	11.40	10.16	10.00	13.35	11.96	11.75
K ₉ V ₂	10.76	9.50	9.73	12.60	11.17	11.48
K ₁₀ V ₂	11.13	9.89	10.13	13.08	11.69	11.88
K ₁₁ V ₂	10.50	9.24	9.87	12.33	10.90	11.62
S. Em.±	0.34	0.35	0.30	0.37	0.36	0.32
CD (0.05)	NS	NS	0.84	NS	NS	0.91
CV (%)	5.32	6.22	6.9	4.97	5.41	6.4

Kuthanagere-2 and Kuthanagere-3 with GPU-28. Lower dry matter accumulation in ear head between soil series and varieties was noticed when MR-2 variety grown in Kuthanagere-4 soil series throughout the growth stages of the crop.

4.1.1.7 Total dry matter accumulation plant⁻¹

The course of total dry matter accumulation (g) as influenced by different soil series and varieties are presented in the Table 13.

At 15 DAS, higher dry matter accumulation was noticed in Kuthanagere-1 soil series and it was on par with Kuthanagere-3 soil during 2011 and 2012. Kuthanagere-3 was on par with Kuthanagere-2 in 2011 but differed significantly during 2012 and in pooled analysis, respectively. Kuthanagere-1, Kuthanagere-2 and Kuthanagere-3 soils were on par with each other at 45 DAS in 2011 but in 2012 and pooled analysis Kuthanagere-1 and Kuthanagere-3 were at par with each other. Similar trend was observed at 45, 60, 75, 90 DAS and at harvest. Throughout the crop growth stages Kuthanagere-2 and Kuthanagere-6 were on par with each other in 2011, 2012 and in pooled analysis, respectively. Significantly lower dry matter accumulation was recorded in Kuthanagere-4 soil series throughout the growth stages.

Varieties differed significantly with respect to dry matter accumulation. Among the two varieties GPU-28 recorded significantly higher dry matter accumulation throughout the crop growth stages when compared to MR-2 in both years of study and in pooled analysis.

There was no significant variation in interaction between soil series and varieties during 2011 and 2012. However, significant interaction between soil series and varieties were observed in pooled analysis. At 15 and 45 DAS Kuthanagere-1 (1.16 and 9.99) and Kuthanagere-3 (1.10 and 9.54) soil series with GPU-28 recorded maximum dry matter accumulation and were found to be on par with each other and varied significantly over other treatment combinations. At 30, 60, 75, 90 DAS and at harvest higher dry matter accumulation was recorded when GPU-28 was grown in Kuthanagere-1 soil and was found to be on par with Kuthanagere-2, Kuthanagere-3 with GPU-28. At 75, 90 DAS and at harvest MR-2 variety grown in Kuthanagere-1 was found to be on par with GPU-28 Grown in Kuthanagere-1, Kuthanagere-2 and Kuthanagere-3. Significantly lower dry

Table 13: Total dry matter accumulation plant⁻¹(g) of finger millet at different growth stages as influenced by different soil series of Kuthanagere and varieties

Treatments	15 DAS			30 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	1.21	0.96	1.09	3.67	3.18	3.42
Kuthanagere-2	0.99	0.76	0.87	3.30	2.81	3.06
Kuthanagere-3	1.09	0.87	0.98	3.45	2.96	3.21
Kuthanagere-4	0.67	0.42	0.54	2.60	2.11	2.35
Kuthanagere-6	0.93	0.67	0.80	3.19	2.69	2.94
Kuthanagere-7	0.79	0.55	0.67	2.95	2.46	2.71
Kuthanagere-9	0.74	0.46	0.60	2.67	2.17	2.42
Kuthanagere-10	0.86	0.61	0.74	3.03	2.54	2.78
Kuthanagere-11	0.75	0.51	0.63	2.75	2.26	2.51
S. Em.±	0.04	0.03	0.03	0.13	0.12	0.09
CD (0.05)	0.12	0.09	0.07	0.38	0.34	0.26
Varieties (V)						
GPU-28 (V ₁)	1.00	0.74	0.87	3.30	2.84	3.07
MR-2 (V ₂)	0.78	0.55	0.67	2.84	2.31	2.58
S. Em.±	0.02	0.01	0.01	0.06	0.06	0.04
CD (0.05)	0.06	0.04	0.03	0.18	0.16	0.12
Interaction (K*V)						
K ₁ V ₁	1.29	1.03	1.16	3.92	3.46	3.69
K ₂ V ₁	1.13	0.88	0.98	3.42	2.89	3.35
K ₃ V ₁	1.11	0.85	1.10	3.58	3.12	3.47
K ₄ V ₁	0.87	0.66	0.64	3.03	2.50	2.51
K ₆ V ₁	1.23	0.97	0.88	3.70	3.24	3.25
K ₇ V ₁	0.95	0.76	0.76	3.21	2.68	2.96
K ₉ V ₁	0.77	0.51	0.73	2.74	2.28	2.59
K ₁₀ V ₁	0.56	0.33	0.82	2.46	1.93	3.08
K ₁₁ V ₁	1.01	0.75	0.74	3.48	3.02	2.70
K ₁ V ₂	0.85	0.60	1.01	2.89	2.36	3.16
K ₂ V ₂	0.89	0.63	0.76	3.19	2.73	2.76
K ₃ V ₂	0.69	0.46	0.85	2.71	2.18	2.94
K ₄ V ₂	0.89	0.58	0.45	2.82	2.36	2.20
K ₆ V ₂	0.59	0.34	0.72	2.51	1.98	2.63
K ₇ V ₂	0.95	0.69	0.58	3.31	2.85	2.45
K ₉ V ₂	0.77	0.53	0.47	2.75	2.22	2.25
K ₁₀ V ₂	0.87	0.61	0.65	2.93	2.47	2.49
K ₁₁ V ₂	0.63	0.40	0.52	2.57	2.04	2.31
S. Em.±	0.06	0.04	0.04	0.18	0.17	0.13
CD (0.05)	NS	NS	0.10	NS	NS	0.36
CV (%)	11.62	11.63	11.8	10.42	11.12	11.2

Treatments	45 DAS			60 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	10.25	8.90	9.57	15.65	13.26	14.46
Kuthanagere-2	9.37	8.02	8.70	14.79	12.40	13.60
Kuthanagere-3	9.87	8.52	9.19	15.32	12.93	14.13
Kuthanagere-4	7.67	6.32	7.00	13.06	10.67	11.87
Kuthanagere-6	9.12	7.77	8.44	14.54	12.15	13.35
Kuthanagere-7	8.55	7.20	7.87	14.01	11.61	12.81
Kuthanagere-9	7.98	6.63	7.30	13.38	10.99	12.19
Kuthanagere-10	8.81	7.46	8.14	14.25	11.86	13.05
Kuthanagere-11	8.27	6.92	7.60	13.69	11.30	12.50
S. Em.±	0.24	0.30	0.21	0.36	0.39	0.29
CD (0.05)	0.68	0.87	0.59	1.04	1.11	0.82
Varieties (V)						
GPU-28 (V ₁)	9.19	7.89	8.54	14.68	12.35	13.52
MR-2 (V ₂)	8.56	7.16	7.86	13.91	11.46	12.69
S. Em.±	0.11	0.14	0.10	0.17	0.18	0.14
CD (0.05)	0.32	0.41	0.28	0.49	0.52	0.38
Interaction (K*V)						
K ₁ V ₁	10.64	9.34	9.99	16.12	13.79	14.96
K ₂ V ₁	9.86	8.45	9.03	15.18	12.73	14.04
K ₃ V ₁	9.68	8.38	9.54	15.20	12.87	14.63
K ₄ V ₁	9.06	7.66	7.33	14.38	11.93	12.17
K ₆ V ₁	10.19	8.89	8.79	15.80	13.47	13.78
K ₇ V ₁	9.54	8.14	8.20	14.85	12.40	13.21
K ₉ V ₁	7.98	6.68	7.64	13.34	11.01	12.55
K ₁₀ V ₁	7.37	5.97	8.44	12.78	10.33	13.49
K ₁₁ V ₁	9.44	8.14	7.92	14.94	12.61	12.85
K ₁ V ₂	8.79	7.39	9.15	14.14	11.69	13.95
K ₂ V ₂	8.85	7.54	8.36	14.38	12.05	13.16
K ₃ V ₂	8.25	6.85	8.84	13.63	11.17	13.63
K ₄ V ₂	8.29	6.99	6.67	13.71	11.38	11.56
K ₆ V ₂	7.67	6.27	8.09	13.05	10.60	12.91
K ₇ V ₂	9.09	7.79	7.55	14.65	12.32	12.40
K ₉ V ₂	8.53	7.13	6.97	13.84	11.39	11.83
K ₁₀ V ₂	8.57	7.27	7.83	14.01	11.68	12.62
K ₁₁ V ₂	7.97	6.57	7.27	13.37	10.92	12.15
S. Em.±	0.33	0.43	0.30	0.51	0.55	0.41
CD (0.05)	NS	NS	0.84	NS	NS	1.15
CV (%)	6.53	9.87	8.9	6.19	7.96	7.7

Treatments	75 DAS			90 DAS		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	19.57	16.97	18.27	23.27	20.35	21.81
Kuthanagere-2	18.78	16.16	17.47	22.47	19.55	21.03
Kuthanagere-3	19.17	16.55	17.86	22.68	19.93	21.39
Kuthanagere-4	16.84	14.22	15.53	20.51	17.60	19.06
Kuthanagere-6	18.43	15.81	17.12	22.07	19.15	20.61
Kuthanagere-7	17.79	15.20	16.50	21.45	18.53	19.99
Kuthanagere-9	17.13	14.56	15.84	20.81	17.89	19.35
Kuthanagere-10	18.12	15.50	16.81	21.77	18.85	20.31
Kuthanagere-11	17.44	14.86	16.15	21.15	18.23	19.69
S. Em.±	0.50	0.31	0.35	0.49	0.48	0.37
CD (0.05)	1.43	0.90	0.99	1.41	1.39	1.05
Varieties (V)						
GPU-28 (V ₁)	18.63	16.06	17.34	22.30	19.45	20.89
MR-2 (V ₂)	17.65	15.02	16.34	21.29	18.34	19.82
S. Em.±	0.23	0.15	0.17	0.23	0.23	0.18
CD (0.05)	0.67	0.42	0.47	0.66	0.65	0.50
Interaction (K*V)						
K ₁ V ₁	20.01	17.47	18.74	23.75	20.87	22.31
K ₂ V ₁	19.12	16.46	17.97	22.78	19.82	21.53
K ₃ V ₁	19.26	16.68	18.33	22.97	20.09	21.88
K ₄ V ₁	18.29	15.63	16.03	21.96	19.00	19.61
K ₆ V ₁	19.62	17.04	17.66	22.99	20.44	21.16
K ₇ V ₁	18.72	16.06	17.01	22.37	19.41	20.51
K ₉ V ₁	17.32	14.74	16.37	21.05	18.17	19.93
K ₁₀ V ₁	16.37	13.71	17.34	19.96	17.04	20.83
K ₁₁ V ₁	18.95	16.37	16.63	22.60	19.72	20.29
K ₁ V ₂	17.91	15.25	17.79	21.54	18.57	21.30
K ₂ V ₂	18.30	15.72	16.96	21.95	19.07	20.53
K ₃ V ₂	17.29	14.69	17.39	20.96	18.00	20.89
K ₄ V ₂	17.66	15.08	15.04	21.37	18.49	18.52
K ₆ V ₂	16.60	14.03	16.58	20.24	17.28	20.05
K ₇ V ₂	18.63	16.05	15.99	22.27	19.39	19.48
K ₉ V ₂	17.62	14.96	15.31	21.26	18.30	18.76
K ₁₀ V ₂	17.92	15.34	16.29	21.73	18.85	19.78
K ₁₁ V ₂	16.96	14.38	15.67	20.56	17.60	19.08
S. Em.±	0.70	0.44	0.50	0.69	0.68	0.53
CD (0.05)	NS	NS	1.40	NS	NS	1.49
CV (%)	6.70	4.92	7.2	5.51	6.26	6.4

Treatments	At harvest		
	2011	2012	Pooled
Soil series (K)			
Kuthanagere-1	24.12	21.47	22.80
Kuthanagere-2	23.22	20.57	21.89
Kuthanagere-3	23.68	21.03	22.35
Kuthanagere-4	21.42	18.76	20.09
Kuthanagere-6	22.87	20.22	21.54
Kuthanagere-7	22.31	19.66	20.99
Kuthanagere-9	21.71	19.06	20.39
Kuthanagere-10	22.59	19.94	21.27
Kuthanagere-11	21.98	19.32	20.65
S. Em.±	0.50	0.50	0.40
CD (0.05)	1.44	1.45	1.14
Varieties (V)			
GPU-28 (V ₁)	23.19	20.58	21.88
MR-2 (V ₂)	22.12	19.43	20.77
S. Em.±	0.24	0.24	0.19
CD (0.05)	0.68	0.68	0.54
Interaction (K*V)			
K ₁ V ₁	24.69	22.08	23.38
K ₂ V ₁	23.56	20.87	22.42
K ₃ V ₁	23.73	21.11	22.93
K ₄ V ₁	22.71	20.02	20.65
K ₆ V ₁	24.23	21.62	22.12
K ₇ V ₁	23.12	20.43	21.53
K ₉ V ₁	21.95	19.34	20.92
K ₁₀ V ₁	20.88	18.19	21.84
K ₁₁ V ₁	23.43	20.82	21.17
K ₁ V ₂	22.31	19.62	22.21
K ₂ V ₂	22.83	20.22	21.37
K ₃ V ₂	21.79	19.10	21.78
K ₄ V ₂	22.23	19.61	19.53
K ₆ V ₂	21.20	18.51	20.97
K ₇ V ₂	23.15	20.53	20.45
K ₉ V ₂	22.04	19.35	19.85
K ₁₀ V ₂	22.47	19.86	20.69
K ₁₁ V ₂	21.48	18.79	20.13
S. Em.±	0.71	0.71	0.57
CD (0.05)	NS	NS	1.61
CV (%)	5.42	6.18	6.6

matter accumulation was noticed when MR-2 was grown in Kuthanagere-4 soil series at all the stages of crop growth.

4.1.2 Yield components

Yield components viz. test weight, finger length, number of fingers per ear, number of effective tillers at harvest are presented in Table 14 and 15.

4.1.2.1 Test weight (1000grains)

Table 13 indicates the test weight (g) of finger millet as influenced by soil series and varieties. Test weight did not differ significantly with regard to soil series during both the years of study and also in pooled analysis. However lower test weight was noticed during 2012 compared to 2011.

Varieties had a significant influence on test weight of the finger millet. Among the two varieties GPU-28 (3.40, 3.15 and 3.28) recorded significantly higher test weight compared to MR-2 (3.08, 2.64, and 2.86) in both the years of study and also in pooled analysis.

A significant variation was noticed between soil series and varieties in pooled analysis but it remained insignificant during 2011 and 2012. Among the treatment combinations higher test weight was recorded when GPU-28 (3.30) was grown in Kuthanagere-1 and Kuthanagere-3 soil series followed by Kuthanagere-2 (3.29) with GPU-28, both these treatment combinations were found to be on par with all other soil series with GPU-28 and differed significantly with other soil series having MR-2. Significantly lower test weight was recorded when MR-2 (2.75) was grown in Kuthanagere-4 soil and was on par with the other soil series with the same variety.

4.1.2.2 Finger length

There was no significant difference noticed between soil series with respect to finger length (cm) in 2011, 2012 and in pooled analysis, respectively (Table 14)

Varieties showed significant variations with respect to finger length. Longer fingers were noticed in MR-2 (8.70, 8.34 and 8.52) variety in both the years of study and in pooled analysis when compared to GPU-28 (8.04, 7.66 and 7.85).

The interaction between soil series and varieties with respect to finger length did not differ significantly in 2011 and 2012, whereas, in pooled analysis interaction varied

Table 14: 1000 grain weight (g) and finger length (cm) of finger millet as influence by different soil series at Kuthanagere and varieties

Treatments	1000 grain weight			Finger length		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	3.30	2.96	3.13	8.83	8.44	8.63
Kuthanagere-2	3.29	2.94	3.12	8.67	8.31	8.48
Kuthanagere-3	3.30	2.95	3.13	8.76	8.39	8.57
Kuthanagere-4	3.18	2.83	3.00	7.82	7.45	7.63
Kuthanagere-6	3.26	2.91	3.08	8.56	8.19	8.37
Kuthanagere-7	3.22	2.87	3.04	8.22	7.85	8.03
Kuthanagere-9	3.20	2.85	3.02	7.96	7.59	7.77
Kuthanagere-10	3.23	2.88	3.06	8.38	8.01	8.19
Kuthanagere-11	3.21	2.86	3.03	8.15	7.78	7.97
S. Em.±	0.08	0.07	0.05	0.24	0.23	0.19
CD (0.05)	NS	NS	NS	NS	NS	NS
Varieties (V)						
GPU-28 (V ₁)	3.40	3.15	3.28	8.04	7.66	7.85
MR-2 (V ₂)	3.08	2.64	2.86	8.70	8.34	8.52
S. Em.±	0.04	0.03	0.03	0.11	0.11	0.09
CD (0.05)	0.11	0.10	0.07	0.32	0.32	0.25
Interaction (K*V)						
K ₁ V ₁	3.42	3.17	3.30	8.42	8.01	8.22
K ₂ V ₁	3.17	2.75	3.29	9.23	8.86	8.07
K ₃ V ₁	3.41	3.16	3.30	8.27	7.90	8.18
K ₄ V ₁	3.17	2.72	3.26	9.07	8.73	7.35
K ₆ V ₁	3.42	3.17	3.28	8.37	8.00	7.99
K ₇ V ₁	3.18	2.73	3.27	9.15	8.78	7.75
K ₉ V ₁	3.38	3.13	3.26	7.53	7.16	7.50
K ₁₀ V ₁	2.97	2.52	3.27	8.10	7.73	7.90
K ₁₁ V ₁	3.40	3.15	3.27	8.18	7.81	7.68
K ₁ V ₂	3.11	2.66	2.96	8.93	8.56	9.05
K ₂ V ₂	3.39	3.14	2.95	7.93	7.56	8.90
K ₃ V ₂	3.04	2.59	2.96	8.50	8.13	8.97
K ₄ V ₂	3.39	3.14	2.75	7.68	7.31	7.92
K ₆ V ₂	3.01	2.56	2.89	8.23	7.86	8.75
K ₇ V ₂	3.40	3.15	2.82	8.08	7.71	8.32
K ₉ V ₂	3.07	2.62	2.79	8.67	8.30	8.05
K ₁₀ V ₂	3.39	3.14	2.85	7.87	7.50	8.48
K ₁₁ V ₂	3.02	2.57	2.80	8.43	8.06	8.25
S. Em.±	0.12	0.10	0.08	0.34	0.33	0.27
CD (0.05)	NS	NS	0.22	NS	NS	0.75
CV (%)	6.30	6.26	6.2	6.95	7.18	8.0

significantly. Longer fingers were noticed when MR-2 (9.05) was grown in Kuthanagere-1 soil when compared to other treatment combinations. It was found to be on par with Kuthanagere-3 (8.97), Kuthanagere-2 (8.90) and Kuthanagere-6 (8.75) which had MR-2 variety. Shorter fingers (7.35) were recorded when GPU-28 was grown in Kuthanagere-4 soil series and it was found to be on par with Kuthanagere-9 (7.50) with same variety.

4.1.2.3 Number of fingers ear⁻¹

The data pertaining to number of fingers per ear as influenced by soil series and varieties are presented in the Table 15

Soil series had no significant impact on the number of fingers per ear. However, more number of fingers was recorded in Kuthanagere-1 (5.69, 5.23 and 5.46) soil during 2011, 2012 and in pooled analysis compared to other soil series.

Varieties showed significant variation with respect to number of fingers per ear. More number of fingers was observed in GPU-28 (5.62, 5.15 and 5.39) which varied significantly compared to MR-2 (4.46, 4.00 and 4.23) in both year of study and in pooled analysis.

There was no significant interaction between soil series and varieties during 2011 and 2012. In pooled analysis significant interaction was observed. More number of fingers per ear was noticed when Kuthanagere-1 was sown with GPU-28 (6.04) which was on par with Kuthagere-3 (5.87) Kuthanagere-2(5.64) and Kuthanagere-6(5.51) with same variety. Significantly less number of fingers was observed when MR-2 (3.68) variety was grown in Kuthanagere-4 soil series.

4.1.2.4 Number of effective tillers plant⁻¹ at harvest

Number of effective tillers per plant was influenced but the soil series and varieties are presented in Table 15

More numbers of effective tillers were noticed in Kuthanagere-1 (2.98, 2.71 and 2.82) which was followed by Kuthanagere-3 (2.87, 2.49 and 2.60) soil series. Both these soils along with Kuthanagere-2 (2.76, 2.49 and 2.60) were found to be on par with each other in both the years of study and in pooled analysis. Less number of effective tillers was noticed in Kuthanagere-4 (2.10, 1.83 and 1.94) soil series when compared to other soil series.

Table 15: Number of fingers ear⁻¹ and number of effective tillers plant⁻¹ at harvest of finger millet as influenced by different soil series at kuthanagere and varieties

Treatments	Number of fingers ear ⁻¹			Number of effective tiller plant ⁻¹ at harvest		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	5.69	5.23	5.46	2.98	2.71	2.82
Kuthanagere-2	5.28	4.83	5.06	2.76	2.49	2.60
Kuthanagere-3	5.53	5.08	5.30	2.87	2.60	2.71
Kuthanagere-4	4.48	4.04	4.26	2.10	1.83	1.94
Kuthanagere-6	5.15	4.70	4.93	2.62	2.35	2.46
Kuthanagere-7	4.88	4.40	4.64	2.41	2.13	2.25
Kuthanagere-9	4.61	4.10	4.35	2.19	1.92	2.03
Kuthanagere-10	5.00	4.53	4.77	2.49	2.22	2.33
Kuthanagere-11	4.75	4.25	4.50	2.28	2.01	2.12
S. Em.±	0.27	0.27	0.18	0.11	0.11	0.08
CD (0.05)	NS	NS	0.52	0.33	0.33	0.23
Varieties (V)						
GPU-28 (V ₁)	5.62	5.15	5.39	2.65	2.38	2.47
MR-2 (V ₂)	4.46	4.00	4.23	2.39	2.11	2.25
S. Em.±	0.13	0.13	0.09	0.05	0.05	0.04
CD (0.05)	0.36	0.37	0.24	0.16	0.16	0.11
Interaction (K*V)						
K ₁ V ₁	6.27	5.81	6.04	3.17	2.90	2.99
K ₂ V ₁	5.10	4.64	5.64	2.79	2.52	2.74
K ₃ V ₁	5.86	5.41	5.87	2.93	2.66	2.87
K ₄ V ₁	4.70	4.25	4.84	2.58	2.31	2.03
K ₆ V ₁	6.10	5.64	5.51	3.05	2.78	2.56
K ₇ V ₁	4.95	4.52	5.23	2.70	2.43	2.34
K ₉ V ₁	5.06	4.61	4.92	2.21	1.94	2.11
K ₁₀ V ₁	3.90	3.46	5.36	1.99	1.72	2.41
K ₁₁ V ₁	5.73	5.29	5.08	2.74	2.47	2.20
K ₁ V ₂	4.56	4.12	4.87	2.50	2.23	2.65
K ₂ V ₂	5.46	4.99	4.47	2.53	2.26	2.45
K ₃ V ₂	4.30	3.82	4.74	2.29	2.00	2.56
K ₄ V ₂	5.20	4.65	3.68	2.29	2.02	1.86
K ₆ V ₂	4.03	3.54	4.34	2.08	1.81	2.36
K ₇ V ₂	5.60	5.13	4.06	2.59	2.32	2.15
K ₉ V ₂	4.40	3.94	3.79	2.38	2.11	1.95
K ₁₀ V ₂	5.33	4.83	4.17	2.39	2.12	2.24
K ₁₁ V ₂	4.16	3.66	3.91	2.18	1.91	2.04
S. Em.±	0.38	0.39	0.26	0.16	0.16	0.11
CD (0.05)	NS	NS	0.73	NS	NS	0.32
CV (%)	12.92	14.70	13.2	11.16	12.46	11.7

Number of effective tillers per plant was significantly influenced by varieties. Among the two varieties more number of effective tillers was recorded in GPU-28 (2.65, 2.38 and 2.47) during 2011, 2012 and in pooled analysis when compared to MR-2.

Interaction between soil series and varieties was not significant during 2011 and 2012 but it was found significant in pooled analysis. More number of effective tillers was recorded with treatment combination which includes Kuthanagere-1 with GPU-28 (2.99) which was on par with Kuthanagere-3 (2.87) and Kuthanagere-2 (2.74). Whereas, Kuthanagere-6 (2.56) with GPU-28 was on par with the Kuthanagere-1 (2.65), Kuthanagere-2 (2.45) and Kuthanagere-3 (2.56) having MR-2. Significantly less number of effective tillers compared to other treatment combinations was recorded when MR-2 (1.86) was grown in Kuthanagere-4 soil series.

4.1.2.5 Yield

The data pertaining to grain yield and straw yield of finger millet per hectare as influence by different soil series of Kuthanagere and varieties are presented in the Table 16.

4.1.2.5.1 Grain yield

The grain yield ($q\ ha^{-1}$) of finger millet differed significantly due to soil series of Kuthanagere and varieties (Table 16). Among soil series, Kuthanagere-1 resulted in higher grain yield (38.58, 24.90 and $31.74\ q\ ha^{-1}$) during 2011, 2012 and in pooled analysis. In 2011 and in pooled analysis Kuthanagere-1 was found to be on par with Kuthanagere-3 whereas in 2012 it was found to be on par with Kuthanagere-2 also. In 2012 and in pooled analysis yield obtained in Kuthanagere-6 was on par with Kuthanagere-2. Significantly lower yield was recorded in Kuthanagere-4 soil series in both the years of study and also in pooled analysis.

Significantly higher grain yield was noticed in GPU-28 (30.42, 19.81, and 25.11) in 2011 and 2012 and in pooled analysis than MR-6. Among the two years, yield obtained in 2011 was higher compare to 2012 in the period of study.

During 2011 and 2012, the interactions between the soil series and varieties were not significant however, in pooled analysis it varied significantly. Kuthanagere-1 soil series with GPU-28 recorded significantly higher grain yield (32.55 q ha^{-1}) followed by Kuthanagere-3 with GPU-28 (21.03 q ha^{-1}). Both these treatment combinations were found to be on par with each other. Kuthanagere-3, Kuthanagere-2 (29.14 q ha^{-1}) with GPU-28 was found to be on par with Kuthanagere-1 with MR-2 (30.92 q ha^{-1}). Significantly lower yield (18.05 q ha^{-1}) was noticed when MR-2 was taken up in Kuthanagere-4 soil series.

4.1.2.5.2 Straw yield

Significant difference was noticed in the straw yield (t ha^{-1}) of finger millet varieties grown in different soil series. Kuthanagere-1 recorded significantly higher straw yield ($5.80, 3.74$ and 4.77 t ha^{-1}) compared to all other soil series during 2011, 2012 and in pooled analysis. It was found to be on par with Kuthanagere-3 soil series ($5.52, 3.67$ and 4.60 t ha^{-1}) during 2011, 2012 and in pooled analysis but in 2012 it was on par with Kuthanagere-2 soil series along with Kuthanagere-3. Significantly lower straw yield was noticed in Kuthanagere-4 ($3.67, 2.16$ and 2.92 t ha^{-1}) soil series in both the years of the study and in pooled analysis as compared to that in other soil series.

Among the two varieties MR-2 recorded significantly higher straw yield compared to GPU-28 during 2011 and similar trend was noticed in 2012 and in pooled analysis.

Interaction between soil series and varieties was found to be insignificant during 2011 and 2012 period of study where as in pooled analysis it was significant. Higher straw yield was noticed when MR-2 variety was grown in Kuthanagere-1 soil series (5.26 t ha^{-1}) which was on par with Kuthanagere-3 (5.30 t ha^{-1}) with same variety. Kuthanagere-1 soil series with GPU-28 (4.28 t ha^{-1}) was found to be on par with the Kuthanagere-6 soil series with MR-2 variety (4.26 t ha^{-1}). Significantly lower straw yield was recorded when GPU-28 (2.47 t ha^{-1}) was grown in Kuthanagere-4 soil series.

4.1.2.6 Harvest index

Harvest index did not show significant difference with respect to soil series during 2011, 2012 and in pooled analysis (Table 17).

Table 16: Grain yield (q ha⁻¹) and straw yield (t ha⁻¹) of finger millet as influenced by different soil series at Kuthanagere and varieties

Treatments	Grain yield			Straw yield		
	2011	2012	Pooled	2011	2012	Pooled
Soil series (K)						
Kuthanagere-1	38.58	24.90	31.74	5.80	3.74	4.77
Kuthanagere-2	33.19	22.12	27.65	5.19	3.45	4.32
Kuthanagere-3	37.96	23.88	29.92	5.52	3.67	4.60
Kuthanagere-4	23.92	14.01	18.97	3.67	2.16	2.92
Kuthanagere-6	29.91	21.16	25.54	4.42	3.11	3.77
Kuthanagere-7	25.24	16.66	20.95	3.85	2.53	3.19
Kuthanagere-9	24.03	15.12	19.57	3.85	2.42	3.14
Kuthanagere-10	27.01	18.26	22.64	4.17	2.80	3.49
Kuthanagere-11	24.30	15.55	19.93	3.79	2.41	3.10
S. Em.±	1.19	1.06	0.78	0.18	0.12	0.11
CD (0.05)	3.41	3.04	2.21	0.53	0.35	0.32
Varieties (V)						
GPU-28 (V ₁)	30.42	19.81	25.11	3.83	2.49	3.16
MR-2 (V ₂)	27.83	18.34	23.09	5.11	3.36	4.24
S. Em.±	0.56	0.50	0.37	0.09	0.06	0.05
CD (0.05)	1.61	1.43	1.04	0.25	0.16	0.15
Interaction (K*V)						
K ₁ V ₁	39.52	25.59	32.55	5.20	3.37	4.28
K ₂ V ₁	37.63	24.21	29.14	6.41	4.12	3.59
K ₃ V ₁	35.04	23.24	31.03	4.32	2.85	3.89
K ₄ V ₁	31.35	20.99	19.88	6.07	4.05	2.47
K ₆ V ₁	37.60	24.47	26.83	4.72	3.06	3.27
K ₇ V ₁	34.32	23.29	21.62	6.33	4.28	2.70
K ₉ V ₁	25.28	14.48	20.29	3.14	1.80	2.59
K ₁₀ V ₁	22.57	13.54	23.98	4.19	2.53	2.94
K ₁₁ V ₁	31.40	22.27	20.70	3.83	2.71	2.71
K ₁ V ₂	28.42	20.06	30.92	5.00	3.52	5.26
K ₂ V ₂	26.18	17.05	26.17	3.27	2.12	5.06
K ₃ V ₂	24.30	16.27	28.81	4.42	2.93	5.30
K ₄ V ₂	24.94	15.64	18.05	3.18	1.99	3.36
K ₆ V ₂	23.12	14.59	24.24	4.52	2.85	4.26
K ₇ V ₂	28.55	19.42	20.29	3.50	2.38	3.67
K ₉ V ₂	25.47	17.11	18.86	4.83	3.23	3.69
K ₁₀ V ₂	25.27	16.13	21.29	3.32	2.10	4.03
K ₁₁ V ₂	23.33	14.97	19.15	4.25	2.72	3.48
S. Em.±	1.68	1.50	1.11	0.26	0.17	0.16
CD (0.05)	NS	NS	3.13	NS	NS	0.46
CV (%)	9.99	13.58	11.3	10.01	10.14	10.7

Table 17: Harvest index of finger millet as influenced by different soil series of Kuthanagere

Treatments	Harvest index		
	2011	2012	Pooled
Soil series (K)			
Kuthanagere-1	0.40	0.36	0.38
Kuthanagere-2	0.39	0.36	0.37
Kuthanagere-3	0.40	0.36	0.38
Kuthanagere-4	0.40	0.35	0.37
Kuthanagere-6	0.41	0.37	0.39
Kuthanagere-7	0.40	0.36	0.38
Kuthanagere-9	0.39	0.35	0.37
Kuthanagere-10	0.40	0.36	0.38
Kuthanagere-11	0.39	0.35	0.37
S. Em.±	0.02	0.02	0.01
CD (0.05)	NS	NS	NS
Varieties (V)			
GPU-28 (V ₁)	0.44	0.39	0.42
MR-2 (V ₂)	0.35	0.32	0.34
S. Em.±	0.01	0.01	0.01
CD (0.05)	0.02	0.02	0.02
Interaction (K*V)			
K ₁ V ₁	0.43	0.39	0.41
K ₂ V ₁	0.37	0.33	0.42
K ₃ V ₁	0.45	0.39	0.41
K ₄ V ₁	0.34	0.32	0.42
K ₆ V ₁	0.44	0.38	0.43
K ₇ V ₁	0.35	0.33	0.42
K ₉ V ₁	0.45	0.39	0.41
K ₁₀ V ₁	0.35	0.31	0.43
K ₁₁ V ₁	0.45	0.41	0.41
K ₁ V ₂	0.36	0.34	0.35
K ₂ V ₂	0.45	0.40	0.33
K ₃ V ₂	0.36	0.33	0.34
K ₄ V ₂	0.44	0.39	0.33
K ₆ V ₂	0.34	0.31	0.35
K ₇ V ₂	0.46	0.41	0.34
K ₉ V ₂	0.34	0.32	0.32
K ₁₀ V ₂	0.43	0.38	0.33
K ₁₁ V ₂	0.35	0.32	0.34
S. Em.±	0.02	0.02	0.02
CD (0.05)	NS	NS	0.05
CV (%)	9.56	10.52	10.7

Varieties showed a significant variation with respect to harvest index. Higher harvest index was recorded in GPU-28 (0.44, 0.39 and 0.42) during 2011, 2012 and in pooled analysis. It differed significantly compared to MR-2 (0.35, 0.32 and 0.34) during the same period.

Soil series and varieties did not had significant influence on harvest index during 2011 and 2012 however significant interaction between soil series and varieties was notice in pooled analysis. Among the different treatment combinations, Kuthanagere-6 soil series with GPU-28 recorded higher harvest index (0.43) and was found to be on par with GPU-28 grown in all the soil series but it significantly varied when MR-2 was grown in different soil series. Lower harvest index was recorded when MR-2 was grown in Kuthanagere-9 (0.32) which was found to be on par with all the soil series having MR-2 variety.

4.2 Characterization of profile samples for morphological, physical and chemical properties

4.2.1 Morphological properties

The detail descriptions of morphological properties of 13 pedons are presented in Table 18. The salient morphological characteristics are described below.

In Kuthanagere-1 pedon, the surface horizon is up to 12cm, with solum extending to a depth of 125cm. The colour of surface horizon was yellowish red (5YR 4/6). As depth increased the colour became darker with the lower most horizon (78-125 cms) having a colour of dark red (2.5YR 3/6). The texture of surface horizon was sandy loam.

In Kuthanagere-2 pedon, the solum depth was 122cms and surface horizon extends up to 12cms and the argillic horizon extends from 12 to 122cms. The colour of surface horizon was dark red (2.5YR 3/6) and Bt1 horizon was dark reddish brown (2.5YR 3/4), whereas C horizon was red (2.5YR 4/6). Solum was sandy clay in texture whereas, C horizon was sandy clay loam.

In Kuthanagere-3 and 5 pedons, the surface horizon extends up to 14cms and colour of surface horizon was red (2.5YR 4/6) and dark brown (7.5YR 3/4), respectively. In Kuthanagere-5 as depth increased the colour became reddish with lower most horizon

(33-51cms) having colour of dark reddish brown. The solum texture of both pedons was sandy clay whereas, Kuthanagere-3 had sandy loam and Kuthanagere-5 had sandy clay loam surface horizons.

In Kuthanagere-4 and 9 pedons, the surface horizon extends to a depth of 11cms with solum depth of 133 and 151cms, respectively. The surface horizon of Kuthanagere-4 had dark reddish brown (5YR 3/4), the colour became still darker as increase in depth with lower most horizon (104-133cms) having dark red colour (2.5YR 3/6). The surface horizon had sandy loam texture, whereas subsurface horizon had sandy clay loam followed by sandy clay. Strong brown (7.5YR 4/6) colour was observed in surface horizon of Kuthanagere-9 pedon, which turned to reddish brown and yellowish red, strong brown in subsequent horizons. Surface layer had sandy clay loam texture, whereas subsurface had sandy clay and sandy clay loam texture.

In Kuthanagere-6 pedon, soloum extends up to 89cms with surface horizon extending up to 22cms and it was yellowish red (5YR 4/6), where as subsurface had dark red colour. The texture of Ap and Bt1 horizons was sandy clay loam and sandy clay, respectively.

In Kuthanagere-7 pedon, surface horizon extends to a depth of 17cms with solum depth of 80cms and the argillic horizon extends from 17 to 80cms. The colour of Ap and bBt1 horizon was dark reddish brown and C horizon had yellowish red colour (5YR 4/6) with Ap and C horizon having sandy loam and Bt horizon having sandy clay loam texture.

In Kuthanagere-8 pedon, soil depth was 115cms with surface horizon extending up to 18cms. The solum depth ranged from 18cms to 115cms. All the horizons except Ap and Bw2 were strong brown (7.5YR 4/6), whereas Ap and Bw2 had dark yellowish brown (10YR 4/6) and brown (7.5YR 5/4) colour, respectively. Ap, Bw1 and Bw4 horizons had sandy clay loam texture and Bw2 and Bw3 had loamy sand and sandy loam texture.

In Kuthanagere-10 pedon, surface horizon had yellowish red (5YR 4/6) colour with a depth of 10cms. Subsurface layer had red and dark red colour with solum depth of

Table 18: Morphological properties of typifying pedon

Sl. No.	Soil series	Horizon	Depth (cm)	Colour (moist)	Colour name	Textural class
1.	Kuthanagere -1	Ap	0-12	5YR 4/6	Yellowish red	SL
		Bt1	12-46	2.5YR 3/6	Dark red	SC
		Bt2	46-78	2.5YR 3/6	Dark red	SC
		Bt3	78-125	2.5YR 3/6	Dark red	SC
2.	Kuthanagere -2	Ap	0-12	2.5YR 3/6	Dark red	SL
		Bt1	12-46	2.5YR 3/4	Dark reddish brown	SC
		Bt2	46-71	2.5YR 3/6	Dark red	SC
		Bt3	71-98	2.5YR 3/6	Dark red	SC
		Bt4	98-122	2.5YR 3/4	Dark reddish brown	SC
		Bc	122-138	2.5YR 4/6	Red	SCL
3.	Kuthanagere -3	Ap	0-14	2.5YR 4/6	Red	SL
		Bt1	14-49	2.5YR 3/6	Dark red	SC
		Bt2	49-88	2.5YR 3/6	Dark red	SC
		Bc	88-125	2.5YR 4/6	Red	SCL
4.	Kuthanagere -4	Ap	0-11	5YR 3/4	Dark reddish brown	SL
		Bt1	11-31	2.5YR 3/6	Dark red	SCL
		Bt2	31-54	2.5YR 4/6	Red	SC
		Bt3	54-76	2.5YR 4/6	Red	SC
		Bt4	76-104	2.5YR 3/6	Dark red	SCL
		Bt5	104-133	2.5YR 3/6	Dark red	SCL
5.	Kuthanagere -5	A	0-14	7.5YR 3/4	Dark brown	SCL
		Bt1	14-33	5YR 3/3	Dark reddish brown	SC
		Bt2	33-51	5YR 3/4	Dark reddish brown	SC
6.	Kuthanagere -6	AP	0-22	5YR 4/6	Yellowish red	SCL
		Bt1	22-55	2.5YR 3/6	Dark red	SC
		Bt2	55-89	2.5YR 3/6	Dark red	SC
		Bc	89-118	2.5YR 3/6	Dark red	SCL
7.	Kuthanagere -7	Ap	0-17	5YR 3/4	Dark reddish brown	SL
		Bt1	17-45	2.5YR 3/4	Dark reddish brown	SCL
		Bt2	45-80	2.5YR 3/6	Dark red	SCL
		Cb	80-112	5YR 4/6	Yellowish red	SL

8.	Kuthanagere -8	Ap	0-18	10YR 4/6	Dark yellowish brown	SCL
		Bw1	18-34	7.5YR 4/6	Strong brown	SCL
		Bw2	34-62	7.5YR 5/4	Brown	LS
		Bw3	62-102	7.5YR 4/6	Strong brown	SL
		Bw4	102-115	7.5YR 4/6	Strong brown	SCL
9.	Kuthanagere -9	Ap	0-11	7.5YR 4/6	Strong brown	SCL
		Bt1	11-45	5YR 4/4	Reddish brown	SC
		Bt2	45-81	5YR 4/6	Yellowish red	SC
		Bt3	81-108	7.5YR 4/6	Strong brown	SCL
		Bt4	108-128	7.5YR 5/6	Strong brown	SCL
		Bt5	128-151	7.5YR 5/6	Strong brown	SCL
10.	Kuthanagere -10	Ap	0-10	5YR 4/6	Yellowish red	SCL
		Bt1	10-34	2.5YR 4/6	Red	SC
		Bt2	34-56	2.5YR 3/6	Dark red	SC
		Bt3	56-90	2.5YR 4/6	Red	SC
		Bc	90-120	2.5YR 4/6	Red	SCL
11.	Kuthanagere -11	Ap	0-16	7.5YR 4/4	Brown	LS
		Bt1	16-42	5YR 4/4	Reddish brown	SC
		Bt2	42-71	5YR 4/6	Yellowish red	SC
		Bt3	71-115	5YR 4/6	Yellowish red	SC
		Bt4	115-129	5YR 4/6	Yellowish red	SC
		Bt5	129-150	5YR 4/6	Yellowish red	SCL
12.	Kuthanagere -12	Ap	0-18	7.5YR 4/6	Strong brown	SL
		Bw1	18-41	7.5YR 5/6	Strong brown	SCL
		Bw2	41-65	7.5YR 5/6	Strong brown	SCL
		Bw3	65-88	10YR 5/8	Yellowish brown	SCL
		Cb	88-101	10YR 6/6	Brownish yellow	SCL
13.	Kuthanagere -13	Ap	0-12	10YR 4/6	Dark yellowish brown	SCL
		Bw	12-30	10YR 4/6	Dark yellowish brown	SCL
SC: Sandy clay, SCL: Sandy clay loam, LS: Loamy sand, SL: Sandy loam						

10 to 90cms. The surface Ap and lower most Bc horizon had sandy clay loam texture, whereas Bt horizons had sandy clay texture.

In Kuthanagere-11 pedon, the surface horizon extends up to 16cms with solum extending to a depth of 150cms. The colour of surface horizon was brown (7.5YR 4/4) and Bt1 was reddish brown (5YR 4/4) and subsequent horizons were found to be yellowish red (5YR 4/6). Horizons of sandy clay were observed between the loamy sand Ap horizon and sandy clay loam Bt5 horizon.

In Kuthanagere-12, solum depth was 88cms. The colour of the top three horizons (Ap, Bw1 and Bw2) were strong brown, whereas Bw3 and Cb horizons had yellowish brown (10YR 5/8) and brownish yellow (10YR 6/6), respectively. The surface horizon was sandy loam texture and subsurface horizons were sandy clay loam.

In Kuthanagere-13 pedon, surface horizon extends up to 12cms with solum depth of 30cms. The colour of both horizons was dark yellowish (10YR 4/6) with sandy clay loam texture.

4.2.2 Physical properties

Physical properties of typifying pedons of each soil series of Kuthanagere watershed are presented in the Table 19.

4.2.2.1 Coarse fragments (%)

Irregular variations were noticed with respect to coarse fragments with the depth and soil series. Generally lower coarse fragments were noticed on surface (Ap horizon) which increased with depth.

Among 13 soil series weighted mean coarse fragments ranged from 4.89 to 39.38%. Higher amount of coarse fragments was noticed in Kuthanagere-7 (39.38%) followed by Kuthanagere-5 (34.03%), Kuthanagere-13 (29.45%), Kuthanagere-10 (28.20%), Kuthanagere-4 (26.32%), Kuthanagere-9 (22.68%), Kuthanagere-6 (20.75%), Kuthanagere-8 (20.16%), Kuthanagere-2 (19.52%), Kuthanagere-3 (18.61%), Kuthanagere-11 (16.20%), Kuthanagere-1 (15.12%) and Kuthanagere-12 (4.89%).

In Kuthanagere-1 lower coarse fragments was noticed in Ap horizon (3.8%) which showed increasing trend with depth and higher coarse fragments was recorded in Bt3 (39.3%). Similar trend was noticed in Kuthanagere-2.

Table 19: Physical properties of typifying pedons (master profiles) of each soil series of Kuthanagere watershed during 2012

Sl. No.	Soil series	Horizon	Depth (cm)	Coarse fragments (%)	Sand (%)	Silt (%)	Clay (%)
1.	Kuthanagere -1	Ap	0-12	3.8	69.28	14.49	16.23
		Bt1	12-46	5.8	52.67	8.77	38.57
		Bt2	46-78	11.5	51.52	10.63	37.85
		Bt3	78-125	39.3	50.78	12.83	36.39
		WM	-	15.12	56.06	11.68	32.26
2.	Kuthanagere -2	Ap	0-12	9.1	63.71	16.45	19.84
		Bt1	12-46	9.4	51.82	7.05	41.13
		Bt2	46-71	28.6	50.95	9.27	39.78
		Bt3	71-98	19.2	50.18	13.61	36.21
		Bt4	98-122	32.3	50.05	14.32	35.63
		Bc	122-138	18.5	63.92	12.23	23.85
		WM	-	19.52	55.11	12.16	32.74
3.	Kuthanagere -3	Ap	0-14	17.9	70.03	14.25	15.72
		Bt1	14-49	17.4	52.38	8.23	39.39
		Bt2	49-88	22.5	50.23	12.30	37.47
		Bc	88-125	16.7	50.48	19.22	30.29
		WM	-	18.61	55.78	13.50	30.72
4.	Kuthanagere -4	Ap	0-11	22.2	69.82	12.97	17.21
		Bt1	11-31	33.3	61.80	11.75	26.45
		Bt2	31-54	39.1	56.08	6.44	37.48
		Bt3	54-76	19.2	54.45	10.05	35.50
		Bt4	76-104	28.0	58.51	11.69	29.80
		Bt5	104-133	16.0	56.41	17.50	26.09
		WM	-	26.32	59.51	11.73	28.76
5.	Kuthanagere -5	A	0-14	30.7	67.15	7.43	25.42
		Bt1	14-33	39.3	53.12	7.16	39.72
		Bt2	33-51	32.1	51.15	12.14	36.71
		WM	-	34.03	57.14	8.91	33.95
6.	Kuthanagere -6	AP	0-22	29.0	67.93	11.66	20.41
		Bt1	22-55	26.7	52.38	7.06	40.57
		Bt2	55-89	12.5	53.74	8.78	37.47
		Bc	89-118	14.8	54.56	19.81	25.63
		WM	-	20.75	57.15	11.83	31.02
7.	Kuthanagere -7	Ap	0-17	32.4	66.35	15.67	17.99
		Bt1	17-45	57.6	64.25	11.72	24.03

		Bt2	45-80	32.6	62.60	9.93	27.46
		Cb	80-112	35.0	62.21	18.60	19.19
		WM	-	39.38	63.85	13.98	22.17
8.	Kuthanagere -8	Ap	0-18	16.0	60.08	8.30	31.62
		Bw1	18-34	25.0	59.09	13.00	27.91
		Bw2	34-62	20.6	79.65	7.54	12.82
		Bw3	62-102	21.4	68.02	13.37	18.60
		Bw4	102-115	17.9	59.93	15.58	24.49
		WM	-	20.16	65.35	11.56	23.09
9.	Kuthanagere -9	Ap	0-11	18.6	57.21	12.31	30.48
		Bt1	11-45	12.0	53.74	6.24	40.02
		Bt2	45-81	18.3	52.76	9.91	37.32
		Bt3	81-108	10.8	51.11	16.88	32.01
		Bt4	108-128	24.9	50.21	18.88	30.91
		Bt5	128-151	51.4	50.02	23.76	26.22
		WM	-	22.68	52.51	14.66	32.83
10.	Kuthanagere -10	Ap	0-10	25.8	63.23	15.15	21.62
		Bt1	10-34	40.0	50.12	6.49	43.39
		Bt2	34-56	26.9	50.05	9.03	40.92
		Bt3	56-90	20.8	50.02	12.58	37.40
		Bc	90-120	27.4	63.12	12.98	23.90
		WM	-	28.20	55.31	11.25	33.45
11.	Kuthanagere -11	Ap	0-16	11.5	79.91	6.77	13.33
		Bt1	16-42	17.2	54.88	3.63	41.49
		Bt2	42-71	17.6	53.20	6.58	40.22
		Bt3	71-115	5.1	51.91	9.43	38.66
		Bt4	115-129	20.7	50.12	12.66	37.22
		Bt5	129-150	25.0	66.47	7.31	26.22
		WM	-	16.20	59.41	7.73	32.86
12.	Kuthanagere -12	Ap	0-18	11.5	64.78	16.60	18.62
		Bw1	18-41	6.8	61.65	10.72	27.63
		Bw2	41-65	1.5	59.32	9.87	30.81
		Bw3	65-88	2.3	54.85	12.56	32.59
		Cb	88-101	2.3	52.59	18.98	28.43
		WM	-	4.89	58.64	13.75	27.62
13.	Kuthanagere -13	Ap	0-12	28.1	64.24	10.71	25.05
		Bw	12-30	30.8	59.76	11.67	28.58
		WM	-	29.45	62.00	11.19	26.81
Note: WM: weighted mean of all the horizons; C.fragments:coarse fragments							

In Kuthanagere-3 coarse fragments varied from 17.9% to 22.5%. Irregular distribution was noticed with depth. Slight reduction from 17.9% to 17.4% was noticed in upper two horizons followed by slight increase (22.5%) and decrease (16.7%) in last two horizons. Similar pattern was noticed in Kuthanagere-4 soil series, however, coarse fragments ranged from 16.0% (Bt5 horizon) to 39.1% (Bt2 horizon). Ap horizon recorded 22.2% coarse fragments which increased to 33.3% in Bt1 and 39.1% in Bt2 horizon. Reverse trend was noticed in Kuthanagere-6 soil series where in coarse fragments decreased with the depth. Higher coarse fragments were recorded in Ap horizon (29.0%) which reduced to 26.7% (Bt1 horizon) and 12.5% (Bt2 horizon).

In Kuthanagere-5, Kuthanagere-7 and Kuthanagere-8 Ap horizon recorded lesser coarse fragments followed by slight increase in Bt1 and decrease in Bt2 horizon. Whereas in Kuthanagere-9 Ap horizon recorded higher coarse fragments (18.6%) compared to Bt1 (12.0%), Bt2 (18.3%) and Bt3 (10.8%) which was less compared to Bt4 (24.9%) and Bt5 (51.4%) horizons. Coarse fragments ranged from 20.8% (Bt3 horizon) to 40.0% (Bt1 horizon) in Kuthanagere-10.

Ap horizon of Kuthanagere-11 recorded 11.5% coarse fragments which increased to 17.2% (Bt1 horizon) and 17.6% (Bt2 horizon) but it was reduced to 5.1% in Bt3 followed by increase in Bt4 (20.7%) and Bt5 (25.0%) horizons. Decreasing trend was noticed in Kuthanagere-12 soil series with depth. Higher coarse fragments was noticed in Ap horizon (11.5%) followed by Bw1 (6.8%) and bw2 (1.5%) horizons with slight increase in Bw3 (2.3%). In Kuthanagere-13 Ap horizon recorded lesser (28.1%) coarse fragments compared to Bw (30.81%).

4.2.2.2 Particle size

Sand, silt and clay fraction gives the textural class to the soil. Distribution of sand, silt and clay particles varied with respect to depth. All the pedons showed decreasing trend with sand whereas irregular distribution of silt and clay was noticed with the depth.

Among the 13 soil series, higher sand percent was noticed in Kuthanagere-8 (64.52%) followed by Kuthanagere-7 (62.10%) and lowest was recorded in Kuthanagere-9 (51.53%). Silt and clay percentage ranged from 7.28% (Kuthanagere-11) to 14.88% (Kuthanagere-9) and 22.17% (Kuthanagere-7) and 33.95% (Kuthanagere-5) respectively.

Decreasing trend of sand percentage with the depth till the last horizon was noticed in Kuthanagere-1, Kuthanagere-5, Kuthanagere-7, Kuthanagere-9, Kuthanagere-12 and Kuthanagere-13, whereas in Kuthanagere-2, Kuthanagere-3, Kuthanagere-4 and in Kuthanagere-6 sand percentage showed similar decreasing trend but in last horizon slight increase was noticed. In Kuthanagere-8 sand was found to be high in middle Bw2 horizon (79.65%) which showed decreasing trend with depth.

Silt percentage was found to be more in top layer i.e., Ap horizon which decreased in Bt1 horizon in most of the soil series of Kuthanagere and from Bt2 it showed increasing trend with depth.

Irregular distribution of clay was noticed in different depth of the profile. Ap horizons of all the pedons recorded lower clay fractions compared to Bt1, except in Kuthanagere-8 which showed decreasing trend up to Bw2 (12.82) and gradual increase up to Bw4 (24.49). In Kuthanagere-12, increase in clay content was noticed with the depth which ranged from 18.62% to 32.59%.

4.2.3 Chemical properties

4.2.3.1 Soil reaction (pH)

Data on the pH presented in the Table 20 revealed that soils varied from acidic to neutral in reaction on weighted mean basis. Among 13 soil series pH ranged from 5.80 to 7.95. The lower pH was noticed in Kuthanagere-6 soil and the higher pH was observed in Kuthanagere-12 soil series.

pH of the surface soil was found to be acidic (5.36) in Kuthanagere-1 and tends to neutral with increase in depth. Similar trend was noticed in Kuthanagere-2, Kuthanagere-3, Kuthanagere-9, Kuthanagere-10, Kuthanagere-11 and Kuthanagere-13. Whereas in Kuthanagere-4 pH differed irregularly with depth. Ap horizon was found to be acidic (6.43) which further reduced in Bt1 horizon (6.2) and increased to neutral (6.72) in subsequent horizons. Neutral (6.56) pH was recorded in Ap horizon of Kuthanagere-5 and it turned to acidic with the increase in depth. Soils of Kuthanagere-6 was found to be acidic in Ap horizon and increased with the depth but remained acidic throughout the pedon. Similar trend was noticed in Kuthanagere-7. In Kuthanagere-8 pH of Ap was

found to be neutral (7.74) and with increase in depth it was found to be alkaline. At Bw3 horizon soils was found to be acidic with reduced pH (6.2) and found to be neutral at Bw4 (6.83). Similar trend was noticed in Kuthanagere-12 soil series. In general surface soil was found to be acidic in reaction compared to subsurface horizons.

4.2.3.2 Electrical conductivity (dsm^{-1})

The electrical conductivity of pedons ranged from 0.026 to 0.190 dsm^{-1} indicating low salt content in these pedons. Higher electrical conductivity was recorded in Kuthanagere-12 soil series and the lower was noticed in Kuthanagere-1 on mean weight basis (Table 20).

In Kuthanagere-1 higher electrical conductivity was noticed in Ap horizon (0.036 dsm^{-1}) which showed decreased with the depth Bt1 (0.017 dsm^{-1}), Bt2 (0.015 dsm^{-1}) and Bt3 (0.035 dsm^{-1}). Similar trend was noticed in Kuthanagere-3, Kuthanagere-6, Kuthanagere-7, Kuthanagere-8, Kuthanagere-11, Kuthanagere-12 and Kuthanagere-13 soil series. However, in Kuthanagere-2 electrical conductivity decreased with depth up to Bt1 (0.038 dsm^{-1}) and slightly increased in Bt2 (0.04 dsm^{-1}) and Bt3 (0.071 dsm^{-1}) horizons which was followed by Bt4 horizon (0.038 dsm^{-1}) with reduced electrical conductivity. It increased with the depth in Kuthanagere-4 soil except Bt2 (0.024 dsm^{-1}) horizon.

Irregular variation in electrical conductivity was noticed in Kuthanagere-5 which reduced to 0.026 from 0.272 dsm^{-1} in Ap to Bt1 horizon and in Bt2 horizon it raised to 0.036. In Kuthanagere-9 Ap (0.148 dsm^{-1}), Bt1 (0.051 dsm^{-1}) and Bt2 (0.035 dsm^{-1}) horizons showed reduced electrical conductivity compared to Bt3 (0.061 dsm^{-1}) and Bt5 (0.055 dsm^{-1}) horizons. Higher electrical conductivity was recorded in Ap (0.106 dsm^{-1}) followed by Bt1 (0.076 dsm^{-1}) in Kuthanagere-10 whereas, Bt2 and Bc horizons recorded lower electrical conductivity.

4.2.3.3 Organic carbon (%)

Low to medium organic carbon content was noticed in Kuthanagere soils (Table 20). Among 13 soil series higher organic carbon percentage was observed in Kuthanagere-5 (1.02%) followed by Kuthanagere-7 (0.50%) and Kuthanagere-1 (0.49%).

Table 20: pH, Electrical conductivity, organic carbon and Cation exchange capacity of typifying pedons (master profiles) of each soil series of Kuthanagere watershed during 2012

Sl. No.	Soil series	Horizon	Depth (cm)	pH	EC (dsm ⁻¹)	O.C (%)	CEC (C mol p ⁺ kg ⁻¹)
1.	Kuthanagere -1	Ap	0-12	5.36	0.036	0.57	2.70
		Bt1	12-46	6.32	0.017	0.50	5.90
		Bt2	46-78	6.79	0.015	0.44	5.10
		Bt3	78-125	7.2	0.035	0.44	5.70
		WM	-	6.42	0.026	0.49	4.85
2.	Kuthanagere -2	Ap	0-12	5.54	0.081	0.50	4.00
		Bt1	12-46	6.44	0.038	0.54	5.90
		Bt2	46-71	6.98	0.04	0.34	5.70
		Bt3	71-98	7.18	0.071	0.17	6.70
		Bt4	98-122	7.58	0.038	0.13	6.90
		Bc	122-138	7.67	0.052	0.13	5.80
		WM	-	6.90	0.053	0.30	5.83
3.	Kuthanagere -3	Ap	0-14	4.69	0.196	0.48	2.50
		Bt1	14-49	6.24	0.026	0.52	5.90
		Bt2	49-88	6.65	0.019	0.32	5.70
		Bc	88-125	7.03	0.022	0.27	5.80
		WM	-	6.15	0.066	0.40	4.98
4.	Kuthanagere -4	Ap	0-11	6.43	0.061	0.72	3.70
		Bt1	11-31	6.49	0.068	0.67	6.30
		Bt2	31-54	6.2	0.024	0.53	5.70
		Bt3	54-76	6.45	0.035	0.34	4.30
		Bt4	76-104	6.56	0.036	0.27	4.50
		Bt5	104-133	6.72	0.043	0.24	6.30
		WM	-	6.48	0.045	0.46	5.13
5.	Kuthanagere -5	A	0-14	6.56	0.272	0.81	7.10
		Bt1	14-33	6.09	0.026	1.11	7.00
		Bt2	33-51	6.38	0.036	1.14	7.90
		WM	-	6.34	0.111	1.02	7.33
6.	Kuthanagere -6	AP	0-22	5.12	0.121	0.60	3.70
		Bt1	22-55	5.76	0.025	0.56	5.10
		Bt2	55-89	6.03	0.021	0.48	5.70
		Bc	89-118	6.28	0.017	0.28	4.20
		WM	-	5.80	0.046	0.48	4.68
7.	Kuthanagere -7	Ap	0-17	5.24	0.153	0.67	3.90
		Bt1	17-45	5.76	0.066	0.64	5.30

		Bt2	45-80	6.28	0.031	0.41	4.90
		Cb	80-112	6.41	0.04	0.29	5.10
		WM	-	5.92	0.073	0.50	4.80
8.	Kuthanagere -8	Ap	0-18	7.74	0.223	0.53	7.30
		Bw1	18-34	8.3	0.175	0.27	6.30
		Bw2	34-62	8.28	0.068	0.26	4.50
		Bw3	62-102	6.2	0.035	0.22	4.90
		Bw4	102-115	6.83	0.023	0.16	8.80
		WM	-	7.47	0.105	0.29	6.36
9.	Kuthanagere -9	Ap	0-11	5.15	0.148	0.71	5.20
		Bt1	11-45	6.41	0.051	0.44	5.50
		Bt2	45-81	6.88	0.035	0.51	6.10
		Bt3	81-108	7.81	0.061	0.32	6.20
		Bt4	108-128	8.01	0.04	0.17	6.60
		Bt5	128-151	8.02	0.055	0.07	7.00
		WM	-	7.05	0.065	0.37	6.10
10.	Kuthanagere -10	Ap	0-10	5.03	0.166	0.67	4.70
		Bt1	10-34	5.48	0.076	0.47	5.90
		Bt2	34-56	6.3	0.031	0.38	5.40
		Bt3	56-90	6.58	0.035	0.24	5.30
		Bc	90-120	6.64	0.031	0.20	4.10
		WM	-	6.01	0.068	0.39	5.08
11.	Kuthanagere -11	Ap	0-16	4.95	0.062	0.39	3.80
		Bt1	16-42	5.8	0.065	0.44	5.70
		Bt2	42-71	6.28	0.031	0.30	5.21
		Bt3	71-115	6.5	0.024	0.20	6.10
		Bt4	115-129	6.5	0.031	0.13	4.70
		Bt5	129-150	6.62	0.021	0.20	4.90
		WM	-	6.11	0.039	0.28	5.07
12.	Kuthanagere -12	Ap	0-18	6.82	0.372	0.52	6.70
		Bw1	18-41	8.31	0.157	0.33	6.80
		Bw2	41-65	8.61	0.156	0.24	7.00
		Bw3	65-88	7.97	0.125	0.13	7.60
		Cb	88-101	8.06	0.14	0.13	7.80
		WM	-	7.95	0.190	0.27	7.18
13.	Kuthanagere -13	Ap	0-12	5.12	0.108	0.55	6.20
		Bw	12-30	6.77	0.031	0.31	9.70
		WM	-	5.95	0.070	0.43	7.95
Note: WM: weighted mean of all the horizons; O.C: organic carbon							

Lower organic carbon per cent was recorded in Kuthanagere-12 (0.27%) on mean weight basis.

Organic carbon per cent in Ap horizon varied from low to high which gradually reduced to medium to high in Bt1 horizons. Organic carbon decreased with depth in Kuthanagere -1, Kuthanagere-4, Kuthanagere-6, Kuthanagere-7, Kuthanagere-8, Kuthanagere-10, Kuthanagere-12 and Kuthanagere-13. Whereas in Kuthanagere-2, Kuthanagere-3, Kuthanagere-5 and Kuthanagere-9 soils higher organic carbon was noticed in Bt1 horizon compared to Ap horizon. Kuthanagere-5 recorded high organic carbon content throughout the pedon i.e., Ap (0.81%), Bt1 (1.11%) and Bt2 (1.14%).

4.2.3.4 Cation exchange capacity ($C \text{ mol p}^+ \text{ kg}^{-1}$) (CEC)

Cation exchange capacity is a measure of quantity of readily exchangeable cations neutralizing the negative charge in the soil. On weighted mean CEC of different soil series of Kuthanagere ranged from 4.68 to 7.95 $C \text{ mol p}^+ \text{ kg}^{-1}$. Higher CEC was recorded in Kuthanagere-13 followed by Kuthanagere-5 (7.33 $C \text{ mol p}^+ \text{ kg}^{-1}$) and lower CEC was noticed in Kuthanagere-1 soil series (Table 20).

With increase in depth CEC varied irregularly within the pedon. However Ap horizon recorded lower CEC as compared to other subsurface horizons in all the soil series except in Kuthanagere-13 where Ap horizon (0.108 $C \text{ mol p}^+ \text{ kg}^{-1}$) recorded higher CEC compared to subsurface Bw horizon (0.031 $C \text{ mol p}^+ \text{ kg}^{-1}$). In Kuthanagere-8 higher CEC was noticed in Bw4 (8.80 $C \text{ mol p}^+ \text{ kg}^{-1}$) horizon and lower was recorded in Bw2 (4.50 $C \text{ mol p}^+ \text{ kg}^{-1}$) but Ap horizon recorded (7.30 $C \text{ mol p}^+ \text{ kg}^{-1}$) which was found to be higher compared to Bw1 (6.30 $C \text{ mol p}^+ \text{ kg}^{-1}$), Bw2 (4.50 $C \text{ mol p}^+ \text{ kg}^{-1}$) and Bw3 (4.90 $C \text{ mol p}^+ \text{ kg}^{-1}$) horizons.

4.2.3.5 Base saturation (%)

The base saturation varied differently among soil series (Table 21). Descending order of the Kuthanagere soil series with respect to base saturation as follows. Higher base saturation was recorded in Kuthanagere-2 (82.57%) followed by Kuthanagere-12 (82.10%), Kuthanagere-3 (80.56%), Kuthanagere-1 (79.52%), Kuthanagere-8 (75.98%), Kuthanagere-11 (75.10%), Kuthanagere-9 (74.79%), Kuthanagere-5 (74.65%), Kuthanagere-7 (74.27%), Kuthanagere-10 (72.69%), Kuthanagere-6 (69.75%), Kuthanagere-4 (68.49%) and Kuthanagere-13 (67.35%).

Base saturation in pedons varied irregularly with depth. In Kuthanagere-1 base saturation increased with depth and higher percentage was observed in Bt3 (91.42%) and lower value in Ap (65.95%) horizon, whereas reverse trend was noticed in Kuthanagere-13. In Kuthanagere-2 Ap horizon (76.06%) recorded less base saturation compared to Bt1 horizon (79.60%). Similar trend was noticed in Kuthanagere-3, Kuthanagere-5, Kuthanagere-6, Kuthanagere-7, Kuthanagere-8 and Kuthanagere-12. Whereas in Kuthanagere-4, Kuthanagere-10 and Kuthanagere-11 reverse trend was noticed i.e., Ap horizon recorded higher base saturation compared to Bt1 horizon.

4.2.3.6 Exchangeable sodium ($C \text{ mol p}^+ \text{ kg}^{-1}$)

The exchangeable sodium ranged from 0.55 to 0.93 $C \text{ mol p}^+ \text{ kg}^{-1}$ among the soil series of Kuthanagere on weighted mean basis. Higher exchangeable sodium was observed in Kuthanagere-13 ($0.90 C \text{ mol p}^+ \text{ kg}^{-1}$) followed by Kuthanagere-12 ($0.80 C \text{ mol p}^+ \text{ kg}^{-1}$) and Kuthanagere-1 ($0.55 C \text{ mol p}^+ \text{ kg}^{-1}$) recorded lower exchangeable sodium compared to remaining soil series (Table 21).

Vertical distribution of exchangeable sodium with depth varied irregularly. However, it increased with depth in case of Kuthanagere-5, Kuthanagere-7 and Kuthanagere-13 pedons. In Ap and Bt1 horizons decreasing trend was noticed in Kuthanagere-1 and Kuthanagere-3 (0.54 to 0.52 and 0.72 to $0.57 C \text{ mol p}^+ \text{ kg}^{-1}$). In Kuthanagere-2, Kuthanagere-6, Kuthanagere-9 and Kuthanagere-11 pedons exchangeable sodium increased with depth up to second horizon i.e., Bt1 horizon recorded more exchangeable sodium than Ap horizon. Whereas, in Kuthanagere-4, Kuthanagere-8, Kuthanagere-10 and Kuthanagere-12 increase exchangeable sodium was noticed up to Bt2 horizon.

4.2.3.7 Available nitrogen (ppm)

Based on the weighted mean, available nitrogen ranged from low to medium (Table 21). Most of the soil series in Kuthanagere were low in nitrogen except Kuthanagere-5. Among 13 soil series medium amount of available nitrogen was found in Kuthanagere-5 (171.24 ppm) followed by Kuthanagere-1 (94.77ppm) and lower nitrogen was found in Kuthanagere-12 (54.58 ppm).

Table 21: Base saturation, exchangeable sodium, available nitrogen and available phosphorus of typifying pedons (master profiles) of each soil series of Kuthanagere watershed during 2012

Sl. No.	Soil series	Horizon	Depth (cm)	BS (%)	Exch. Na (C mol p ⁺ kg ⁻¹)	Avail. N (ppm)	Avail. P ₂ O ₅ (ppm)
1.	Kuthanagere -1	Ap	0-12	65.95	0.54	116.21	19.14
		Bt1	12-46	71.79	0.52	96.65	12.87
		Bt2	46-78	88.95	0.57	84.10	11.83
		Bt3	78-125	91.42	0.57	82.10	9.39
		WM	-	79.52	0.55	94.77	13.31
2.	Kuthanagere -2	Ap	0-12	76.06	0.52	122.65	16.35
		Bt1	12-46	79.60	0.72	121.43	14.61
		Bt2	46-71	78.72	0.61	82.77	9.05
		Bt3	71-98	87.10	0.70	49.24	7.31
		Bt4	98-122	83.58	0.57	38.36	6.26
		Bc	122-138	90.34	0.59	35.11	5.57
	WM	-	82.57	0.62	74.93	9.86	
3.	Kuthanagere -3	Ap	0-14	76.85	0.72	102.56	15.66
		Bt1	14-49	68.70	0.57	105.44	12.53
		Bt2	49-88	91.32	0.61	67.04	12.18
		Bc	88-125	85.38	0.63	57.22	10.79
	WM	-	80.56	0.63	83.06	12.79	
4.	Kuthanagere -4	Ap	0-11	87.99	0.48	129.84	24.01
		Bt1	11-31	59.64	0.54	118.24	17.75
		Bt2	31-54	55.72	0.59	95.16	9.39
		Bt3	54-76	62.23	0.65	62.77	8.70
		Bt4	76-104	90.56	0.63	47.22	6.61
		Bt5	104-133	54.79	0.63	43.28	4.52
	WM	-	68.49	0.59	82.75	11.83	
5.	Kuthanagere -5	A	0-14	62.26	0.59	138.65	14.61
		Bt1	14-33	89.43	0.59	190.64	13.57
		Bt2	33-51	72.26	0.65	196.42	11.83
	WM	-	74.65	0.61	175.24	13.34	
6.	Kuthanagere -6	AP	0-22	61.67	0.65	103.99	11.48
		Bt1	22-55	68.77	0.67	96.32	9.05
		Bt2	55-89	59.34	0.57	82.56	6.61
		Bc	89-118	89.21	0.59	48.16	6.26
	WM	-	69.75	0.62	82.76	8.35	
7.	Kuthanagere -7	Ap	0-17	64.15	0.52	119.54	7.31
		Bt1	17-45	79.04	0.52	111.76	6.61

		Bt2	45-80	69.70	0.54	73.52	5.92
		Cb	80-112	84.19	0.72	52.88	5.92
		WM	-	74.27	0.58	89.43	6.44
8.	Kuthanagere -8	Ap	0-18	75.46	0.52	92.36	10.79
		Bw1	18-34	89.66	0.54	64.22	9.39
		Bw2	34-62	82.91	0.70	60.43	8.35
		Bw3	62-102	77.47	0.63	47.02	9.74
		Bw4	102-115	54.39	0.61	36.52	6.61
		WM	-	75.98	0.60	60.11	8.98
9.	Kuthanagere -9	Ap	0-11	57.31	0.57	121.32	16.35
		Bt1	11-45	60.71	0.61	90.10	13.92
		Bt2	45-81	77.69	0.54	89.32	12.87
		Bt3	81-108	72.64	0.57	56.54	10.09
		Bt4	108-128	93.81	0.61	29.98	6.61
		Bt5	128-151	86.61	0.54	12.75	4.52
		WM	-	74.79	0.57	66.67	10.73
10.	Kuthanagere -10	Ap	0-10	74.77	0.50	125.54	24.70
		Bt1	10-34	66.24	0.52	88.88	18.44
		Bt2	34-56	59.29	0.87	70.36	10.09
		Bt3	56-90	76.57	0.78	46.44	7.66
		Bc	90-120	86.59	0.65	40.66	5.92
		WM	-	72.69	0.67	74.38	13.36
11.	Kuthanagere -11	Ap	0-16	91.30	0.57	105.08	16.01
		Bt1	16-42	66.65	0.59	95.10	12.18
		Bt2	42-71	79.58	0.54	63.99	12.18
		Bt3	71-115	70.81	0.63	44.66	11.48
		Bt4	115-129	77.07	0.57	38.11	10.44
		Bt5	129-150	65.20	0.59	36.66	6.96
		WM	-	75.10	0.58	63.93	11.54
12.	Kuthanagere -12	Ap	0-18	80.86	0.67	98.44	14.27
		Bw1	18-41	83.36	0.89	67.76	12.87
		Bw2	41-65	81.47	0.93	49.28	11.48
		Bw3	65-88	82.13	0.70	30.21	11.48
		Cb	88-101	82.67	0.83	27.21	9.05
		WM	-	82.10	0.80	54.58	11.83
13.	Kuthanagere -13	Ap	0-12	89.61	0.57	94.60	17.05
		Bw	12-30	45.10	1.24	53.32	16.01
		WM	-	67.35	0.90	73.96	16.53
Note: WM: weighted mean of all the horizons, Avail: available, Exch.: Exchangeable							

In all the pedons higher amount of nitrogen was noticed in Ap and Bt1 horizons which decreased with the increase in depth. Ap horizons of Kuthanagere-4 (129.84 ppm), Kuthanagere-5 (138.65 ppm) and Kuthanagere-10 (125.54 ppm) fall into the category of medium range and all other Ap horizons found to be low in nitrogen content. Between Ap and Bt1 horizon, Ap horizon recorded higher amount of nitrogen compared to Bt1 horizon in all pedons except in Kuthanagere-3 and Kuthanagere-5 which recorded lower amount in Ap horizon (102.56 and 138.65 ppm) compared to Bt1 horizon (105.44 and 138.65 ppm).

4.2.3.8 Available phosphorus (P_2O_5) (ppm)

Available P_2O_5 in soils of Kuthanagere ranged from low to medium, none of the soil series was found to be high in P_2O_5 content (Table 21). Kuthanagere-1 (13.31 ppm), Kuthanagere-3 (12.79 ppm), Kuthanagere-4 (11.83 ppm), Kuthanagere-5 (13.34 ppm), Kuthanagere-9 (10.73 ppm), Kuthanagere-11 (11.54 ppm), Kuthanagere-12 (11.83 ppm) and Kuthanagere-13 (16.53 ppm) found to be medium in available P_2O_5 content whereas Kuthanagere-2 (9.86 ppm), Kuthanagere-6 (8.35 ppm), Kuthanagere-7 (6.44 ppm) and Kuthanagere-8 (8.98 ppm) found to be low in available P_2O_5 status based on weighted mean. Higher amount of P_2O_5 was observed in Kuthanagere-13 (16.53 ppm) and lower P_2O_5 was noticed in Kuthanagere-7 (6.44 ppm).

Available P_2O_5 decreased with the depth in all the profiles. Ap horizons of all the pedons found to be medium in available P_2O_5 except Kuthanagere-7 which was found to be low in P_2O_5 . Higher amount of P_2O_5 was observed in Ap and Bt1 horizons when compared to other subsurface horizons.

4.2.3.9 Exchangeable potassium (K) ($C \text{ mol } P^+ \text{ kg}^{-1}$)

Based on weighted mean, higher amount of exchangeable potassium was noticed in Kuthanagere-1 ($0.26 \text{ C mol } P^+ \text{ kg}^{-1}$) and Kuthanagere-6 ($0.26 \text{ C mol } P^+ \text{ kg}^{-1}$) and the lower amount of exchangeable potassium was observed in Kuthanagere-13 ($0.10 \text{ C mol } P^+ \text{ kg}^{-1}$) and Kuthanagere-2 ($0.10 \text{ C mol } P^+ \text{ kg}^{-1}$) soil series (Table 22).

Among the pedons surface Ap horizon recorded higher amount of exchangeable K and it decreased with the depth in Kuthanagere-1, Kuthanagere-2, Kuthanagere-3,

Kuthanagere-4, Kuthanagere-5, Kuthanagere-6, Kuthanagere-7 and Kuthanagere-9. However, in Kuthanagere-8 soil series it slightly increased in Bw3 horizon. In Kuthanagere-10, higher exchangeable K was noticed in Bt2 (0.19 C mol P⁺ kg⁻¹) followed by Ap (0.15 C mol P⁺ kg⁻¹), Bt3 and Bt4 (0.10 C mol P⁺ kg⁻¹) horizons and lower K was noticed in Bt1 (0.09 C mol P⁺ kg⁻¹) horizon. Vertical distribution of K was found to be irregular in Kuthanagere-11, where in Ap horizon recorded 0.09 C mol P⁺ kg⁻¹ of K and Bt1 (0.13 C mol P⁺ kg⁻¹) Bt2 (0.12 C mol P⁺ kg⁻¹) Bt3 (0.14 C mol P⁺ kg⁻¹) Bt4 (0.10 C mol P⁺ kg⁻¹) and Bt5 (0.12 C mol P⁺ kg⁻¹) horizons. In Kuthanagere-12, Bw-2 (0.10) horizon recorded higher values compared to Ap (0.09 C mol P⁺ kg⁻¹), Bw1 (0.08 C mol P⁺ kg⁻¹) and Bw3 (0.06 C mol P⁺ kg⁻¹) horizons. K content increased with depth in Kuthanagere-13 soil series.

4.2.3.10 Exchangeable calcium (Ca) and magnesium (Mg) (C mol P⁺ kg⁻¹)

Among the 13 soil series exchangeable Ca and Mg ranged from 2.74 to 5.52 and 0.15 to 0.32, respectively (Table 22). Higher amount of Ca was noticed in Kuthanagere-12 followed by Kuthanagere-13 (4.56 C mol P⁺ kg⁻¹) and lower amount was noticed in Kuthanagere-6 (2.74 C mol P⁺ kg⁻¹) whereas, higher amount of Mg was observed in Kuthanagere-2 (0.32 C mol P⁺ kg⁻¹) and lower amount was observed in Kuthanagere-3 (0.15 C mol P⁺ kg⁻¹) soil series.

In Kuthanagere-1 Ap horizon recorded lesser (1.45 C mol P⁺ kg⁻¹) Ca compared to subsurface Bt1 (3.79 C mol P⁺ kg⁻¹), Bt2 (4.15 C mol P⁺ kg⁻¹) and Bt3 (4.91 C mol P⁺ kg⁻¹) which showed increasing trend with increase in depth. Similar pattern of Ca distribution was noticed in Kuthanagere-12 whereas in Kuthanagere-13 reverse trend was noticed. In Kuthanagere-2 increased in Ca content with depth was noticed up to Bt3 horizon and then decreased with depth. Similar trend was observed in Kuthanagere-11 soil series. Exchangeable Ca was found to increase with depth up to Bt2 horizon in Kuthanagere-3 and Kuthanagere-9 (1.49 to 4.86 and 2.25 to 4.44 C mol P⁺ kg⁻¹). however, in Kuthanagere-4, Kuthanagere-5, Kuthanagere-6, Kuthanagere-7, Kuthanagere-8 and Kuthanagere-10 it was found to increase till Bt1 horizon and varied irregularly in subsequent horizons.

Table 22: Exchangeable potassium, calcium and magnesium content of typifying pedons (master profiles) of each soil series of Kuthanagere watershed during 2012

Sl. No.	Soil series	Horizon	Depth (cm)	Exch. K (C mol p ⁺ kg ⁻¹)	Exch. Ca (C mol p ⁺ kg ⁻¹)	Exch. Mg (C mol p ⁺ kg ⁻¹)
1.	Kuthanagere -1	Ap	0-12	0.33	1.45	0.11
		Bt1	12-46	0.26	3.79	0.30
		Bt2	46-78	0.24	4.15	0.23
		Bt3	78-125	0.19	4.91	0.16
		WM	-	0.26	3.57	0.20
2.	Kuthanagere -2	Ap	0-12	0.15	2.66	0.21
		Bt1	12-46	0.10	4.36	0.19
		Bt2	46-71	0.10	4.02	0.50
		Bt3	71-98	0.10	5.52	0.17
		Bt4	98-122	0.09	5.23	0.41
		Bc	122-138	0.06	4.69	0.45
		WM	-	0.10	4.41	0.32
3.	Kuthanagere -3	Ap	0-14	0.27	1.49	0.14
		Bt1	14-49	0.14	3.76	0.12
		Bt2	49-88	0.13	4.86	0.19
		Bc	88-125	0.12	4.64	0.16
		WM	-	0.16	3.69	0.15
4.	Kuthanagere -4	Ap	0-11	0.35	2.73	0.17
		Bt1	11-31	0.15	3.44	0.13
		Bt2	31-54	0.13	2.86	0.15
		Bt3	54-76	0.14	2.39	0.12
		Bt4	76-104	0.12	3.69	0.24
		Bt5	104-133	0.09	2.99	0.34
		WM		0.16	3.02	0.19
5.	Kuthanagere -5	A	0-14	0.26	3.84	0.29
		Bt1	14-33	0.15	5.80	0.26
		Bt2	33-51	0.14	5.33	0.18
		WM	-	0.18	4.99	0.24
6.	Kuthanagere -6	AP	0-22	0.33	1.77	0.15
		Bt1	22-55	0.26	3.05	0.17
		Bt2	55-89	0.24	2.84	0.27
		Bc	89-118	0.19	3.32	0.21
		WM	-	0.26	2.74	0.20
7.	Kuthanagere -7	Ap	0-17	0.15	2.20	0.13
		Bt1	17-45	0.12	3.91	0.13

		Bt2	45-80	0.09	3.08	0.22
		Cb	80-112	0.08	4.05	0.13
		WM	-	0.11	3.31	0.15
8.	Kuthanagere -8	Ap	0-18	0.17	5.15	0.15
		Bw1	18-34	0.12	5.22	0.28
		Bw2	34-62	0.09	3.21	0.40
		Bw3	62-102	0.10	3.50	0.16
		Bw4	102-115	0.06	4.26	0.41
		WM	-	0.11	4.27	0.28
9.	Kuthanagere -9	Ap	0-11	0.21	2.50	0.25
		Bt1	11-45	0.15	2.96	0.19
		Bt2	45-81	0.13	4.44	0.14
		Bt3	81-108	0.12	4.12	0.23
		Bt4	108-128	0.12	5.84	0.20
		Bt5	128-151	0.12	5.72	0.19
		WM		0.14	4.26	0.20
10.	Kuthanagere -10	Ap	0-10	0.15	3.12	0.22
		Bt1	10-34	0.09	3.65	0.14
		Bt2	34-56	0.19	2.65	0.31
		Bt3	56-90	0.10	3.56	0.35
		Bc	90-120	0.10	3.25	0.17
		WM	-	0.13	3.25	0.24
11.	Kuthanagere -11	Ap	0-16	0.09	3.25	0.11
		Bt1	16-42	0.13	3.53	0.11
		Bt2	42-71	0.12	3.78	0.23
		Bt3	71-115	0.14	3.90	0.24
		Bt4	115-129	0.10	3.30	0.20
		Bt5	129-150	0.12	2.96	0.10
		WM	-	0.12	3.45	0.16
12.	Kuthanagere -12	Ap	0-18	0.09	5.12	0.16
		Bw1	18-41	0.08	5.26	0.27
		Bw2	41-65	0.10	5.31	0.23
		Bw3	65-88	0.06	5.80	0.33
		Cb	88-101	0.04	6.12	0.23
		WM	-	0.07	5.52	0.24
13.	Kuthanagere -13	Ap	0-12	0.09	5.26	0.17
		Bw	12-30	0.12	3.86	0.28
		WM		0.10	4.56	0.23
Note: WM: weighted mean of all the horizons, Exch.: Exchangeable						

Mg distribution varied ununiformly in all the profiles. Mg content was high in Bt1 horizon than Ap horizon in Kuthanagere-1, Kuthanagere-6, Kuthanagere-7, Kuthanagere-8, Kuthanagere-11 and Kuthanagere-12 whereas reverse trend was noticed in Kuthanagere-2, Kuthanagere-3, Kuthanagere-4, Kuthanagere-5, Kuthanagere-9, Kuthanagere-10 and Kuthanagere-13 soil series.

4.2.3.11 Micronutrients (Fe, Cu, Zn and Mn) (ppm)

Micronutrients ranged from low to high on weighted mean basis (Table 23). Fe content was found to be high in all the soil series except Kuthanagere-9 and Kuthanagere-12 which was found to be low. However higher amount of Fe was noticed in Kuthanagere-13 (19.45 ppm) followed by Kuthanagere-5 (12.43 ppm) and Kuthanagere-8 (11.02 ppm). In case of Cu Kuthanagere-3 (2.80 ppm), Kuthanagere-5 (2.27 ppm), Kuthanagere-7 (5.05 ppm) and Kuthanagere-10 (2.23 ppm) fall under high category whereas Kuthanagere-12 (0.56 ppm) comes under lower category. With respect to Zn, all the soil series accounted higher amount than the critical limit except Kuthanagere-12 (0.41 ppm). Mn content was found to be higher than critical limit in Kuthanagere-1 (2.23 ppm), Kuthanagere-3 (2.92 ppm), Kuthanagere-4 (2.91 ppm), Kuthanagere-7 (6.28 ppm), Kuthanagere-11 (2.15 ppm) and Kuthanagere-13 (3.57 ppm). Lower amount of Mn was noticed in Kuthanagere-12 (0.63 ppm).

In Kuthanagere-1 soil Ap horizon (9.40 ppm) recorded higher amount of Fe which decreased with depth to 7.10 ppm (Bt1), 0.70 ppm (Bt2) and 0.52 ppm (Bt3). Similar trend was noticed in Kuthanagere-6, Kuthanagere-10 and Kuthanagere-13 soil series. In other pedons irregular variations was observed with the increase in depth.

Ununiform distribution of copper with increase in depth was observed in Kuthanagere-4, Kuthanagere-5, Kuthanagere-6, Kuthanagere-8, Kuthanagere-10 and Kuthanagere-12. In Kuthanagere-1 Cu content showed uniform decline with depth where in Ap horizon (2.60 ppm) recorded higher amount followed by Bt1 (1.70 ppm), Bt2 (0.70 ppm) and Bt3 (0.52 ppm) horizons. Similar trend was observed in Kuthanagere-7, Kuthanagere-9 and Kuthanagere-13 soil series.

Marked difference was noticed with respect to Zn content in different horizons of Kuthanagere-4. It was found to increase with depth from Ap horizon to Bt2 horizon and showed decreasing trend from Bt3 to Bt5 horizons. In Kuthanagere-3 and Kuthanagere-

Table 23. Micronutrient content of typifying pedons (master profiles) of each soil series of Kuthanagere watershed during 2012

Sl. No.	Soil series	Horizon	Depth (cm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	B (ppm)
1.	Kuthanagere -1	Ap	0-12	9.40	2.60	2.60	2.80	0.58
		Bt1	12-46	7.10	1.70	2.40	3.90	0.41
		Bt2	46-78	2.60	0.70	0.42	1.32	0.24
		Bt3	78-125	1.24	0.52	0.44	0.90	0.15
		WM	-	5.09	1.38	1.47	2.23	0.34
2.	Kuthanagere -2	Ap	0-12	6.10	3.10	2.10	2.60	0.54
		Bt1	12-46	21.60	2.50	3.00	1.90	0.69
		Bt2	46-71	0.94	0.62	0.50	0.66	0.60
		Bt3	71-98	0.90	0.52	0.52	0.68	0.33
		Bt4	98-122	1.38	0.64	0.62	1.12	0.47
		Bc	122-138	1.14	0.56	0.50	1.04	0.52
		WM	-	5.34	1.32	1.21	1.33	0.52
3.	Kuthanagere -3	Ap	0-14	5.10	2.80	2.40	3.60	0.33
		Bt1	14-49	10.50	4.70	2.10	6.20	0.60
		Bt2	49-88	3.30	1.16	0.38	1.18	0.50
		Bc	88-125	3.48	0.36	0.50	0.70	0.13
		WM	-	5.60	2.26	1.35	2.92	0.39
4.	Kuthanagere -4	Ap	0-11	5.70	2.20	1.90	5.60	0.82
		Bt1	11-31	4.30	2.30	2.10	3.90	0.60
		Bt2	31-54	8.00	3.10	3.10	2.80	0.69
		Bt3	54-76	10.30	2.80	2.50	3.20	0.52
		Bt4	76-104	2.66	0.54	0.36	1.46	0.20
		Bt5	104-133	1.34	0.50	0.54	0.52	0.33
		WM		5.38	1.91	1.75	2.91	0.53
5.	Kuthanagere -5	A	0-14	6.70	0.70	0.38	0.58	0.73
		Bt1	14-33	17.50	2.60	2.20	3.20	0.60
		Bt2	33-51	13.10	3.50	3.10	1.80	0.61
		WM	-	12.43	2.27	1.89	1.86	0.64
6.	Kuthanagere -6	AP	0-22	9.80	2.50	2.40	2.80	0.47
		Bt1	22-55	8.20	1.90	2.60	4.20	0.13
		Bt2	55-89	8.20	1.30	1.00	3.30	0.19
		Bc	89-118	4.90	1.50	3.30	2.80	0.15
		WM	-	7.78	1.80	2.33	3.28	0.23
7.	Kuthanagere -7	Ap	0-17	10.30	7.10	1.90	6.80	0.76
		Bt1	17-45	23.30	6.50	3.10	6.20	0.37

		Bt2	45-80	10.70	3.40	1.00	5.90	0.63
		Cb	80-112	38.50	3.20	2.80	6.20	0.65
		WM	-	20.70	5.05	2.20	6.28	0.60
8.	Kuthanagere -8	Ap	0-18	7.64	0.70	0.42	0.54	1.06
		Bw1	18-34	2.74	0.54	0.52	0.62	0.84
		Bw2	34-62	2.06	0.64	0.62	0.70	0.56
		Bw3	62-102	34.70	4.10	1.70	5.90	0.87
		Bw4	102-115	7.96	0.78	0.38	1.62	0.32
		WM	-	11.02	1.35	0.73	1.88	0.73
9.	Kuthanagere -9	Ap	0-11	9.10	4.20	2.60	2.20	0.58
		Bt1	11-45	9.80	2.80	2.20	2.50	0.56
		Bt2	45-81	2.40	0.62	0.48	0.78	0.74
		Bt3	81-108	1.58	0.52	0.62	0.66	0.80
		Bt4	108-128	2.02	0.46	0.56	0.36	0.60
		Bt5	128-151	1.86	0.62	0.38	0.52	0.71
		WM		4.46	1.54	1.14	1.17	0.67
10.	Kuthanagere -10	Ap	0-10	12.60	3.50	2.40	1.40	0.30
		Bt1	10-34	18.20	4.20	1.80	2.90	0.69
		Bt2	34-56	18.00	1.70	2.10	3.80	0.39
		Bt3	56-90	2.70	1.02	0.62	0.90	0.47
		Bc	90-120	1.04	0.72	0.52	0.66	0.20
		WM	-	10.51	2.23	1.49	1.93	0.41
11.	Kuthanagere -11	Ap	0-16	26.70	4.10	2.10	3.40	0.26
		Bt1	16-42	8.80	3.10	3.20	4.10	0.30
		Bt2	42-71	7.20	2.90	1.20	3.50	0.41
		Bt3	71-115	1.86	0.36	0.40	0.84	0.47
		Bt4	115-129	2.94	0.52	0.40	0.52	0.39
		Bt5	129-150	2.74	0.34	0.34	0.56	0.41
		WM	-	8.37	1.89	1.27	2.15	0.37
12.	Kuthanagere -12	Ap	0-18	2.04	0.50	0.36	0.70	0.52
		Bw1	18-41	1.58	0.42	0.52	0.72	0.65
		Bw2	41-65	1.82	0.44	0.34	0.56	0.71
		Bw3	65-88	1.12	0.62	0.42	0.72	0.52
		Cb	88-101	1.36	0.82	0.40	0.44	0.50
		WM	-	1.58	0.56	0.41	0.63	0.58
13.	Kuthanagere -13	Ap	0-12	27.80	2.80	2.10	6.30	0.45
		Bw	12-30	11.10	0.52	0.62	0.84	0.63
		WM		19.45	1.66	1.36	3.57	0.54
Note: WM: weighted mean of all the horizons								

13 uniform decline in Zn with depth was noticed from last horizon. In Kuthanagere-9 soil series Ap horizon (2.60 ppm) recorded higher amount of Zn which reduced with depth up to Bt2 (0.48 ppm) horizon and in Bt3 (0.62 ppm) horizon it increased slightly followed by reduced Zn content in Bt4 (0.56 ppm) and Bt5 (0.38 ppm) horizons.

Mn showed decreasing trend with depth in Kuthanagere-13, and in Kuthanagere-2 and Kuthanagere-7 it decreased with depth till Bt2 horizon and found to be increased with depth. Whereas, in Kuthanagere-8 and Kuthanagere-10 Mn content increased with depth until Bt3 and Bt2 horizons. In Kuthanagere-3, Kuthanagere-4, Kuthanagere-5, Kuthanagere-6, Kuthanagere-9, Kuthanagere-11 and Kuthanagere-12 Mn content varied irregularly with the depth.

4.2.3.12 Available Boron (B) (ppm)

Among 13 soil series available B content ranged from 0.23 ppm to 0.73 ppm. Increasing B content in Kuthanagere soil series was found to be in this order Kuthanagere-6 (0.23), Kuthanagere-1 (0.34 ppm), Kuthanagere-11 (0.37 ppm), Kuthanagere-3 (0.39 ppm), Kuthanagere-10 (0.41 ppm), Kuthanagere-2 (0.52 ppm), Kuthanagere-4 (0.53 ppm), Kuthanagere-13 (0.54 ppm), Kuthanagere-12 (0.58 ppm), Kuthanagere-7 (0.60 ppm), Kuthanagere-5 (0.64 ppm), Kuthanagere-9 (0.67 ppm) and Kuthanagere-8 (0.73 ppm) (Table 23).

Available B content showed uniform decline with depth in Kuthanagere-1 and Kuthanagere-5, whereas in Kuthanagere-8 showed decline in B content was noticed till Bw2 (0.56 ppm) and in Kuthanagere-4, Kuthanagere-6, Kuthanagere-7 and Kuthanagere-9 soil series B content was found to be reduced in Bt1 horizon (0.60, 0.13, 0.37 and 0.56 ppm) compared with Ap horizon (0.82, 0.47, 0.76 and 0.58 ppm). However, reverse trend was noticed in Kuthanagere-2, Kuthanagere-3, Kuthanagere-10 and Kuthanagere-13 wherein Ap horizon (0.54, 0.33, 0.30 and 0.45 ppm) recorded lower B content than Bt1 horizon (0.69, 0.60, 0.69 and 0.63 ppm). In case of Kuthanagere-11 B content increase with depth from Ap (0.26 ppm) to Bt3 (0.47 ppm) horizon and in Kuthanagere-12 B content increased with depth from Ap (0.52 ppm) to Bw2 (0.71 ppm) horizons.

4.3 Characterization of surface samples for chemical properties

The data on the chemical properties of surface soil samples to study the fertility status are presented in Table 24.

4.3.1 Soil reaction

Soil reaction of the surface soils varied from acidic to neutral which ranged from 4.7 to 7.6. Acidic pH was noticed in Phase-13 (4.7) and the higher pH of 7.6 was observed in Phase-27.

4.3.2 Electrical conductivity (EC) (dsm^{-1})

Among the Phases difference was observed with respect to electrical conductivity. Its values ranged between 0.023 to 0.195 dsm^{-1} . Higher EC values are observed in Phase-27 and lower values was observed in Phase-10.

4.3.3 Organic carbon (%)

Organic carbon in the surface soils was low to medium and varied from 0.44% in Phase-32 to 0.73% in Phase-17.

4.3.4 Major nutrients

Nitrogen values ranged from 67.16 ppm to 127.06 ppm which falls under the category of low to medium. Phosphorus (P_2O_5) content in soils varied between 10.09 ppm to 19.83 ppm and most of the surface soils were low to medium in P_2O_5 content. Whereas K was found to be higher in Phase-23 (1.23) and lower amount was observed in Phase-5 (0.06).

4.3.5 Secondary nutrients

Exchangeable Ca and Mg content varied from 0.63 to 7.66 $\text{C mol p}^+ \text{ kg}^{-1}$ and 0.14 to 1.44 $\text{C mol p}^+ \text{ kg}^{-1}$, respectively. All the surface soil was found to be deficient in sulphur and the values ranged from 0.76 ppm to 4.17 ppm.

4.3.6 Micronutrients (ppm)

Zn content in the soil varied from 0.38 to 3.90 ppm, Fe was observed between 1.62 to 32.50 ppm and Mn and Cu content in the surface soils ranged from 0.32 to 6.30 and 0.26 to 7.12 ppm, respectively.

4.3.7 Exchangeable sodium ($\text{C mol p}^+ \text{ kg}^{-1}$)

Exchangeable sodium content in surface soils was higher in Phase-43 (2.22 $\text{C mol p}^+ \text{ kg}^{-1}$) and lower amount was noticed in Phase-45 (0.26 $\text{C mol p}^+ \text{ kg}^{-1}$)

4.3.8 Available boron (ppm)

Available boron status ranged from 0.32 to 0.84 ppm. Most of the soil phases were found to be sufficient in boron content.

Table 24. Chemical properties and nutrient status of surface soil samples

Soil phases	pH	Ec (dSm ⁻¹)	OC (%)	Avail. N (ppm)	Avail. P ₂ O ₅ (ppm)	Avail. K (ppm)	Exch. Ca (C mol p ⁺ kg ⁻¹)	Exch. Mg (C mol p ⁺ kg ⁻¹)	Exch. Na (C mol p ⁺ kg ⁻¹)	Avail. S (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	B (ppm)
Ku1cB1	6.69	0.57	0.61	106.92	18.44	75.19	2.65	0.15	0.48	1.29	0.38	3.98	0.82	0.72	0.69
Ku1hC2	6.92	0.087	0.53	92.36	19.14	47.62	7.66	0.20	0.61	0.76	0.62	2.12	0.64	0.58	0.73
Ku1hB1	4.93	0.125	0.58	101.26	12.18	40.10	3.64	0.14	0.48	1.59	2.40	6.50	4.10	3.10	0.33
Ku1hB2	5.36	0.045	0.69	119.88	13.22	37.60	2.76	0.32	0.41	1.52	3.20	7.20	5.30	4.10	0.52
Ku2cB2	6.5	0.115	0.68	118.76	16.35	12.53	1.58	0.45	0.46	4.17	0.50	2.78	1.26	0.52	0.67
Ku2cC2	6.6	0.095	0.72	125.04	17.05	155.40	3.23	0.51	0.35	1.52	0.56	2.82	0.78	0.70	0.69
Ku2hB1	5.09	0.063	0.61	106.22	11.83	110.28	1.93	0.46	0.30	1.82	3.20	8.00	4.20	3.20	0.43
Ku2hB2	5.2	0.041	0.59	103.08	12.53	122.81	2.01	0.45	0.30	2.88	1.90	14.30	2.80	3.50	0.48
Ku2hC2	6.88	0.065	0.72	125.54	16.70	177.96	2.38	0.43	0.37	1.52	0.56	1.62	0.50	0.36	0.71
Ku3cA1	5.36	0.023	0.61	106.72	14.96	135.35	1.84	0.37	0.30	1.74	2.60	7.10	2.60	3.20	0.56
Ku3cB1	5.54	0.029	0.67	116.44	16.01	120.31	1.16	0.36	0.35	1.67	3.20	5.10	3.50	3.50	0.63
Ku3cC2	5.2	0.101	0.63	109.46	12.18	147.88	1.16	0.20	0.46	2.88	2.50	15.00	5.90	4.80	0.52
Ku3hA1	4.7	0.062	0.49	85.78	10.09	100.26	1.34	0.41	0.33	2.80	2.70	14.50	4.10	4.50	0.32
Ku3hB2	5.92	0.027	0.38	67.16	12.53	205.53	0.68	0.43	0.50	3.03	2.50	8.70	4.20	2.10	0.58
Ku4hB2	6.1	0.052	0.68	118.86	13.57	205.53	1.59	0.45	0.48	1.14	2.60	3.70	3.60	2.70	0.65
Ku4hC2	5.75	0.048	0.58	101.46	12.18	7.52	1.73	0.58	0.39	1.97	1.90	10.80	5.10	2.90	0.52
Ku5cF3	6.1	0.12	0.73	127.06	13.57	185.47	2.22	0.16	0.39	1.89	2.10	9.90	2.60	3.10	0.69
Ku5hB2R1	6.33	0.054	0.71	123.22	14.27	213.04	1.51	0.28	0.33	2.95	2.20	8.50	2.20	2.90	0.74
Ku6bB2	6.04	0.045	0.61	106.42	13.22	150.38	1.11	0.29	0.41	2.35	2.50	13.30	2.30	2.60	0.61
Ku6cA1	5.64	0.046	0.58	101.16	16.35	107.78	2.21	0.26	0.43	1.89	3.20	22.10	3.50	3.20	0.52
Ku6cB1	4.97	0.056	0.60	104.80	10.79	175.45	0.70	0.25	0.30	2.58	2.70	11.10	4.30	2.10	0.45
Ku6cB2	5.05	0.047	0.58	101.56	14.27	150.38	1.11	0.40	0.46	1.97	1.90	18.30	1.90	1.80	0.52

Ku6cC2	5.6	0.062	0.65	113.70	15.31	240.62	1.84	0.74	0.43	2.42	2.50	11.80	6.30	2.70	0.50
Ku7cC2	5.87	0.044	0.63	109.46	16.01	117.80	0.74	0.36	0.28	1.89	2.40	14.30	2.80	2.80	0.56
Ku7gcC2R2	5.26	0.07	0.63	110.16	14.96	140.36	1.99	0.28	0.46	1.74	2.20	14.80	1.90	3.10	0.52
Ku7gcD2R1	5.75	0.053	0.65	113.50	14.27	92.74	2.89	0.42	0.33	2.50	3.90	11.30	2.90	2.60	0.54
Ku8hB1	7.6	0.195	0.58	101.36	12.53	180.46	2.83	0.37	0.37	1.59	0.50	6.02	0.66	0.70	0.76
Ku9hD3	6.25	0.042	0.70	121.60	11.13	205.53	1.28	0.42	0.30	2.95	3.00	14.10	1.60	2.60	0.69
Ku9cB2	5.96	0.044	0.61	106.22	15.31	10.03	1.14	0.45	0.30	3.18	2.10	8.60	2.20	3.20	0.58
Ku9cC2	6.28	0.05	0.73	126.76	12.53	203.02	1.29	0.39	0.37	2.95	2.30	5.80	3.20	3.10	0.69
Ku9iC3	6.26	0.063	0.71	123.22	10.79	82.71	5.41	0.42	0.35	2.80	1.40	14.20	3.30	2.80	0.71
Ku9hB2	5.83	0.024	0.44	77.18	10.09	218.06	6.18	1.00	0.43	2.12	3.10	15.10	2.60	3.20	0.56
Ku9hC2	6.1	0.055	0.69	120.48	12.18	160.41	1.76	0.74	0.35	1.59	2.80	11.90	2.50	2.10	0.63
Ku10hB2	5.35	0.068	0.65	113.50	11.83	80.21	0.89	0.20	0.78	3.03	2.30	11.50	3.50	7.10	0.54
Ku11bB1	5.01	0.088	0.59	102.98	10.44	170.44	2.83	0.81	0.37	1.82	3.10	17.40	4.20	2.80	0.48
Ku12cC2	5.14	0.135	0.45	78.80	10.44	112.79	3.08	0.21	0.30	2.12	2.60	14.20	2.80	3.90	0.52
Ku12hB1	4.76	0.078	0.53	92.46	17.40	115.29	4.05	1.44	0.28	2.95	2.50	11.70	2.20	4.20	0.37
Ku12hB2	6.14	0.029	0.69	119.78	16.35	112.79	2.19	0.65	0.33	4.17	2.40	15.80	2.50	3.50	0.58
Ku13bC2	6.7	0.135	0.48	84.06	17.05	100.26	0.49	0.22	0.43	3.86	0.62	3.62	0.52	0.52	0.56
Ku13cC1	6.55	0.059	0.62	108.24	17.05	75.19	3.56	0.83	0.46	2.95	0.56	1.64	0.38	0.36	0.63
Ku13cC2	7.48	0.112	0.45	78.80	19.14	65.17	2.92	1.25	0.35	3.11	0.52	2.84	0.58	1.08	0.78
Ku13cC3	6.18	0.028	0.42	73.74	17.40	70.18	2.02	0.50	0.46	1.06	2.90	32.50	3.30	3.80	0.56
Ku13hB1	7.26	0.136	0.69	119.58	19.83	135.35	3.07	1.22	2.22	1.36	0.62	4.40	0.32	0.80	0.84
Ku13hB2	5.38	0.072	0.47	82.64	12.53	105.27	0.96	0.28	0.33	1.36	2.10	12.80	2.20	3.40	0.56
Ku13hC2	7.1	0.043	0.65	113.70	16.01	110.28	2.16	0.63	0.26	1.74	0.70	2.00	0.64	0.26	0.82

Note: Avail: available, Exch.: Exchangeable

4.4 Correlation and regression between growth, yield component, soil parameters and grain yield

Table 25, 26, 27 and 28 shows the correlation and regression relationships of growth, yield and soil parameters with grain yield of finger millet.

The relation between the growth and yield parameter with grain yield of finger millet have been quantified by establishing both correlation and regression equations. Growth parameters *viz.*, plant height ($r=0.49^{**}$) had significantly moderate positive correlation, whereas, number of leaves ($r=0.66^{**}$), dry matter accumulation in leaves ($r=0.78^{**}$), dry matter accumulation in ear head ($r=0.76^{**}$) and total dry matter production ($r=0.79^{**}$) had significantly high positive correlation. Significantly very high positive correlation was noticed with number of tillers ($r=0.83^{**}$) and dry matter accumulation in stem ($r=0.81^{**}$). Among yield parameters, finger length ($r=0.35^{**}$) had significantly low positive correlation, whereas test weight ($r=0.55^{**}$), number of fingers ($r=0.54^{**}$) and effective tillers ($r=0.72^{**}$) had significantly moderate and high positive correlation respectively

Among 25 soil parameters, 12 parameters *viz.*, silt percent ($r=0.069$), clay percent ($r=0.156$), organic carbon percent ($r=0.094$), exchangeable sodium ($r=0.054$), available phosphorus ($r=0.178$), exchangeable calcium and magnesium ($r=0.119$ and $r=0.138$), depth ($r=0.119$), CEC ($r=0.142$), pH ($r=0.016$), Zinc ($r=0.069$) and Manganese ($r=0.089$) was found to be non-significant with grain yield of finger millet. Six parameters were found to be significant and positively influencing the yield of finger millet of which plant available water content (PAWC) ($r=0.612^{**}$) had high positive correlation, whereas base saturation ($r=0.427^{**}$) and length of growing period (LGP) ($r=0.559^{**}$) had moderate correlation and ground water depth ($r=0.261^{**}$), exchangeable potassium ($r=0.311^{**}$) and available nitrogen ($r=0.334^{**}$) had low correlation.

Seven parameters *viz.*, erosion ($r=-0.186^*$), Electrical conductivity ($r=-0.186^*$), iron (Fe) ($r=-0.196^*$), Copper (Cu) ($r=-0.184^*$) had significantly very low negative correlation whereas, coarse fragments ($r=-0.319^{**}$), slope ($r=-0.396^{**}$) and sand ($r=-0.208^*$) had low negative correlation with grain yield of finger millet.

Table 25: Relationship between yield and growth parameters and regression equations established with the seed yield of finger millet

Parameters	Type	r value	Regression equation	R ² value
Yield parameters				
Test weight	Linear	0.55**	Y=-14.06+12.44X	0.30**
	Quadratic	0.55**	Y=-14.57+12.78X-0.06X ²	0.30**
Finger length	Linear	0.35**	Y=-5.59+3.63X	0.12**
	Quadratic	0.38**	Y=73.64-15.84X+1.19X ²	0.14*
No. of fingers	Linear	0.54**	Y=3.71+4.24X	0.52**
	Quadratic	0.55**	Y=18.72-2.23X+0.67X ²	0.30**
Effective tillers	Linear	0.72**	Y=-6.72+13.06X	0.52**
	Quadratic	0.72**	Y=10.55-1.96x+3.17X ²	0.53**
Growth parameters				
Plant height	Linear	0.49**	Y=-9.36+0.40X	0.24**
	Quadratic	0.50**	Y=-36.34+1.03x-0.003X ²	0.25**
No. of leaves	Linear	0.66**	Y=-2.53+3.68X	0.43**
	Quadratic	0.67**	Y=-23.18+9.22X-0.36X ²	0.44**
Number of tillers	Linear	0.83**	Y=-16.85+13.65X	0.69**
	Quadratic	0.84**	Y=13.29-6.85X+3.41X ²	0.70**
Leaf dry matter	Linear	0.78**	Y=-23.28+15.10X	0.61**
	Quadratic	0.78**	Y=-3.36+2.36+2.01X ²	0.62**
Stem dry matter	Linear	0.81**	Y=-39.26+10.74X	0.66**
	Quadratic	0.81**	Y=14.90-7.64X+1.55X ²	0.66**
Ear head dry matter	Linear	0.76**	Y=-40.81+5.28X	0.57**
	Quadratic	0.76**	Y=-4.04-0.69X+0.24X ²	0.57**
Total dry matter	Linear	0.79**	Y=-40.40+3.02X	0.63**
	Quadratic	0.79**	Y=-26.57+1.73X+0.03X ²	0.63**
n=108, **significant at 1%, * significant at 5%				

Table 26: Multiple linear regression coefficients of growth and yield parameters on yield of finger millet in different models

Parameters	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Plant height	0.1320**	0.1252**									
No. of leaves	0.8670*	0.8290*	1.0034**	1.0051**							
No. of tillers	35.2189**	34.2002**	34.2379**	34.2743**	30.1078**	27.8524**	7.8476**	8.6737**	8.7066**	8.5569**	13.6456**
LDM	7.5438**	7.4994**	8.6709**	8.6824**	8.7665**	8.9313**	2.2172	0.3513			
SDM	-3.5724	-3.4976	-2.3006	-2.3001	-0.6682	-0.2899	7.2031**	6.8653**	8.7066**	6.2256**	
EDM	1.0515	1.0508	0.6244	0.6407	0.7075	1.1831	1.3535				
TDM	-0.6042	-0.5911	-0.7814	-0.7854	-0.8636	-0.9967	-1.2340	-0.2839	-0.2684		
Test weight	0.6797	1.0035	0.0974								
Finger length	-0.2729										
No. of fingers	0.3475	0.3366	0.2905	0.3014	0.5991						
Effective tillers	-29.7525**	-28.8132**	-28.0138**	-28.0599**	-23.0542**	-20.5896**					
a	-32.9365	-34.9993	-26.1241	-26.0457	-28.5550	-30.4810	-39.2010	-37.4569	-37.6854	-38.2873	-16.8497
SE of a	6.7068	5.2741	4.5528	4.4162	4.4854	4.2182	3.9183	3.7894	3.5082	3.3232	2.7195
SE of Y	2.7722	2.7614	2.8731	2.8587	2.9614	2.9693	3.1919	3.2155	3.2004	3.1898	4.0986
R²	0.8699**	0.8696**	0.8574**	0.8573**	0.8454**	0.8430**	0.8168**	0.8122**	0.8122**	0.8116**	0.6860**

n=108, **significant at 1%, * significant at 5%

LDM: Leaf Dry Matter, SDM: Stem Dry Matter, EDM: Ear head Dry Matter, TDM: Total Dry Matter

Table 27: Relationship of soil parameters and regression equations established with the seed yield of finger millet (weighted mean)

Sl. no.	Parameters	Type	r value	Regression equation	R ² value
1	Slope (%)	Linear	-0.396**	Y=33.08-2.88X	0.156**
		Quadratic	-0.396**	Y=29.23-0.48X ²	0.157**
2	Erosion rating	Linear	-0.189*	Y=28.39-2.76X	0.035*
		Quadratic	-0.189*	Y=26.55-0.92X ²	0.035*
3	Ground water depth (m)	Linear	0.261**	Y=19.28+0.13X	0.068**
		Quadratic	0.314**	Y=4.67+1.21X-0.016X ²	0.098**
4	Depth (cm)	Linear	-0.119	Y=27.84-0.03X	0.014
		Quadratic	-0.337**	Y=-35.06+1.10X-0.005X ²	0.114**
5	Coarse Fragments (%)	Linear	-0.319**	Y=31.62-0.32X	0.102**
		Quadratic	-0.376**	Y=48-1.69X+0.03X ²	0.139**
6	Sand (%)	Linear	-0.208*	Y=51.80-0.48X	0.043*
		Quadratic	-0.295**	Y=-385.46+14.56X-0.13X ²	0.087**
7	Silt (%)	Linear	0.069	Y=20.86+0.27X	0.004
		Quadratic	0.307**	Y=-33.87+10.37X-0.45X ²	0.09*
8	Clay (%)	Linear	0.156	Y=13.69+0.34X	0.024
		Quadratic	0.187*	Y=-41.34+4.40X-0.07X ²	0.034
9	OC (%)	Linear	0.094	Y=20.44+8.79X	0.009
		Quadratic	0.095	Y=19.50+13.93X-6.31X ²	0.009
10	CEC	Linear	-0.142	Y=35.92-2.28X	0.020
		Quadratic	-0.150	Y=99.98-26.18X+2.21X ²	0.022
11	Base saturation (%)	Linear	0.427**	Y=-27.51+0.69X	0.183**
		Quadratic	0.459**	Y=341.55-9.12X+0.06X ²	0.212**
12	pH	Linear	-0.016	Y=25.98-0.29X	0.0003
		Quadratic	-0.158	Y=-309.74+104.50X-8.14X ²	0.025

13	EC (dsm ⁻¹)	Linear	-0.186*	Y=28.98-91.35X	0.034*
		Quadratic	-0.262**	Y=44.69-770.05X+6685.91X ²	0.069**
14	Ex. Na (C mol p ⁺ kg ⁻¹)	Linear	0.054	Y=17.27+11.36X	0.003
		Quadratic	0.121	Y=239.88-721.75X+601.49X ²	0.014
15	Av. N (ppm)	Linear	0.334**	Y=3.94+0.25X	0.112**
		Quadratic	0.335**	Y=11.35+0.06X+0.001X ²	0.112
16	Av. P ₂ O ₅ (ppm)	Linear	0.178	Y=17.73+0.58X	0.031
		Quadratic	0.225*	Y=38.39-3.74X+0.21X ²	0.051
17	Ex. K (C mol p ⁺ kg ⁻¹)	Linear	0.311**	Y=17.74+39.75X	0.096**
		Quadratic	0.351**	Y=34.02-156.60X+525.30X ²	0.123**
18	Ex. Ca (C mol p ⁺ kg ⁻¹)	Linear	0.119	Y=18.15+1.69X	0.014
		Quadratic	0.131	Y=-0.83+12.39X-1.48X ²	0.017
19	Ex. Mg (C mol p ⁺ kg ⁻¹)	Linear	0.138	Y=20.08+19.95X	0.019
		Quadratic	0.172	Y=33.12-100.18X+258.90X ²	0.029
20	Fe (ppm)	Linear	-0.196*	Y=26.51-0.29X	0.038*
		Quadratic	-0.205*	Y=28.88-0.81X+0.02X ²	0.042
21	Cu (ppm)	Linear	-0.184*	Y=26.78-1.24X	0.033*
		Quadratic	-0.215*	Y=33.71-6.71X+0.84X ²	0.047
22	Zn (ppm)	Linear	-0.069	Y=26.05-1.24X	0.004
		Quadratic	-0.082	Y=18.39+8.14X-2.68X ²	0.007
23	Mn (ppm)	Linear	-0.089	Y=25.31-0.44X	0.008
		Quadratic	-0.191*	Y=19.73+3.39X-0.51X ²	0.037
24	PAWC (mm)	Linear	0.612**	Y=12.69+0.17X	0.374**
		Quadratic	0.612**	Y=13.70+0.14X-0.0002X ²	0.374**
25	LGP (days)	Linear	0.559**	Y=-3.23+0.14X	0.312**
		Quadratic	0.612**	Y=60.80-0.55X+0.0018X ²	0.375**
n=108, **significant at 1%, * significant at 5%					

Table 28: Multiple linear regression coefficients of soil parameters on yield of finger millet in different models

Parameters	I	II	III	IV	V	VI	VII	VIII
Slope	-37.9718	8.4207	0.5343	-0.3767	-0.2001			
Ground water depth	0.6882							
C. fragments	14.3295	-2.4082	-0.1632					
Base saturation	5.8320	-0.4790	0.1357	-0.0637	-0.0886	-0.0552		
Avail. N	-7.9768	1.3611	0.1164	0.0429				
Exch. K	1391.5332	-226.3680						
PAWC	2.4177	-0.2876	0.0983	0.1518*	0.1744*	0.1780*	0.1731**	0.1694**
LGP	-1.8877	0.3507	0.0241	0.0083	0.0011	-0.0016	-0.0035	
a	-26.2813	-33.4225	-4.7098	14.7970	19.4286	16.6003	13.1520	12.6951
SE of a	49.7149	47.6903	30.4128	21.7661	19.7202	13.0369	6.3452	1.5356
SE of Y	5.9226	5.9013	5.8899	5.8854	5.8643	5.8371	5.8118	5.7845
R²	0.3877**	0.3860**	0.3822**	0.3770**	0.3754**	0.3752**	0.3747**	0.3746**

n=108, **significant at 1%, * significant at 5%

4.5 Comparison between benchmark survey data with the results of the experiment conducted during 2011 and 2012

4.5.1 Plant available water content (PAWC) (mm), Length of growing period (days) and grain yield ($q\ ha^{-1}$) of finger millet (Table 29)

4.5.1.1 Plant available water content (PAWC) (mm)

PAWC was found to be higher in Kuthanagere-1 (112.4 mm) and 7 (48.8 mm) soil series when compared to benchmark survey (41.1 and 43.9 mm, respectively). Whereas, the other soil series viz: Kuthanagere-2 (93.1 mm), Kuthanagere-3 (95.5 mm), Kuthanagere-4 (35.3 mm), Kuthanagere-10 (68.3 mm) and Kuthanagere-11 (44.6 mm) was found be lower in PAWC when compared to benchmark survey.

4.5.1.2 Length of growing period (LGP) (days)

Less number of growing days was noticed in Kuthanagere-4 (139 days), Kuthanagere-7 (195 days), Kuthanagere-9 (176 days), Kuthanagere-10 (208 days) and Kuthanagere-11 (184 days) when compared to benchmark survey data. However more number of growing days was observed in Kuthanagere-1 (243 days), Kuthanagere-2 (225 days), Kuthanagere-3 (225 days) and Kuthanagere-6 (213 days) soil series when compared to benchmark results.

4.5.1.3 Grain yield ($q\ ha^{-1}$)

The average yield of two years of experimentation revealed that all the soil series of Kuthanagere recorded lower yield when compared to benchmark survey. The declining trend of Kuthanagere soil series with respect to grain yield during 2012 was in this order; Kuthanagere-1 ($32.55\ q\ ha^{-1}$), Kuthanagere-3 ($31.03\ q\ ha^{-1}$), Kuthanagere-2 ($29.14\ q\ ha^{-1}$), Kuthanagere-6 ($26.83\ q\ ha^{-1}$), Kuthanagere- 10 ($23.98\ q\ ha^{-1}$), Kuthanagere-7 ($21.62\ q\ ha^{-1}$), Kuthanagere-11 ($20.70\ q\ ha^{-1}$), Kuthanagere-9 ($20.29\ q\ ha^{-1}$) and Kuthanagere-4 ($19.88\ q\ ha^{-1}$).

Since rainfall obtained during 2012 was 50 per cent less than the normal rainfall it was considered as drought year and yield obtained was found to much lesser than the normal years. Hence comparison of bench mark results with the results obtained during 2011 experiment was found to be appropriate.

Table 29: Comparison of plant available water content (PAWC), length of growing period (LGP) and grain yield of finger millet with bench mark survey yield

Soil series	PAWC (mm)		LGP (days)		Grain yield (q ha ⁻¹)		
	1995	2012	1995	2012	1995	2011	2012
Kuthanagere -1	41.1	112.4	206	243	36.77	38.58	31.74
Kuthanagere -2	118.3	93.1	224	225	31.25	33.19	27.65
Kuthanagere -3	108.6	95.5	221	228	37.50	37.96	29.92
Kuthanagere -4	40.4	35.5	206	139	20.20	23.92	18.97
Kuthanagere -5	18.9	-	199	-	-		-
Kuthanagere -6	31.5	68.5	202	213	29.00	29.91	25.54
Kuthanagere -7	43.9	48.8	207	195	20.92	25.24	20.95
Kuthanagere -8	40.2	-	204	-	-		-
Kuthanagere -9	111.7	39.0	223	176	19.23	24.03	19.57
Kuthanagere -10	108.2	68.3	221	208	25.00	27.01	22.64
Kuthanagere -11	68.5	44.6	213	184	20.00	24.30	19.93

All the soil series of Kuthanagere watershed recorded higher grain yield of finger millet compared to bench mark yield. Higher grain yield was obtained in Kuthanagere-1 (38.58 q ha⁻¹) followed by Kuthanagere-2 (37.96 q ha⁻¹), Kuthanagere-3 (33.19 q ha⁻¹) Kuthanagere-6 (29.91 q ha⁻¹), Kuthanagere-10 (27.01 q ha⁻¹), Kuthanagere-11 (24.30 q ha⁻¹), Kuthanagere-7 (25.24 q ha⁻¹), Kuthanagere-9 (24.03 q ha⁻¹) and Kuthanagere-4 (23.92 q ha⁻¹).

4.5.2 Soil parameters (Table 30)

4.5.2.1 Physical properties

4.5.2.1.1 Sand

All the pedons showed decline in sand fractions except Kuthanagere-1, 4 and 10 which had accumulated sand over a period of time compared to bench mark survey.

4.5.2.1.2 Silt

When compared to bench mark survey slight increase in the silt content was notice in the Ap horizons of Kuthanagere-1, 2, 3, 4, 7, 9, 10 and 13 pedons.

4.5.2.1.3 Clay

Over a period of time clay content had reduced in Ap horizons of Kuthanagere-1, 4, 10 however, accumulation of clay fractions was witnessed in Kuthanagere-2, 3, 5, 6, 7, 8, 9, 11, 12 and 13 pedons.

4.5.2.2 Chemical properties

4.5.2.2.1 Soil reaction

In Kuthanagere-1, 3, 4, 6, 7, 9, 10, 11 and 13 pedons soil had became acidic than the earlier.

4.5.2.2.2 Electrical conductivity

Among 13 pedons, in 5 pedons *viz.*, Kuthanagere-1, 2, 4, 11 and 12 EC was found to be reduced when compared to bench mark survey.

4.5.2.2.3 Organic carbon

In all the surface soils organic carbon had increased over a period of time except in Kuthanagere-4, 6 and 8.

Table 30: Comparison of soil parameter with bench mark survey data (Ap horizon).

Soil series	Coarse fragments	Sand (%)	Silt (%)	Clay (%)	O.C (%)	pH	EC (dsm⁻¹)	CEC (C mol p⁺kg⁻¹)	Base saturation (%)	Exch. Na (C mol p⁺kg⁻¹)
Kuthanagere -1	3.80	1.98	5.89	-7.87	0.17	-0.14	-0.46	-3.20	13.35	0.44
Kuthanagere -2	1.60	-6.29	4.85	1.54	0.16	0.14	-0.02	-0.90	18.96	0.42
Kuthanagere -3	15.40	-10.67	6.75	3.92	0.22	-0.61	0.17	-0.10	23.05	0.62
Kuthanagere -4	14.70	4.62	7.97	-11.89	-0.04	0.83	-0.02	-1.69	17.39	0.30
Kuthanagere -5	-4.30	-4.95	-4.47	9.42	0.21	0.46	0.17	2.30	-5.74	0.50
Kuthanagere -6	9.00	-0.17	-0.04	0.21	-0.33	-0.78	0.02	-1.70	-6.83	0.55
Kuthanagere -7	-17.60	-5.65	1.57	4.09	0.09	-0.36	0.05	-0.10	-0.85	0.42
Kuthanagere -8	5.60	-15.02	-5.10	20.12	-0.08	2.64	0.12	2.70	16.76	0.22
Kuthanagere -9	11.10	-24.89	2.51	22.38	0.46	-0.15	0.05	2.00	-30.19	0.47
Kuthanagere -10	-1.70	9.03	1.65	-10.68	0.07	-0.97	0.07	-4.94	11.57	0.30
Kuthanagere -11	11.50	-4.69	-2.93	7.63	0.08	-1.75	-0.04	1.30	23.30	0.47
Kuthanagere -12	1.50	-11.02	3.00	8.02	0.20	0.22	0.27	3.60	0.26	0.57
Kuthanagere -13	-11.90	-0.56	1.21	0.05	0.13	-1.68	-0.12	1.10	14.51	0.28

Continued...

Soil series	Avail. N (ppm)	Avail. P ₂ O ₅ (ppm)	Exch. K (C mol p ⁺ kg ⁻¹)	Exch. Ca (C mol p ⁺ kg ⁻¹)	Exch. Mg (C mol p ⁺ kg ⁻¹)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)
Kuthanagere -1	-24.39	1.94	0.13	-0.25	-0.99	6.45	2.22	2.08	-6.82
Kuthanagere -2	-20.45	3.75	0.05	0.96	-0.69	2.30	2.78	1.74	-1.88
Kuthanagere -3	-22.64	3.66	-0.73	0.69	-0.26	2.20	2.44	2.01	-0.05
Kuthanagere -4	-12.66	1.51	0.05	-0.07	-0.33	2.80	1.78	1.34	-22.60
Kuthanagere -5	35.75	5.81	0.06	1.74	-0.71	3.40	0.30	-0.62	-11.27
Kuthanagere -6	-8.01	0.68	-0.07	-0.23	-1.05	6.70	2.21	1.90	-17.50
Kuthanagere -7	25.04	2.51	-0.15	0.80	-0.67	5.50	6.74	1.01	-2.00
Kuthanagere -8	2.86	5.29	0.07	3.35	-0.35	3.44	0.50	-0.28	-8.01
Kuthanagere -9	-8.38	2.65	0.11	1.30	-0.25	6.20	3.80	1.84	-18.36
Kuthanagere -10	-16.66	6.50	0.05	1.32	-0.58	9.10	3.14	1.84	-7.50
Kuthanagere -11	11.08	2.81	-0.11	1.85	0.11	24.72	3.80	1.64	-2.20
Kuthanagere -12	-3.96	5.97	-0.01	3.42	-0.44	-0.46	0.18	-0.10	-19.10
Kuthanagere -13	16.90	7.45	-0.11	2.76	-0.63	26.82	2.51	1.23	4.00

4.5.2.2.4 Cation exchange capacity

The CEC of Kuthanagere-5, 8, 9, 11, 12 and 13 was found to be higher compared to bench mark survey report.

4.5.2.2.5 Base saturation

Surface horizons of all the pedons recorded higher base saturation compared to bench mark survey except in Kuthanagere-5 and 9 which was found to be decreased over a period of time.

4.5.2.2.6 Exchangeable bases

Exchangeable sodium showed higher values in surface horizons of all pedons where as exchangeable calcium was found to be low in Kuthanagere-1, 4 and 6. Exchangeable potassium was found to be reduced in Kuthanagere-3, 6, 7, 11, 12 and 13 over a period of time. However, most of the pedons recorded lower values of exchangeable magnesium except Kuthanagere-11.

4.5.2.2.7 Available nitrogen

Majority of pedons recorded lower nitrogen content in the surface soils except in Kuthanagere-5, 7, 8, 11 and 13 which resulted in higher values compared to benchmark survey report.

4.5.2.2.8 Available phosphorus

Surface soils of all the pedons showed increased phosphorus content when compared to benchmark survey report.

4.5.2.2.9 Micronutrient

Among micronutrient (Fe, Cu, Zn and Mn), Cu was found to be increased in all the pedons whereas, Fe was found to be increased on all the pedon Kuthanagere-12. Zn content was reduced in Kuthanagere-5, 8 and 12 soils however, surface soils of all the pedons showed reduced Mn content except Kuthanagere-12.

4.5.3 Depth

Improvement in soil depth due to soil conservation activities in watershed was found conspicuous in all soil series. The overall increase in depth across all soil series is from 93cms (1995) to 99 cms (2012) (Table 31).

Kuthanagere-1 had a soil depth of 106 cms during benchmark survey and showed an improvement to 125cms after a gap of around 20 years. Similarly the increase in soil depth in Kuthanagere-4 was from 68 to 133 cms, Kuthanagere-5 was from 28 to 51 cms, Kuthanagere-6 was from 79 to 118 cms, Kuthanagere-8 was from 93 to 115 cms, Kuthanagere-9 was from 150 to 151 cms, Kuthanagere-10 was from 102 to 120 cms, Kuthanagere-12 was from 77 to 88 cms and Kuthanagere-13 was from 13 to 30 cms. However depth was found to be decreased in Kuthanagere-2 from 155 to 138cms, Kuthanagere-3 was from 140 to 125cms and Kuthanagere-7 was from 90 to 80 cms whereas depth of Kuthanagere-11 soil series remained unchanged over a period of time with 150 cms.

The highest increase in depth was 130 per cent in Kuthanagere-13 soil series, whereas the lowest improvement was observed in Kuthanagere-7 soil series (11 per cent).

Table 31: Comparison of soil depth with benchmark survey of Kuthanagere watershed

Sl. No.	Soil series	1995		2012	
		Horizon	Depth (cm)	Horizon	Depth (cm)
1.	Kuthanagere -1	Ap	0-15	Ap	0-12
		Bt ₁	15-43	Bt ₁	12-46
		Bt ₂	43-74	Bt ₂	46-78
		Bt ₃	74-106	Bt ₃	78-125
		C	106-110 ⁺		
2.	Kuthanagere -2	Ap	0-12	Ap	0-12
		Bt ₁	12-40	Bt ₁	12-46
		Bt ₂	40-60	Bt ₂	46-71
		Bt ₃	60-113	Bt ₃	71-98
		BC	113-155	Bt ₄	98-122
		C	155 ⁺	Bc	122-138
3.	Kuthanagere -3	Ap	0-12	Ap	0-14
		Bt ₁	12-31	Bt ₁	14-49
		Bt ₂	31-72	Bt ₂	49-88
		Bt ₃	72-105	Bc	88-125
		Bt ₄	105-125		
		BC	125-140 ⁺		
4.	Kuthanagere -4	Ap	0-10	Ap	0-11
		B	10-30	Bt ₁	11-31
		B	30-50	Bt ₂	31-54
		BC	50-65	Bt ₃	54-76
		R	65 ⁺	Bt ₄	76-104
				Bt ₅	104-133
5.	Kuthanagere -5	A	0-10	A	0-14
		Bw	10-28	Bt ₁	14-33
		Cr	28-51	Bt ₂	33-51
6.	Kuthanagere -6	Ap	0-12	AP	0-22
		Bt ₁	12-34	Bt ₁	22-55
		Bt ₂	34-60	Bt ₂	55-89
		BC	60-79	Bc	89-118
		C	79-110 ⁺		
7.	Kuthanagere -7	Ap	0-10	Ap	0-17
		B	10-26	Bt ₁	17-45
		B	26-46	Bt ₂	45-80
		B	46-90	Cb	80-112
		C	90-100 ⁺		

8.	Kuthanagere -8	Ap	0-43	Ap	0-18
		AC1	14-38	Bw ₁	18-34
		AC2	38-56	Bw ₂	34-62
		AC3	56-80	Bw ₃	62-102
		AC4	80-93	Bw ₄	102-115
		C	93-120		
9.	Kuthanagere -9	Ap	0-9	Ap	0-11
		B	9-18	Bt ₁	11-45
		B	18-84	Bt ₂	45-81
		B	84-129	Bt ₃	81-108
		BC	129-150 ⁺	Bt ₄	108-128
				Bt ₅	128-151
10.	Kuthanagere -10	Ap	0-10	Ap	0-10
		Bt ₁	10-38	Bt ₁	10-34
		Bt ₂	38-68	Bt ₂	34-56
		BC	68-102	Bt ₃	56-90
		C	102-130	Bc	90-120
11.	Kuthanagere -11	Ap	0-13	Ap	0-16
		Bw	13-32	Bt ₁	16-42
		Bw ₂	32-56	Bt ₂	42-71
		Bw ₃	56-76	Bt ₃	71-115
		Bw ₄	76-92	Bt ₄	115-129
		Bw ₅	92-150 ⁺	Bt ₅	129-150
12.	Kuthanagere -12	Ap	0-16	Ap	0-18
		A13	16-35	Bw ₁	18-41
		Bw	35-50	Bw ₂	41-65
		BC	50-77	Bw ₃	65-88
		C	77 ⁺	Cb	88-101
13.	Kuthanagere -13	Ap	0-13	Ap	0-12
		C	13-43 ⁺	Bw	12-30

Discussion

V. DISCUSSION

The results of the experiment undertaken to study the long term effect of watershed development on changes in soil properties of Alfisols and productivity of finger millet in Kuthanagere of Ramanagar district, Karnataka are discussed in this chapter.

The growth of the plant is the net result of the interplay of diverse metabolic activities taking place in different parts of the plant during its growth and development in accordance with the supply of light, water, temperature and nutrients from the environment. The plant leaves powered by sunlight, convert simple compounds *viz*: carbon dioxide and water into carbohydrates and other compounds that are required for growth. The synthesis, accumulation and translocation of these metabolites to the economic part of the plant are often influenced by environmental condition. The production of economic yield of crop is outcome of many complicated and yet related physiological, morphological and biochemical events taking place at different plant parts. These complicated events are inturn, based on environment under which the crop is growing. The agronomic practice can modify the environment to certain extent and thereby help the crop to exploit the available resources efficiently to achieve higher productivity. Thus maximum yields are obtained when optimum conditions are provided for crop. Nutrient requirement of the crop vary due to their production potential and ability to mine nutrients from native sources. Nutrient supplying capacity of soil plays a crucial role in deciding the productivity per unit area. The present study was undertaken to determine the suitability of different soil series for productivity of finger millet. The results of the experiment are discussed in this chapter using the pooled mean.

5.1 Performance of finger millet on different soil series

In the present study, the different soil series exerted significant influence on grain yield of finger millet. The highest grain yield of finger millet was obtained in Kuthanagere-1 which was found to be on par with Kuthanagere-3 soil series, both differed significantly compared to other soil series (Table-16). Kuthanagere-1 recorded 67.3, 62.2 and 59.3 per cent higher grain yield over Kuthanagere-4, Kuthanagere-9 and Kuthanagere-11 soil series, respectively (Fig. 12). The higher grain yield in Kuthanagere-

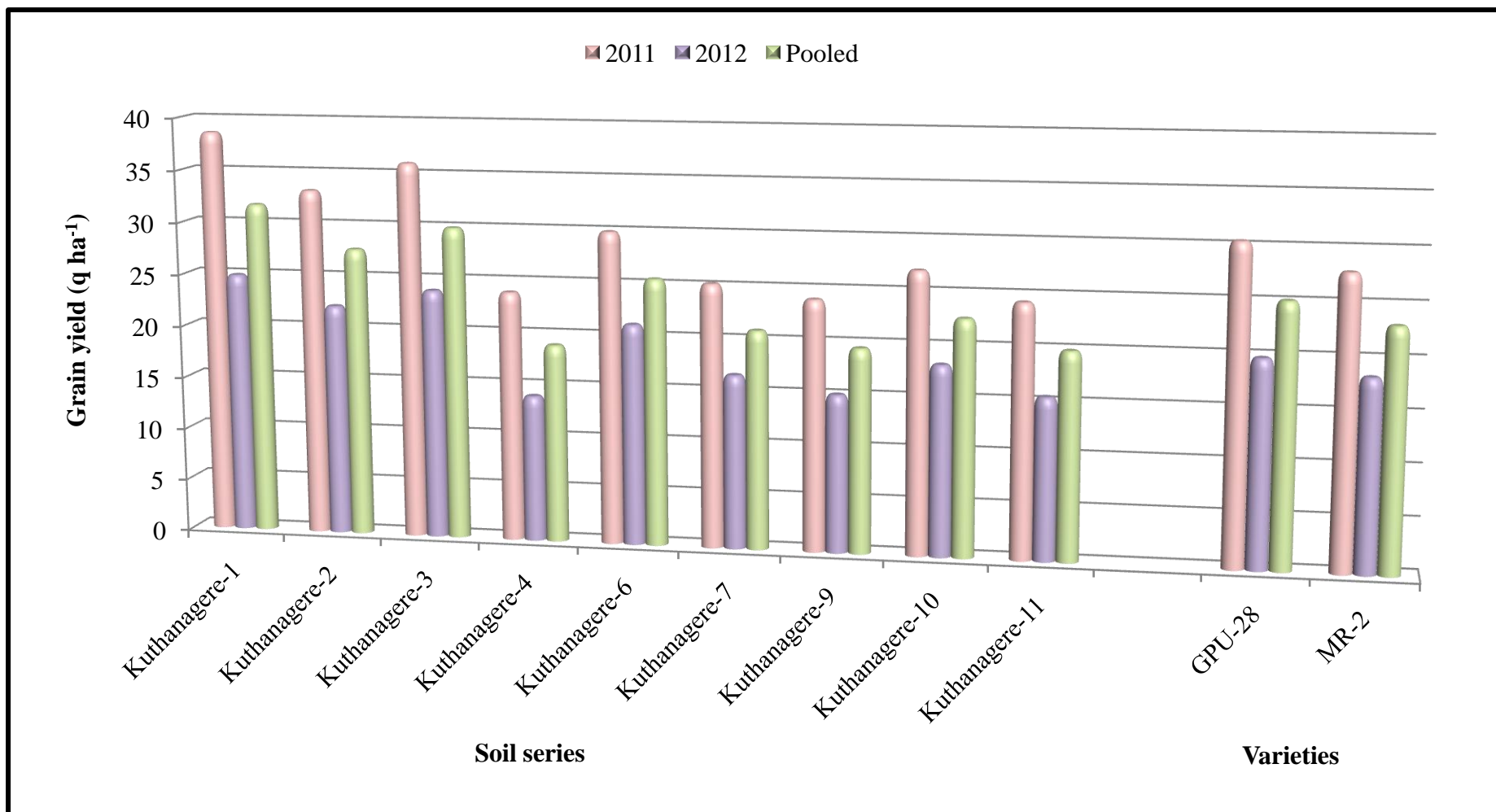


Fig. 12 Grain yield (q ha⁻¹) of finger millet as influenced by different soil series and varieties at Kuthanagere watershed

1 soil series was mainly due to higher growth attributing characters like, higher number of leaves, more number of tillers and higher dry matter production and its accumulation into different parts of plant and higher yield attributing characters like number of fingers (Fig. 14) and number of effective tillers (Fig. 15). The higher productivity of Kuthanagere-1, Kuthanagere-2 and Kuthanagere-3 soil series for finger millet was also observed earlier by Krishnappa *et al.*, (2004).

The reduction in grain yield of finger millet in Kuthanagere-4 could be traced back to significant reduction in yield attributes like number of finger per ear head and number of effective tillers per plant as compared to other soil series. Significantly higher grain yield in Kuthanagere-1 soil series was attributed to higher number of effective tillers per plant (2.82) at harvest of crop and more number of fingers per ear head (5.46) (Table-15). Significant positive correlation was noticed between grain yield and number of fingers ($r=0.54^{**}$) and number of effective tillers per plant ($r=0.72^{**}$) (Table 25).

The straw yield of finger millet differed significantly due to different soil series of Kuthanagere (Table-16). The straw yield of finger millet grown in Kuthanagere-1 was significantly higher (4.77 t ha^{-1}) compared to straw yield obtained in other soil except in Kuthanagere-3 (4.60 t ha^{-1}). The increase in straw yield of finger millet was mainly attributed to significantly higher plant height, number of leaves and dry matter production and its accumulation in leaves and stem (Fig 13).

The grain yield is an end product which obviously depends on dry matter production at different stages of crop growth and its partitioning into stem, leaves and reproductive parts. High positive correlation was observed between grain yield and total dry matter production ($r=0.79^{**}$) and its accumulation in stem ($r=0.81^{**}$), leaves ($r=0.78^{**}$) and ear head ($r=0.76^{**}$). In the present study, dry matter production differed significantly with different soil series of Kuthanagere at all the crop growth stages (Fig. 16). The dry matter produced by finger millet in Kuthanagere-1 soil series was significantly higher compared to all other soil series except Kuthanagere-2 which was found to be on par with each other (Table-13). The higher dry matter production in Kuthanagere-1 was attributed to higher dry matter accumulation in leaves, stem and ear head as compared to other soil series. Significant positive correlation was observed

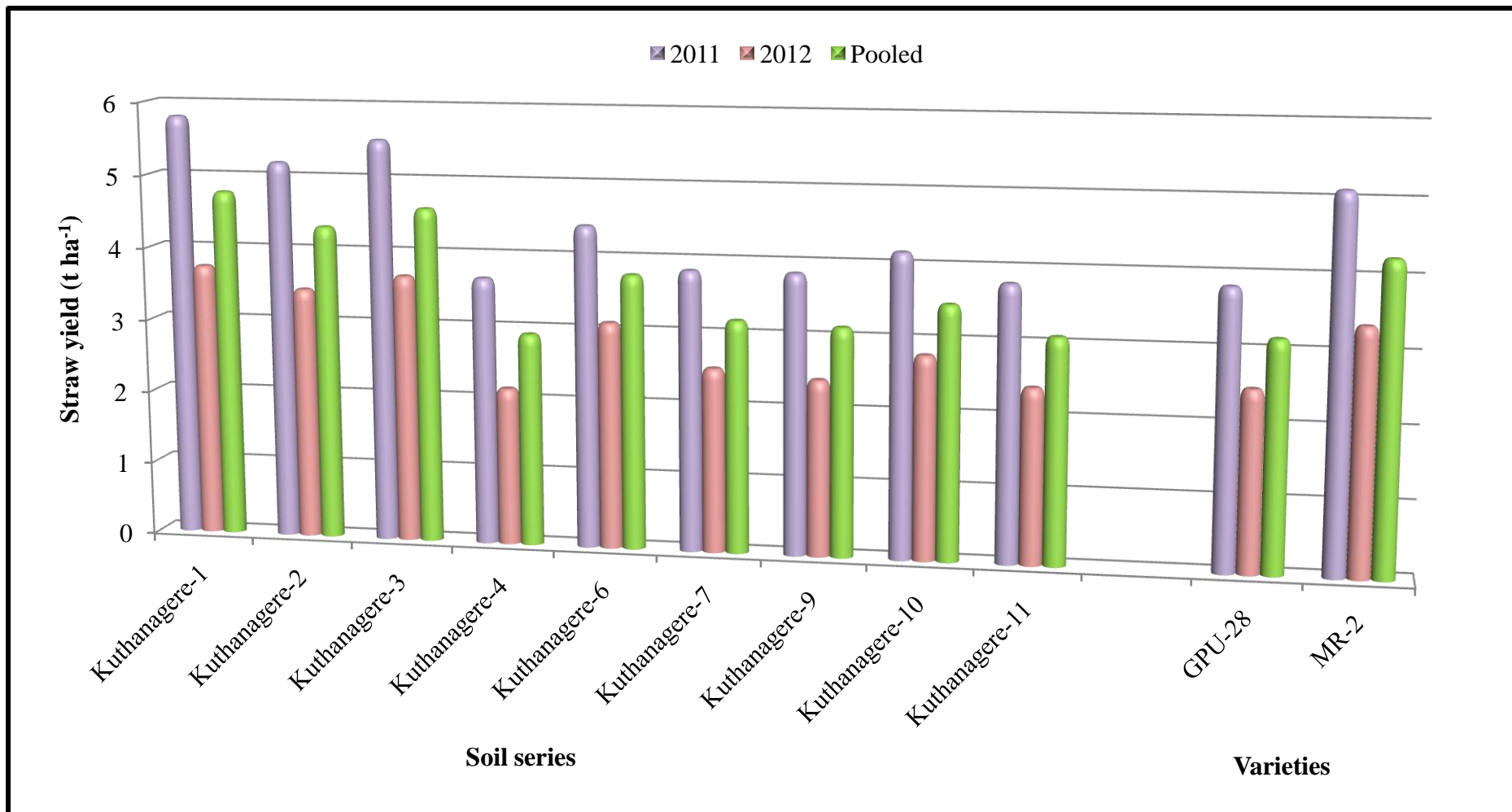


Fig. 13 Straw yield (t ha⁻¹) of finger millet as influenced by different soil series and varieties at Kuthanagere watershed

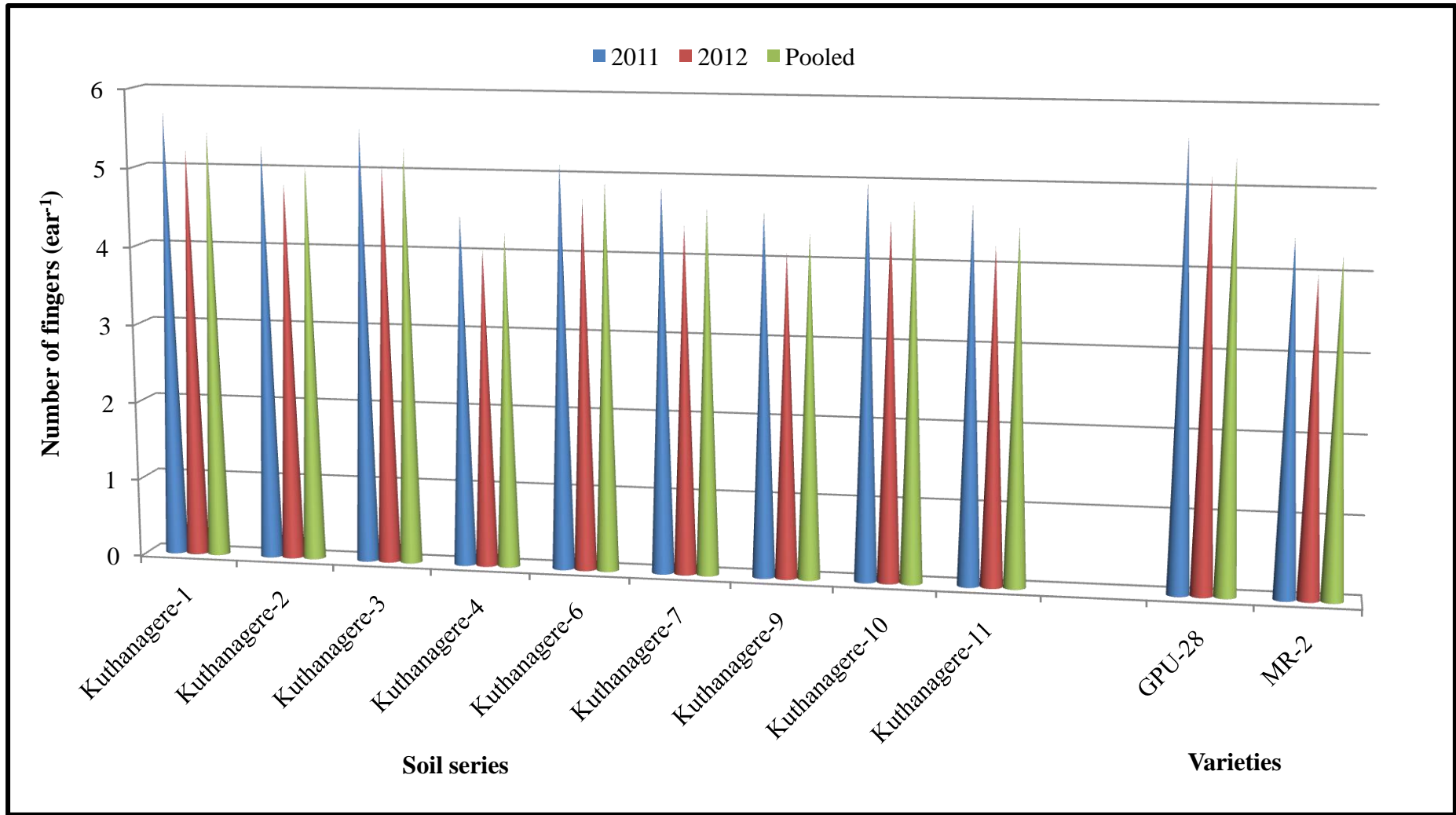


Fig. 14 Number of fingers per ear head of finger millet as influenced by different soil series and varieties at Kuthanagere watershed

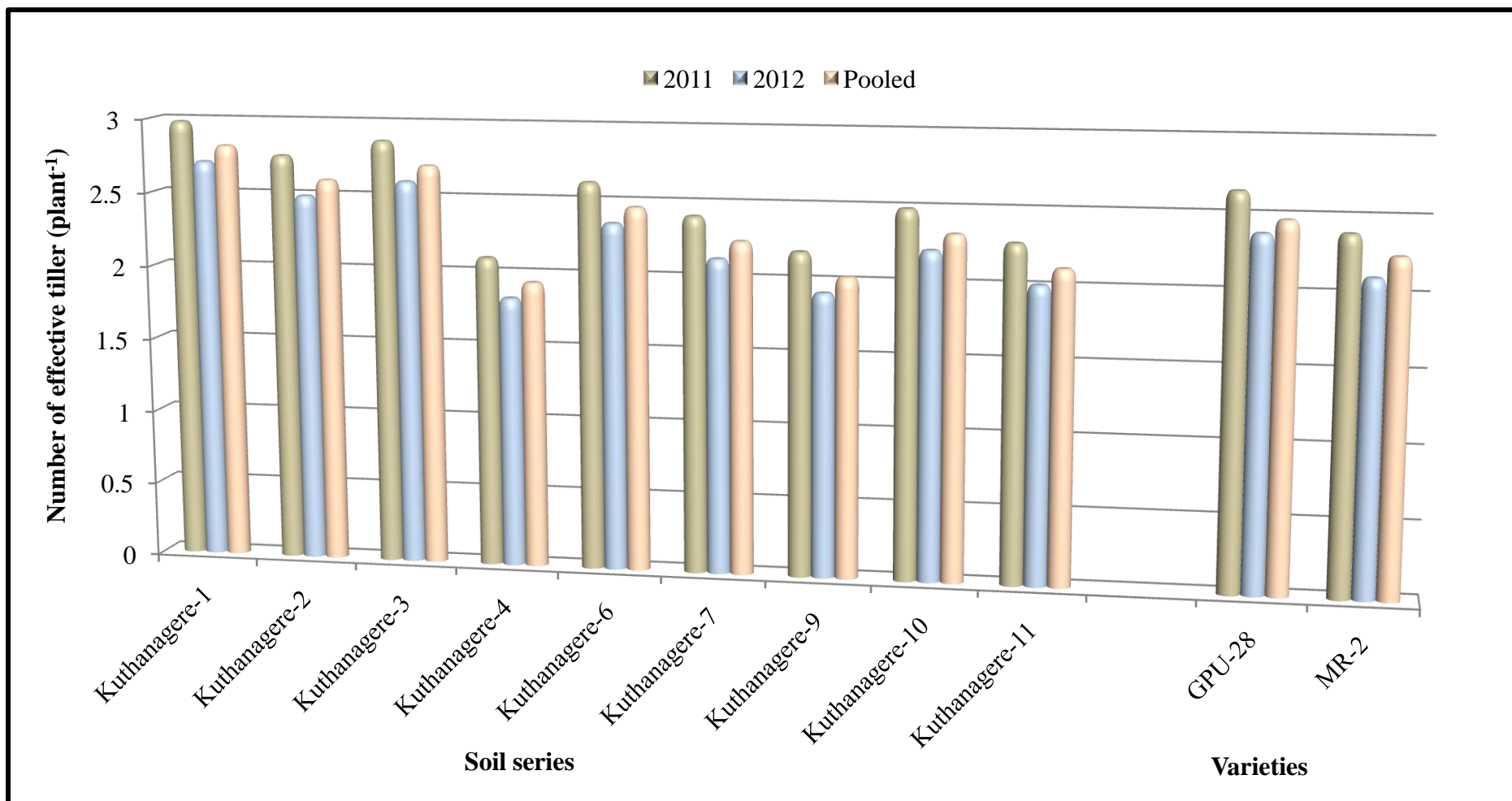


Fig. 15 Number of effective tillers per plant at harvest of finger millet as influenced by different soil series and varieties at Kuthanagere watershed

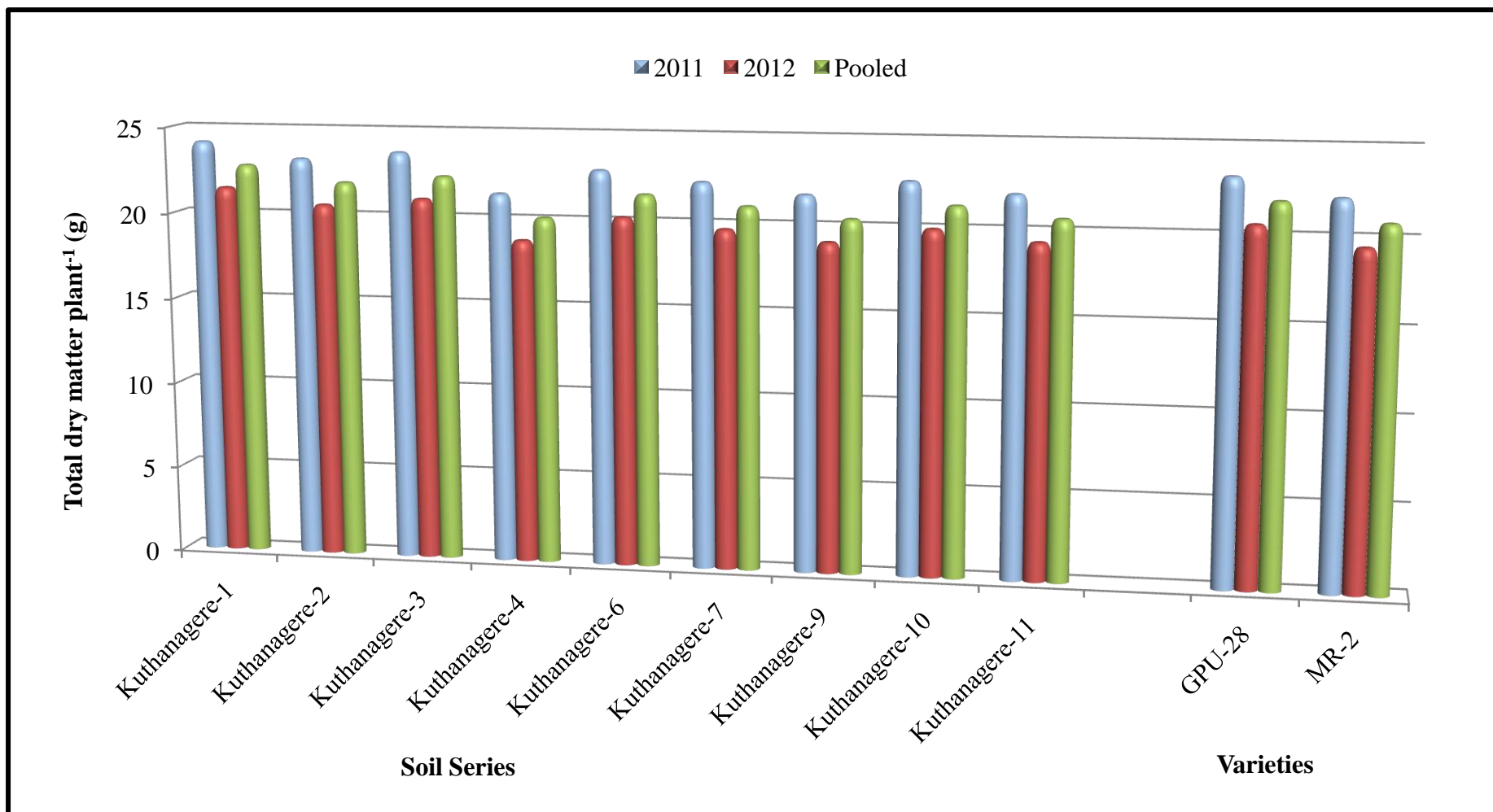


Fig. 16 Total dry matter production per plant at harvest of finger millet as influenced by different soil series and varieties at Kuthanagere watershed

between grain yield of finger millet and growth parameters viz., plant height ($r=0.49^{**}$), number of leaves ($r=0.66^{**}$) and number of tillers ($r=0.83^{**}$) (Table 25).

5.2 Influence of growth and yield parameters on yield of finger millet

The growth and yield parameter viz., plant height, number of leaves, number of tillers, total dry matter production and its distribution to stem, leaves and ear head, test weight, finger length, number of fingers and effective tillers had positive correlation with grain yield of finger millet.

Plant height ($Y=-36.34+1.03X-0.003X^2$, $r=0.50^{**}$, Fig. 23), number of leaves ($Y=-23.18+9.22X-0.36X^2$, $r=0.67^{**}$, Fig. 24) and number of tillers ($Y=13.29-6.85X+3.41X^2$, $r=0.84^{**}$, Fig. 25) were being positively correlated with grain yield, the relationship was quadratic in nature. Total dry matter production ($Y=-26.57+1.73X+0.03X^2$, $r=0.79^{**}$, Fig. 19) and its distribution to stem ($Y=14.90-7.64X+1.55X^2$, $r=0.81^{**}$, Fig. 20), leaves ($Y=-3.36+2.36+2.01X^2$, $r=0.78^{**}$, Fig. 21) and ear head ($Y=-4.04-0.69X+0.24X^2$, $r=0.76^{**}$, Fig. 22) was found to have high positive correlation with grain yield and had linear relationship.

Among yield parameters, effective tillers had high positive correlation ($Y=10.55-1.96x+3.17X^2$, $r=0.72^{**}$, Fig. 18), whereas test weight ($Y=-14.57+12.78X-0.06X^2$, $r=0.55^{**}$), number of fingers ($Y=18.72-2.23X+0.67X^2$, $r=0.55^{**}$, Fig. 17) had moderate positive correlation and finger length ($Y=73.64-15.84X+1.19X^2$, $r=0.38^{**}$) had low positive correlation with grain yield.

Instead of looking at their individual effects the overall interaction of growth and yield parameters on grain yield seemed to be appropriate and hence 11 multi linear regression equations were worked out (Table 26). The significant R^2 value of these MLR equations ranged from 0.8699 in Model I to 0.6860 in Model XI where eleven parameters were regressed involving only number of tillers. Among these 11 models the better models as per the set out criteria were found to be Model III ($R^2=0.8574^{**}$) and Model IV ($R^2=0.8573^{**}$). However, one can use any of these models for judging the influence of growth and yield parameters on yield of finger millet but bearing the risk of associated standard error.

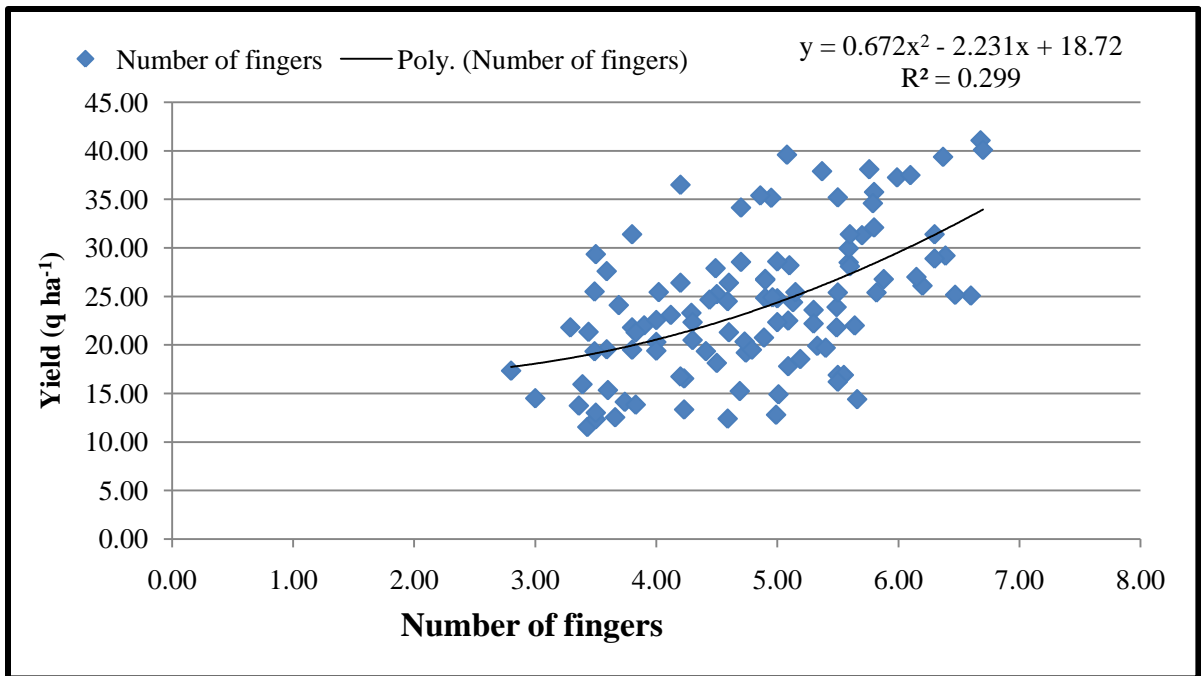


Fig. 17: Regression equation between number of fingers per ear and grain yield of finger millet

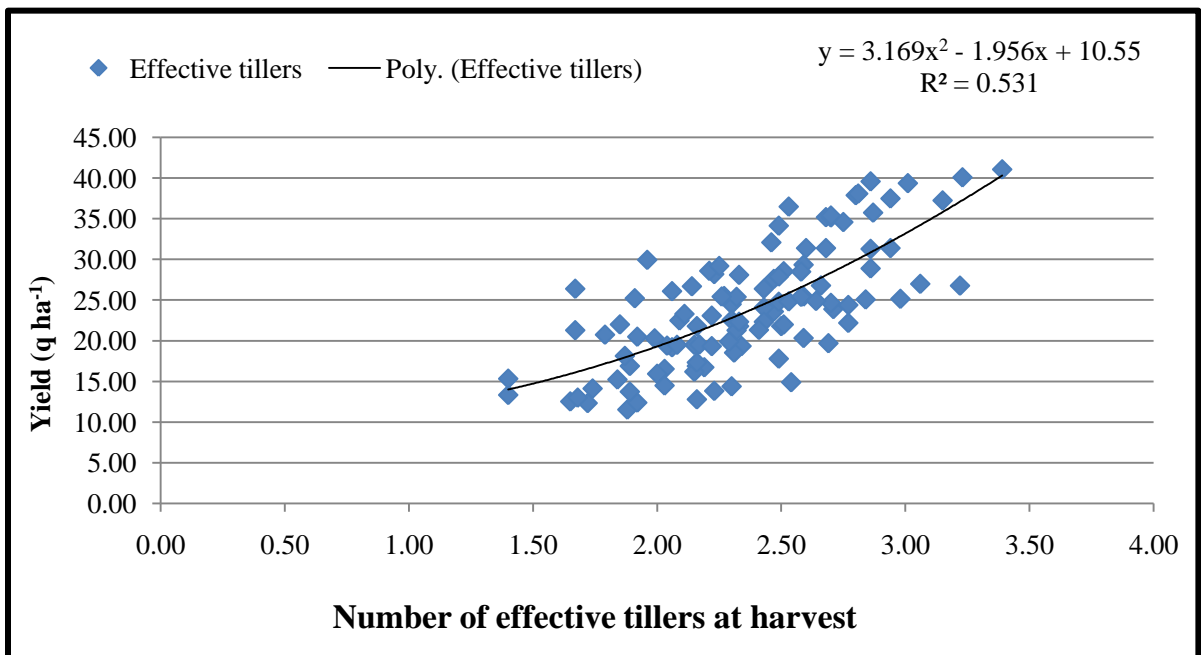


Fig. 18: Regression equation between number of effective tillers at harvest and grain yield of finger millet

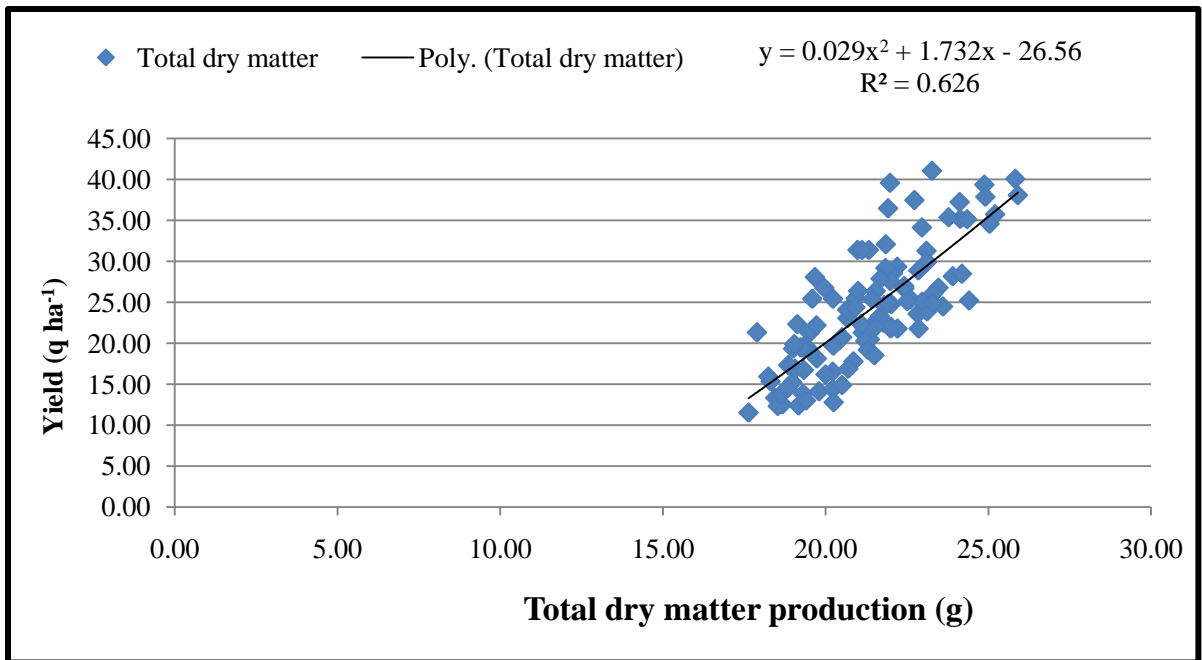


Fig. 19: Regression equation between total dry matter production and grain yield of finger millet

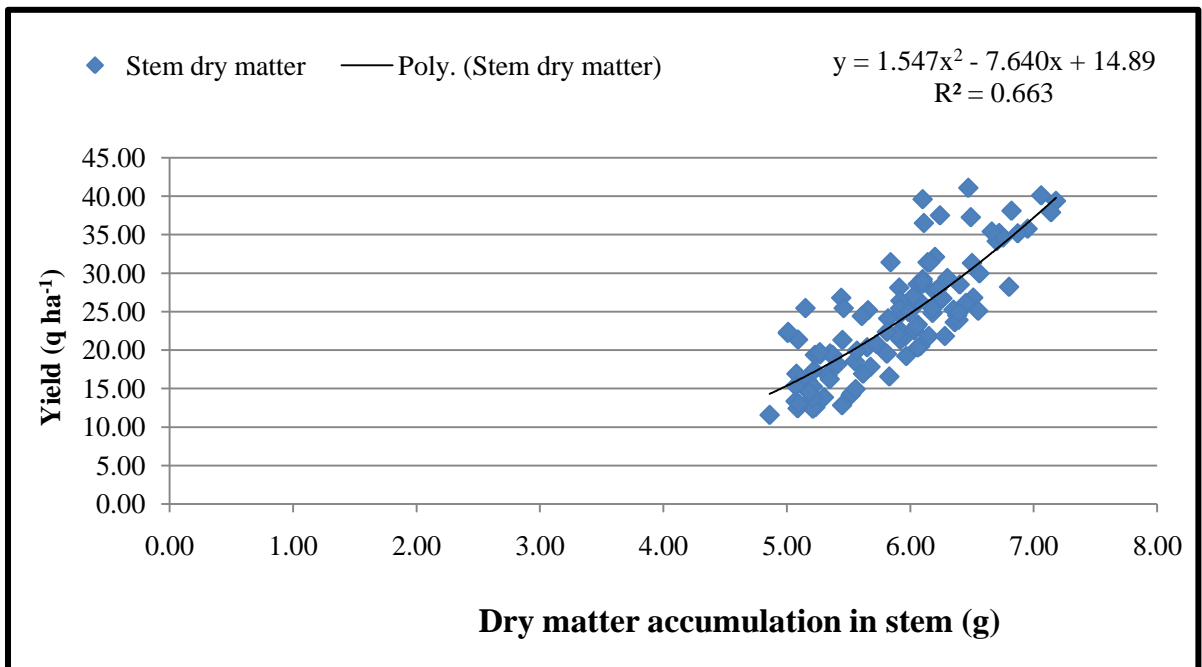


Fig. 20: Regression equation between dry matter accumulation in stem and grain yield of finger millet

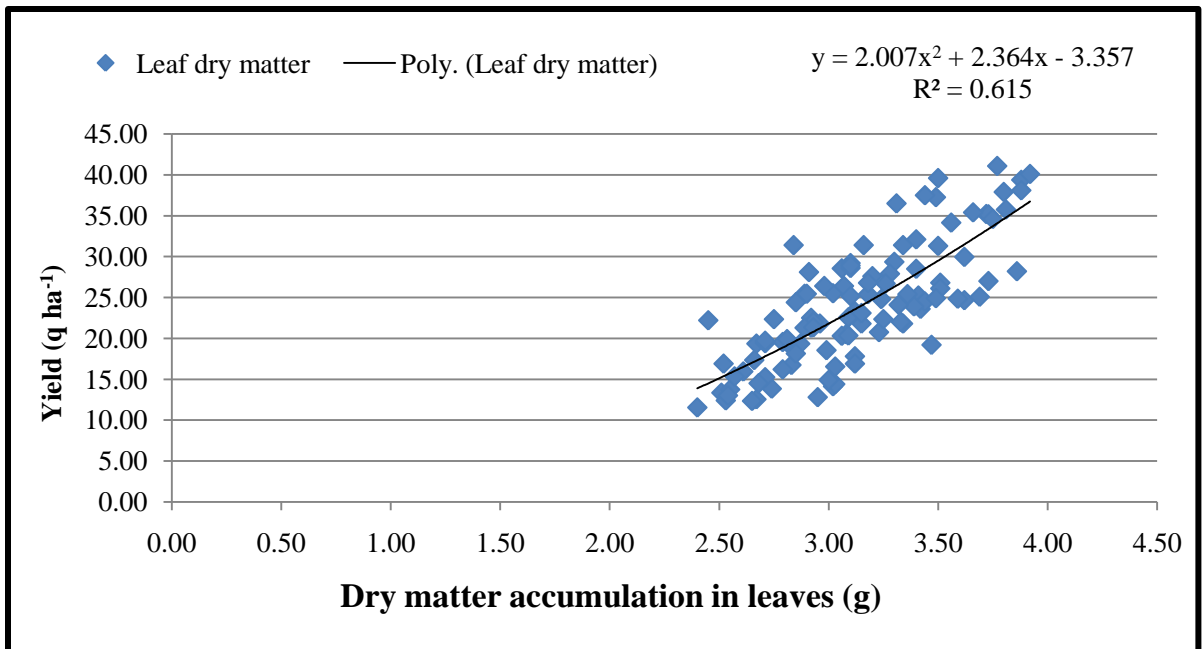


Fig. 21: Regression equation between dry matter accumulation in leaves and grain yield of finger millet

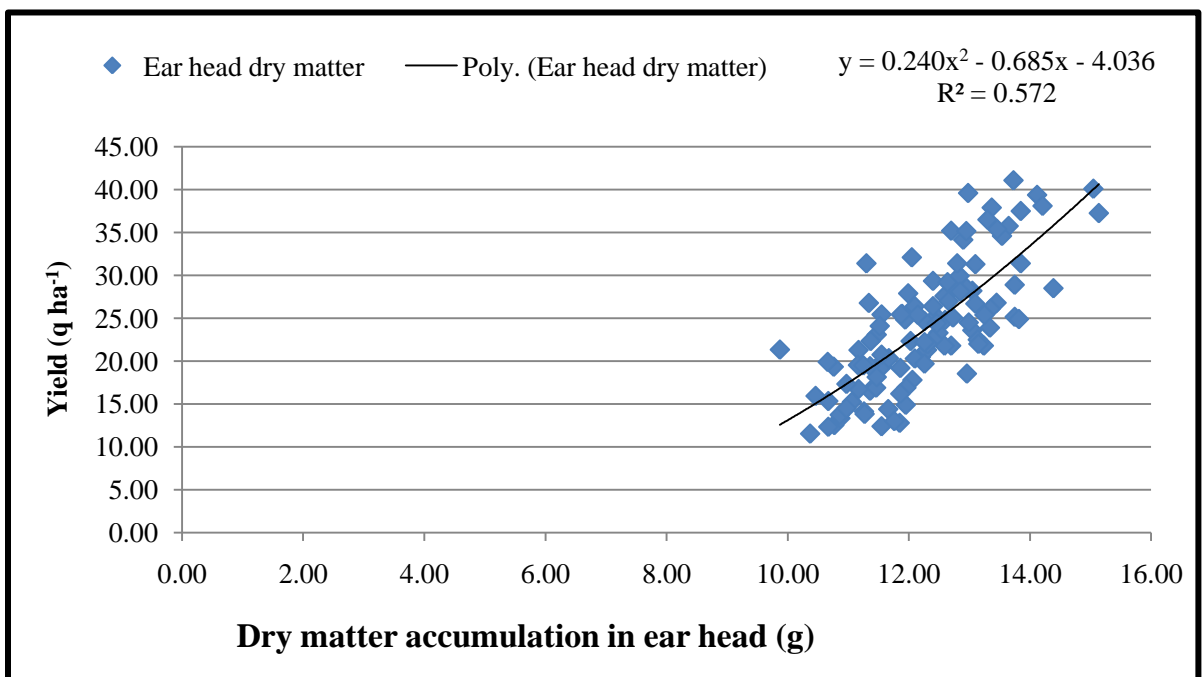


Fig. 22: Regression equation between dry matter accumulation in ear head and grain yield of finger millet

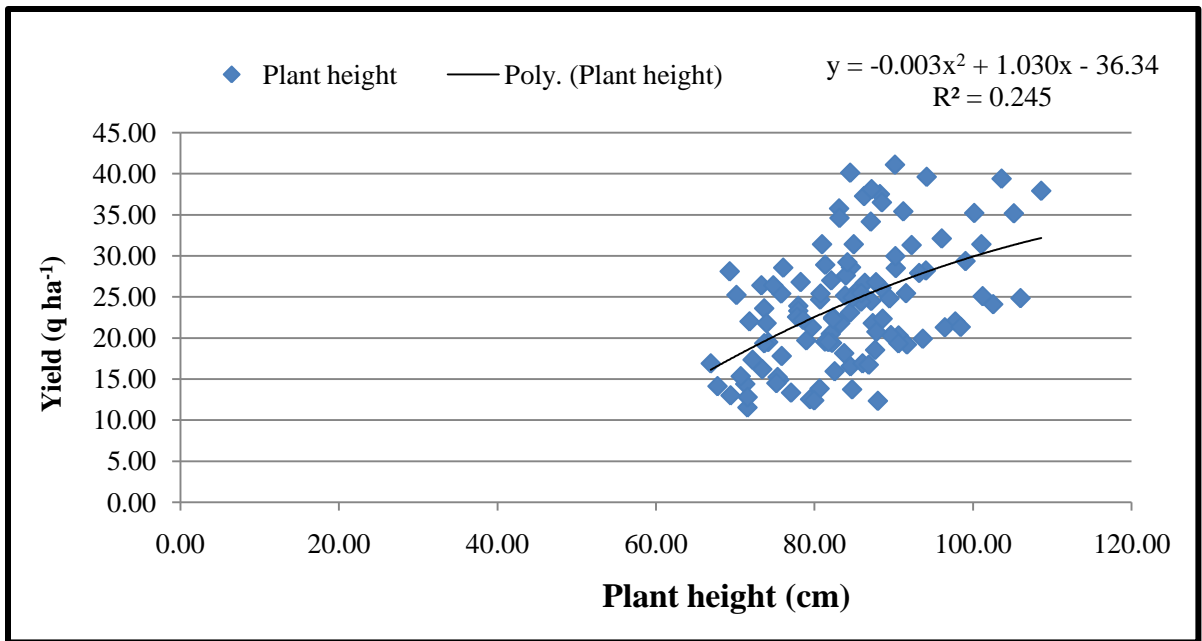


Fig. 23: Regression equation between plant height and grain yield of finger millet

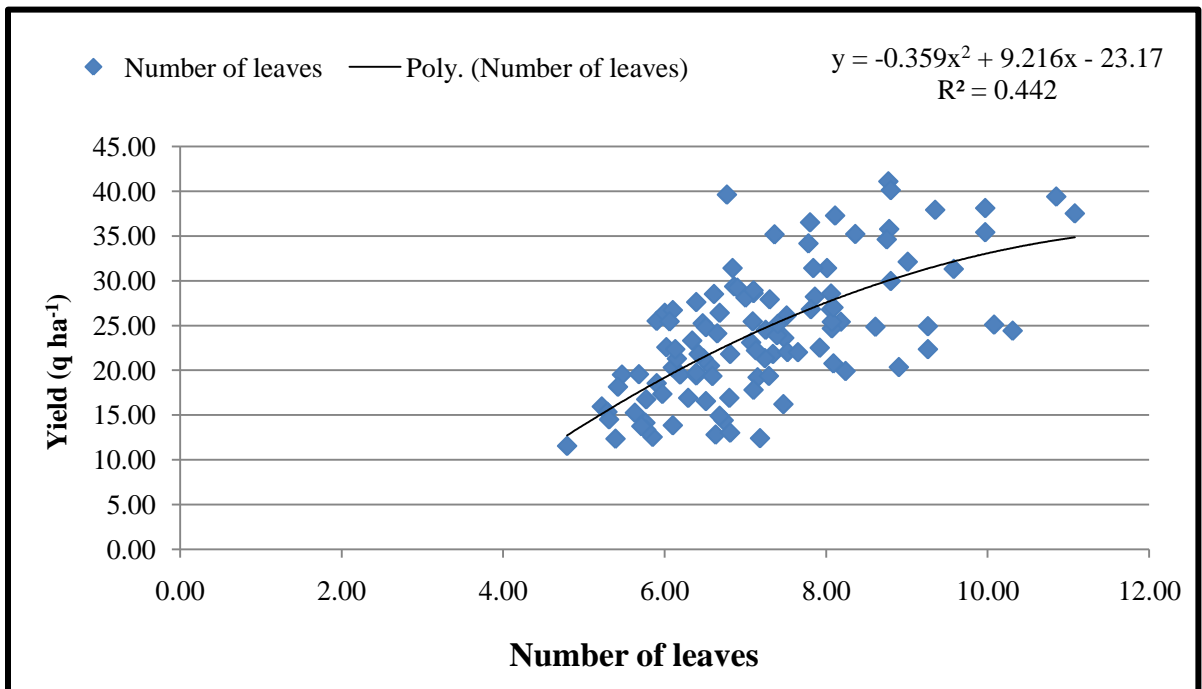


Fig. 24: Regression equation between number of leaves and grain yield of finger millet

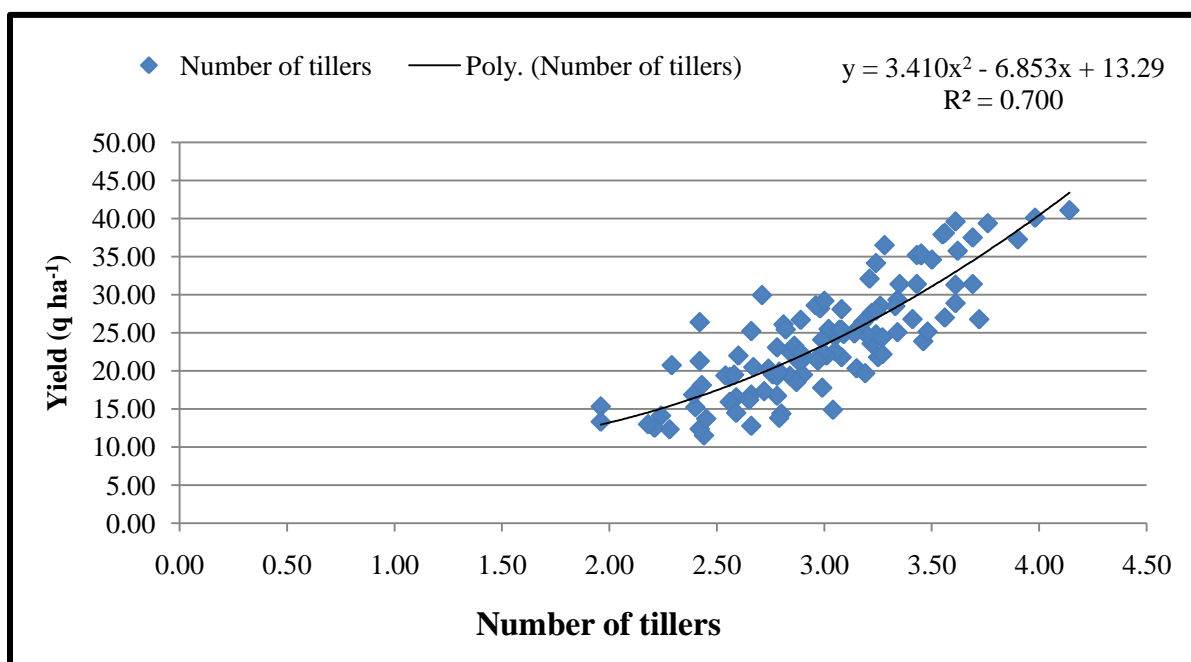


Fig. 25: Regression equation between number of tillers and grain yield of finger millet

5.3 Suitability of finger millet varieties for different soil series of Kuthanagere

Finger millet has many advantages for cultivation due to its resistance to drought and heat. It has great potential of developing to an excellent food and fodder crop provided that attention is given to introduction of improved varieties and appropriate production technology to increase yield per unit area. The potential advantage of finger millet is that, it can be sown upto first fortnight of August and hence may produce satisfactory grain yield with good fodder. Keeping in view importance of finger millet, the present investigation was conducted with two varieties to understand what farmers need the most in varieties of finger millet.

Result of the present investigation revealed that, GPU-28 recorded significantly higher grain yield (25.11 q ha^{-1}) compared to MR-2 (23.09 q ha^{-1}). The higher yield of GPU-28 was mainly due to the higher values of yield components. Ashoka (1996) and Krishnamurthy (1996) opined that pre-release genotype GPU-26 recorded significantly highest grain yield compared to other pre-releasing genotypes due to higher value of growth and yield components.

The yielding ability of crop is the reflection of yield attributing characters. The higher grain yield of GPU-28 was mainly due to significantly higher yield attributes like 1000 grain weight (Subramanian, 1980) and number of fingers (Table-14 & 15).

1000 grain weight is another important yield attribute which differed significantly among varieties. GPU-28 recorded significantly higher 1000 grain weight (3.40 g) compared to MR-2 (3.08 g). The higher yield in GPU-28 was also due to more number of effective tillers per plant (2.47) compared to MR-2 (2.25). These result are in accordance with the findings of Krishnamurthy (1971) who reported high yield of Annapurna variety due to more number of tillers.

Among the two varieties significantly higher straw yield of finger millet was recorded in MR-2 (4.24 t ha^{-1}) compared to that in GPU-28 (3.16 t ha^{-1}). Growth parameters had significant influence on the grain yield of finger millet. Number of leaves, number of tillers, dry matter production and its distribution into stem, leaves and ear head was significantly superior in GPU-28 compared to MR-2. The higher dry matter production and its distribution to stem, leaves and ear head in GPU-28 is mainly

attributed to more number of leaves and higher number of tiller. Puttaswamy (1973) reported varietal difference in dry matter production and its distribution to various plant parts in finger millet.

5.4 Resource inventory of Kuthanagere watershed

Rational utilization of our “finite” soil resources for sustained productivity needs information on nature and extent of distribution of different kind of soils of an area, problems, potentials, capabilities and their suitability for various uses. All the information could be available through systemic characterization and classification of an area. Hence, in the present study 13 representative pedons (Plate 1 to Plate 12) were selected in the watershed of Kuthanagere, Magadi taluk, Ramanagar district of Karnataka covering different physiographic units. With the help of toposheet, water bodies and drainage lines were identified. The spillway of water body was fixed and traversing was done from right side of this point. While traversing elevated places or originating points of first order drainage lines were marked and finally after traversing round about reached back to the starting point. The line drawn touching all the elevated places was considered as boundary line. After the boundary line marking all the information’s was extracted from the toposheet and base map of Kuthanagere watershed was developed (Fig 26). Pedons were examined systematically for morphological features in the field. Horizon wise samples were analyzed in the laboratory for physical, physico-chemical and also nutrient status of surface samples. Further, the suitability of these soils was evaluated for growing finger millet.

5.4.1 Morphological features

5.4.1.1 Depth

The soils of the study area were shallow (Kuthanagere-13) to very deep (Kuthanagere-9). The depth (Fig. 27) of upland pedons (Kuthanagere-1, 2, 3, 4, and 7) was comparatively less than that of the midland (Kuthanagere-9) and lowland pedon (Kuthanagere-11). The depth of pedon is manifestation of topography. Similar observations were also made by Singh and Mishra (1996).

The variation in depth in relation to physiography was mainly because of non availability of adequate amount of water for prolonged period on upland soils associated

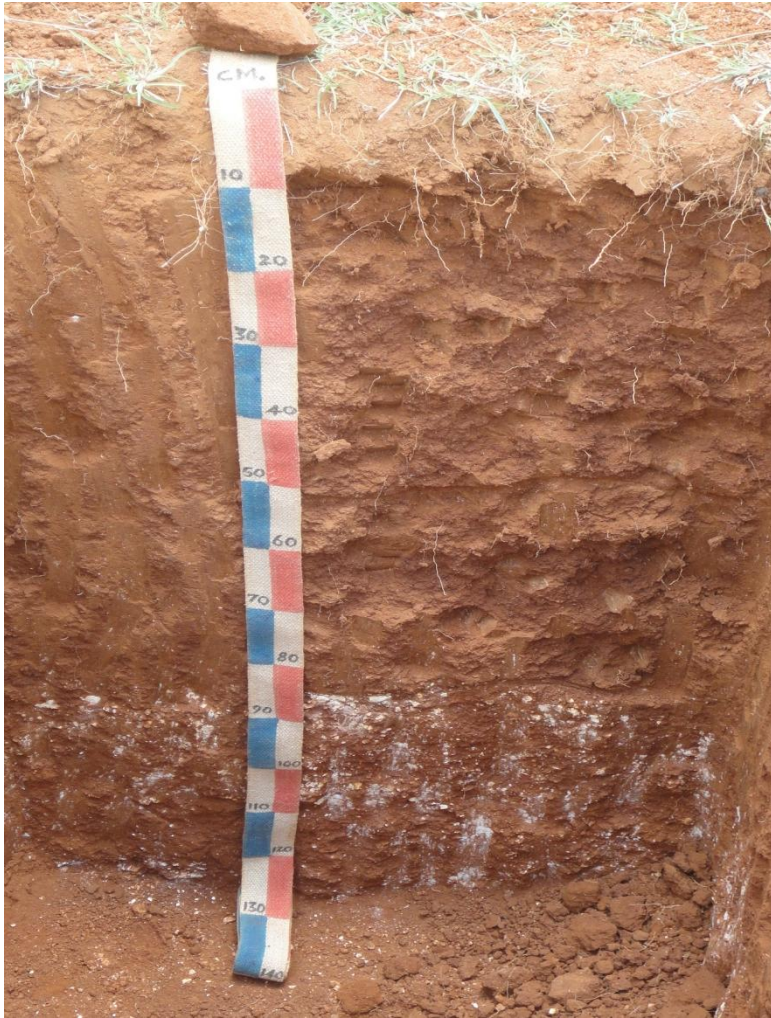


Plate 1. Kuthanagere-1 (Pedon-8)



Plate 2. Kuthanagere-2 (Pedon-21)



Plate 3. Kuthanagere-3 (Pedon-4)



Plate 4. Kuthanagere-4 (Pedon-19)



Plate 5. Kuthanagere-5 (Pedon-41)



Plate 6. Kuthanagere-6 (Pedon-3)



Plate 7. Kuthanagere-7 (Pedon-13)



Plate 8. Kuthanagere-8 (Pedon-R6)



Plate 9. Kuthanagere-9 (Pedon-R5)

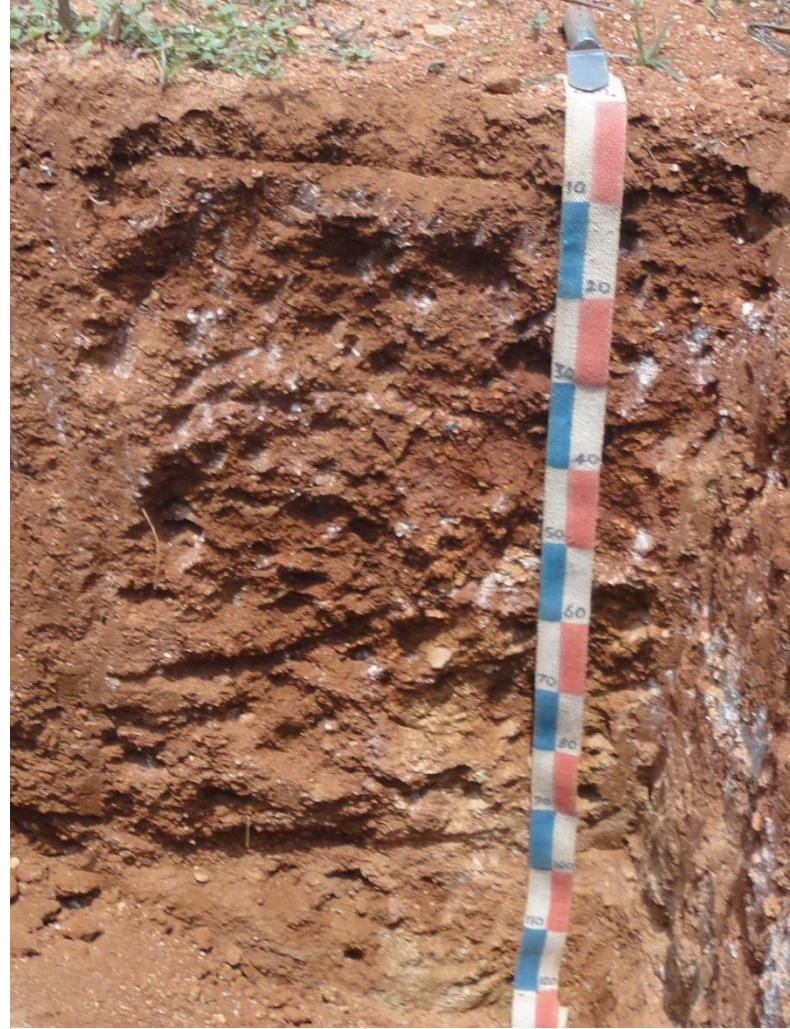


Plate 10. Kuthanagere-10 (Pedon-23)



Plate 11. Kuthanagere-12 (Pedon-20)



Plate 12. Kuthanagere-13 (Pedon-R9)

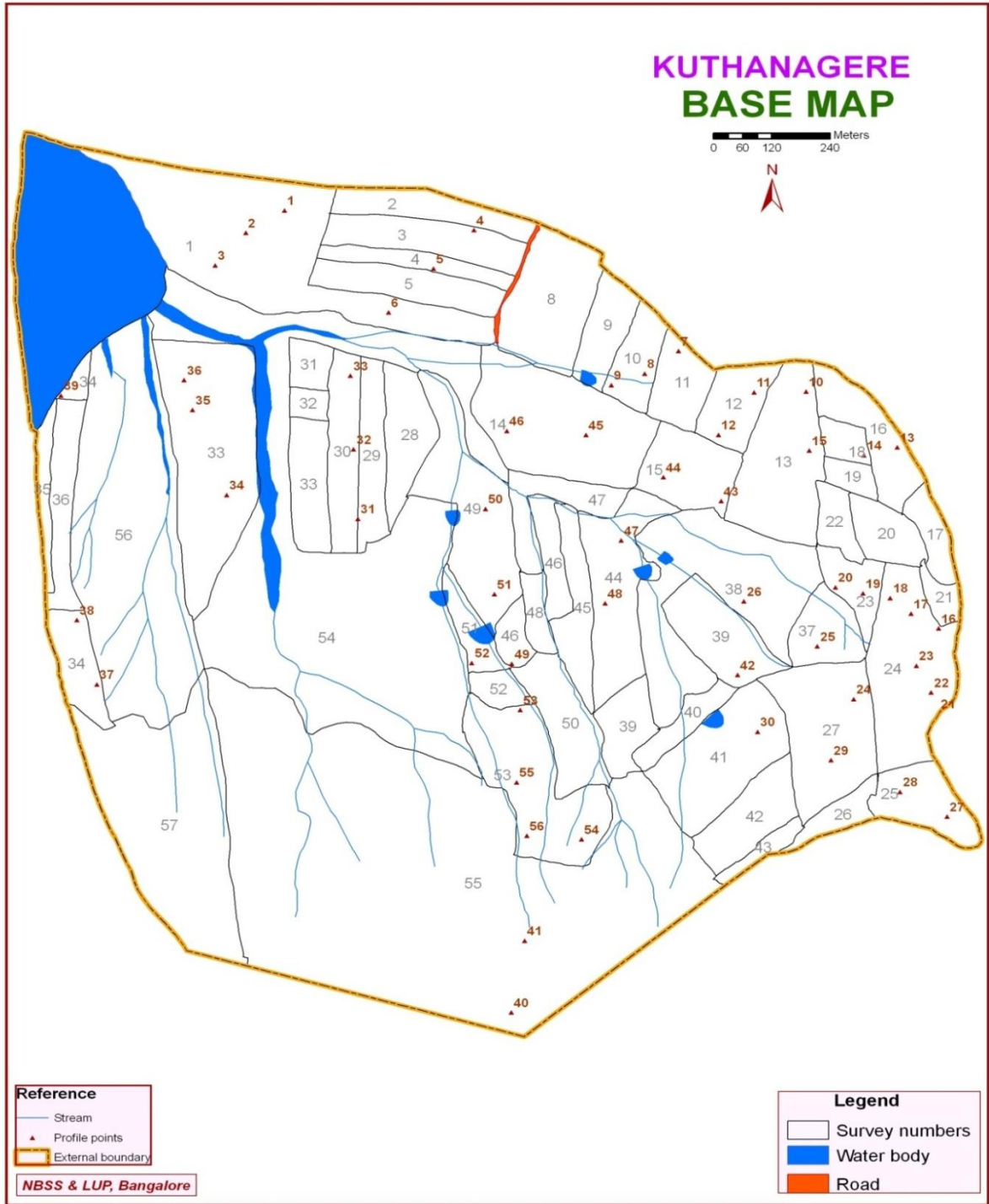


Fig. 26: Base map of Kuthanagere watershed

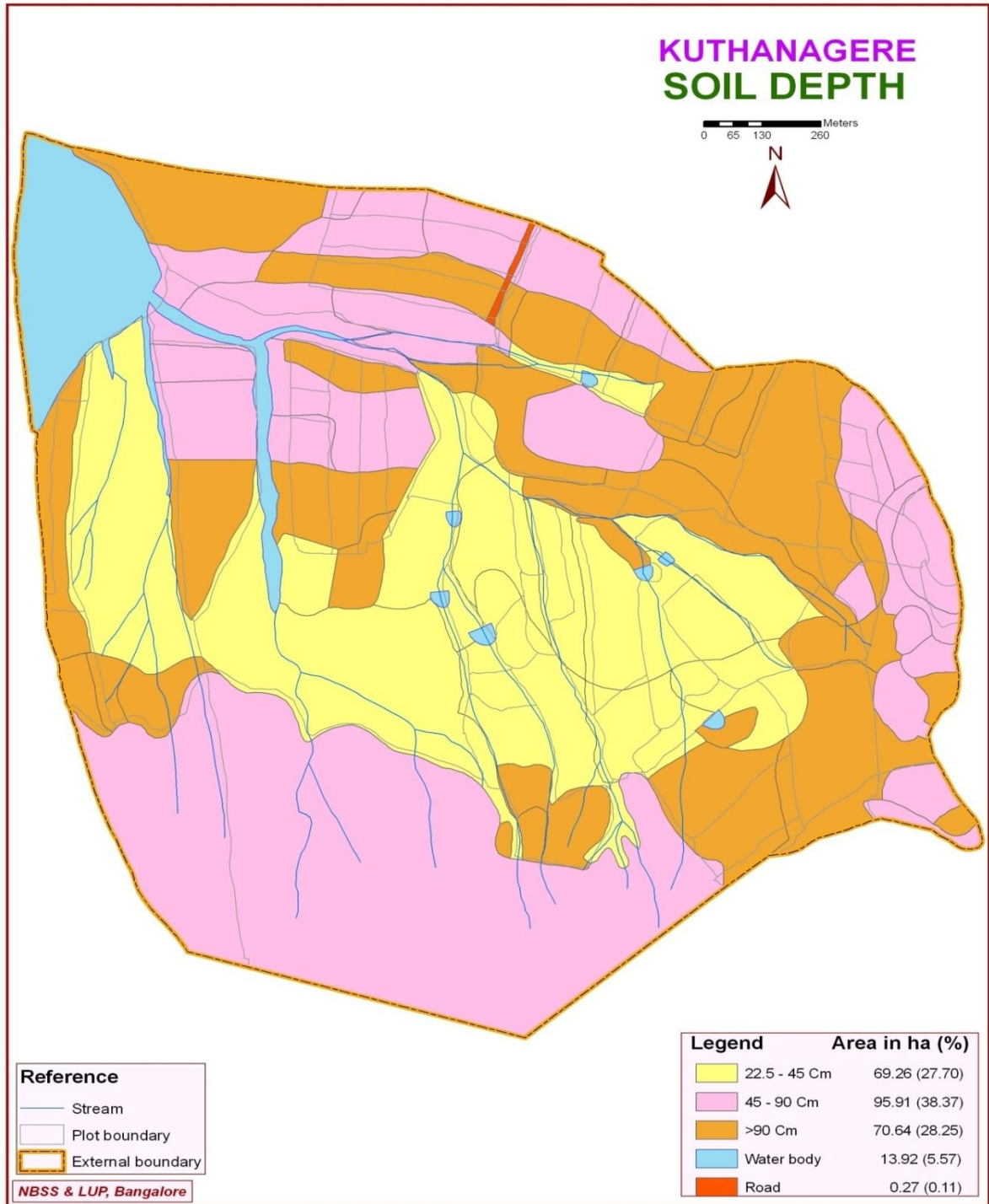


Fig. 27: Soil depth (cm) map of Kuthanagere watershed



Plate 13: Line sowing of finger millet crop



Plate 14: Finger millet crop at 15 DAS



Plate 15: Finger millet crop at 30 DAS



Plate 16: Finger millet crop at 45 DAS



Plate 17: Finger millet crop at 60 DAS



Plate 18: Finger millet crop at 75 DAS



Plate 19: Finger millet crop at 90 DAS



Plate 20: Finger millet crop at harvest

with removal of fine particles and their deposition at lower pediplain. The results obtained in the present study are in agreement with the findings of Rampraksh and Seshagiri Rao (2002).

5.4.1.2 Colour

The colour of Kuthanagere-1, 2, 3, 4, 6, 7 and 10 pedons varied from red to reddish brown (2.5YR to 7.5YR) and colour of Kuthanagere-8, 9 and 11 pedons varied from reddish brown to strong brown (5YR to 7.5 YR) and Kuthanagere-12 and 13 varied from strong brown to dark yellowish brown (7.5YR to 10 YR). This variation in colour is a function of chemical and mineralogical composition, topographic position, textural makeup and moisture regime of the soils. The results of the present study are in accordance with findings of Thangaswamy *et al.* (2005).

The colour 5YR, 7.5 YR and 10YR indicates release of iron oxide and their occurrence in various hydrated form due to difference in drainage of the soils. The results are in conformity with findings of Walia and Rao (1996). The colour of the forest pedon Kuthanagere-5 was darker on the surface than the subsurface. The dark matrix colour on the above horizon might be due to presence of high organic matter content (Tripathi *et al.*, 2006). Whereas, the subsurface horizons has comparatively reddish colour which might be due to high free iron oxides. The results obtained in the present study are in agreement with the findings of Sidhu *et al.* (1994).

5.4.1.3 Texture

The texture of Ap horizons in upland pedons (Kuthanagere-1, 2, 3, 4, 7, and 12) was sandy loam whereas lowland pedon (Kuthanagere-11) was loamy sand (Fig. 28). This variation in texture was mainly because of deposition of finer fractions from uplands. Similar findings were reported by Arunkumar *et al.* (2002). Whereas the upland pedons (Kuthanagere-5) was sandy clay loam in texture, because of lesser mobilization and translocation of finer fractions owing to forest land use, which might be due to improved soil structure by addition of organic matter through leaf foliage.

The texture of the midland pedons was sandy clay loam (Kuthanagere-6, 8, 9, 10 and 13). This variation in texture is mainly due to difference in physiography. The results are in conformity with findings of Nayak *et al.* (2002). The Ap horizon of lowland

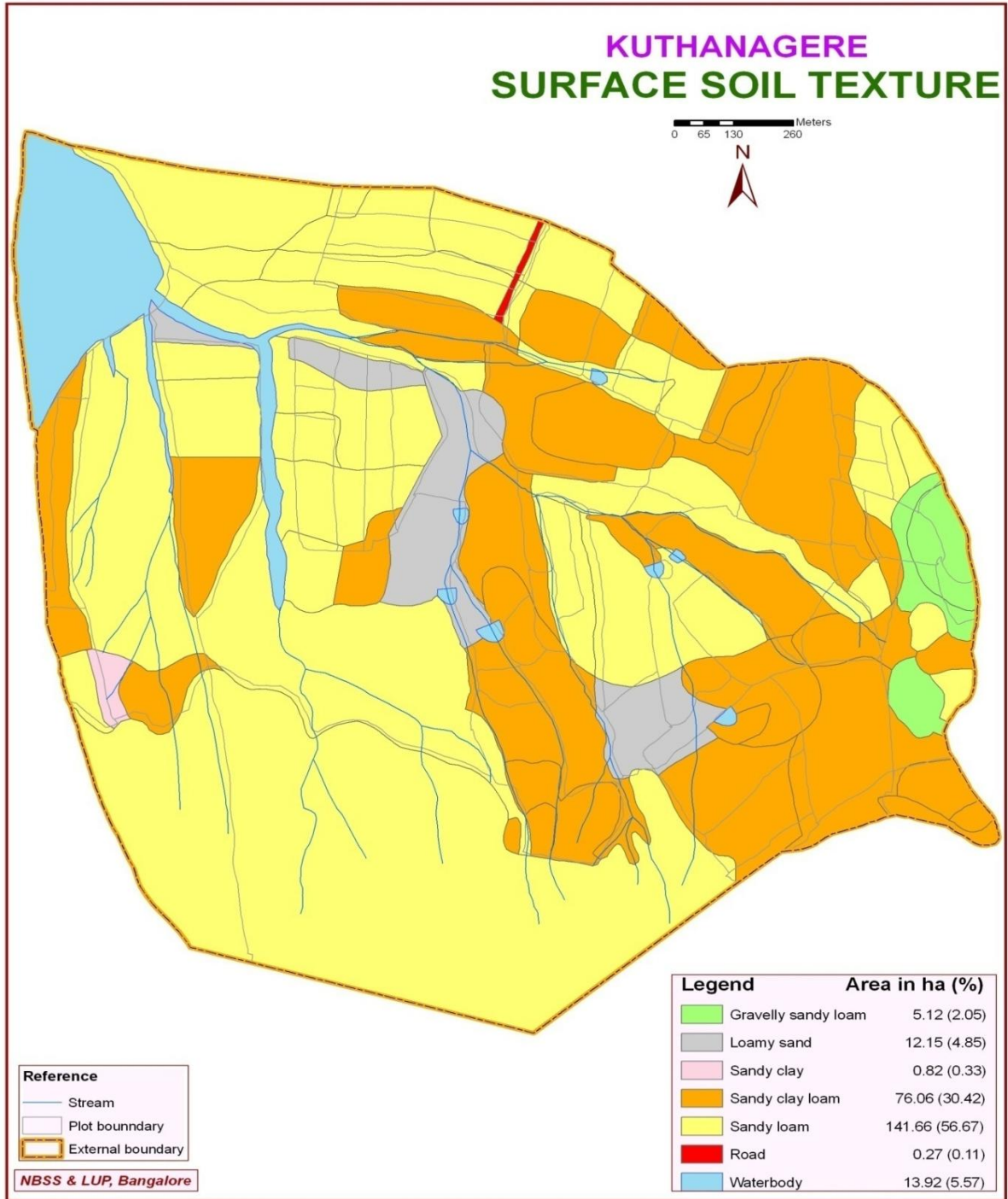


Fig. 28: Surface soil texture of Kuthanagere watershed

pedons was finer in texture than upland and midland pedons, which is attributed to the deposition of finer fractions from uplands and midlands.

5.4.2 Physical properties

5.4.2.1 Particle size distribution

The clay content in different pedons ranged from 12.82 to 43.39 per cent. In upland pedons (Kuthanagere-1, 2, 3, 4, 5, 7, and 12) clay content increased with depth but stabilizes at second or third horizon. These findings are in conformity with the findings of Roy and Landey (1962). In upland pedons, subsurface horizons exhibited higher clay content as compared to surface horizons due to illuviation process occurring during soil development. Similarly, illuviation process also affected vertical distribution of silt and sand. Similar observations were also made by Sharma *et al.* (2004). The midland pedons (Kuthanagere-6, 8, 9, 10 and 13) and lowland pedon (Kuthanagere-11) showed increased trend upto Bt1 horizons of these pedons and it reduced in lower horizons, which might be due to accumulation of clay particles from uplands.

Silt content ranged from 3.63 to 19.81 per cent. All pedons exhibited an irregular trend with depth. This might be due to variation in weathering of parent material. These results are in agreement with the findings of Naidu (2002), who noticed an irregular trend in silt content with depth in sugarcane growing sites of Karnataka. Similar results were also reported by Arunkumar *et al.*, (2002).

Sand content varied from 50.02 to 79.91 per cent. The surface horizons of all the pedons exhibited higher sand content, which could be attributed to removal of finer fractions and consequent enrichment of sand fractions on the upper horizons.

5.4.3 Chemical properties

5.4.3.1 Soil reaction

All pedons showed an increase in pH with depth. This might be due to increase in bases with depth and their incomplete downward leaching (Sitanggang *et al.*, 2006). In Kuthanagere-12 pedon, there was no regular trend in pH, which might be due to downward movement of bases and the get adsorbed at different layers irregularly. The pH of all the surface horizons ranged from 4.69 to 6.82. The lower pH value in surface horizons is mainly due to leaching of bases due to rainfall (Sivashankaran *et al.*, 1993).

5.4.3.2 Electrical conductivity (Ec)

All the pedons showed low Ec values ranging from 0.015 to 0.372 dSm⁻¹ indicating the non saline nature of the soils. Sivashankaran *et al.* (1993) also reported similar low EC values due to the leaching caused by landscape combined with rainfall.

5.4.3.3 Organic carbon

The forest pedon (Kuthanagere-5) had higher organic carbon content than other pedons. The distribution of organic carbon in this profile is mainly associated with physiography and land use. These findings are in conformity with the findings of Walia and Rao (1996).

The organic carbon content of the surface soils were greater than in subsurface soils in all the pedons except in Kuthanagere-2, 3 and 11 pedons and it decreased with the depth. This was attributed to the addition of farmyard manure and plant residues to surface horizons which resulted in higher organic carbon content in surface horizons than that of lower horizons. These observations are in accordance with results of Basavaraju *et al.* (2005) in soils of Chandragiri Mandal of Chittoor district of Andhra Pradesh.

In Kuthanagere-2, 3 and 11 pedons organic carbon was low in surface and slight increase in subsurface layer. This is attributed to sparse vegetative cover.

5.4.3.4 Cation exchange capacity (CEC)

Cation exchange capacity of the soils was generally low in all the pedons and it varied from 2.70 to 9.70 cmol (p⁺) kg⁻¹ of soil. Surface horizons of all the pedons were low in CEC which increased in second horizon except in Kuthanagere-8 pedon, which showed reverse trend. There was no regular trend in CEC after Bt1 horizon. The cation exchange capacity increased with depth and could be correlated to clay content (Shadaksharappa *et al.*, 1995).

5.4.3.5 Base saturation

The base saturation was found to vary from 54.39 to 93.81 per cent. The base saturation was high in surface horizons of Kuthanagere-4, 5, 10, 11 and 13 pedons due to influence of organic matter and showed a tendency to decrease with depth upto Bt2 horizon. Surface horizons of Kuthanagere-1, 2, 5, 6, 7, 8 and 12 has high base saturation

and showed increasing tendency with the depth upto Bt1 except Kuthanagere-9 pedon, which increased with depth upto Bt2 horizon. Increase in base saturation with the depth was due to the leaching of bases from the upper horizon and their deposition in the lower horizons. These findings are in conformity with those reported by Sitanggang *et al.* (2006).

5.4.3.6 Exchangeable bases

The exchangeable bases in all the pedons were in order of $\text{Ca}^{+2} > \text{Na}^+ > \text{Mg}^{+2} > \text{K}^+$ on exchange complex except in Kuthanagere-3 and 6 which followed the order of $\text{Ca}^{+2} > \text{Na}^+ > \text{K}^+ > \text{Mg}^{+2}$. From the distribution of Ca^{+2} and Mg^{+2} , it is evident that Ca^{+2} shows the strong relationship with all the species, comparing these ions it was clear that Mg^{+2} was present in low amount than Ca^{+2} because of its higher mobility. These results are in conformity with findings of Sharma *et al.* (1996a). The low value of exchangeable K^+ compared to Ca^{+2} was due to preferential leaching of monovalents than divalent. These findings are in accordance with those of Das and Roy (1979).

5.4.3.7 Available nitrogen

Soil available nitrogen status was low to medium (63.93 to 175.24 ppm). Nitrogen content decreased with depth in all the pedons except in Kuthanagere-5 pedon. The available nitrogen content in surface soil was higher than that of subsurface soil which can be attributed to accumulation of more organic matter on surface layer and its subsequent decomposition than subsurface horizon. Major portion of the nitrogen pool is contributed by organic matter. Low organic matter content in these areas due to low rainfall and low vegetation cover facilitates faster degradation and removal of organic matter leading to nitrogen deficiency. Medium nitrogen status was noticed in some area that might be due to application of N fertilizer coupled with high vegetative cover (Govindarajan and Datta Biswas, 1968)

5.4.3.8 Available phosphorus

Available phosphorus is a measure of increasing P fractions which is considered as an useful index of phosphorus. Surface horizons has higher amount of phosphorus which had shown decreasing tendency with the depth in all the pedons. The status of

phosphorus could be attributed to nature of soils where phosphorus get fixed (Murthy, 1988). Further it was also related to clay content and soil reaction.

5.4.3.9 Micronutrients

Micronutrients (Fe, Cu, Zn and Mn) showed irregular distribution. The availability of micronutrients increased with increase in organic matter because it protects oxidation and precipitation of micronutrients, on the other hand availability gets reduced with the increased pH and CaCO₃ which are responsible for oxidation. Similar results were reported by Sharma *et al.* (2003).

5.4.3.10 Available boron

Available boron content increased with depth upto Bt1 horizon in Kuthanagere-2, 3, 10, 11, 12 and 13 pedons, this was mainly due to the increase in organic matter. Similar results were noticed by Satyanarayana (1958) where in boron had positive correlation with organic matter content in soil. In Kuthanagere-1, 4, 6, 7, 8 and 9 available boron was higher in surface than in subsurface. This is mainly due to low pH of surface horizons in these pedons resulting in fixation of boron. Present results are in conformity with Berger and Troug (1945).

5.5 Influence of soil site characters on yield of finger millet

It was observed that among 25 soil site characteristics studied (Table 27), 13 of them particularly, ground water depth, slope, erosion rating, depth, coarse fragments, sand, silt, clay, base saturation, electrical conductivity, available nitrogen, available phosphorus, exchangeable potassium, plant available water content (PAWC) and length of growing period (LGP) had significantly positively correlated with grain yield of finger millet. Based on these parameters soil suitability map of finger millet was developed (Fig. 29). Ground water depth being positively correlated with grain yield, the relationship was more of quadratic in nature. The optimum ground water depth from the fitted equation ($Y = 4.672 + 1.218X - 0.016X^2$, $r = 0.31^{**}$) was observed to be around 35mts (Fig. 30). Slope, erosion rating and coarse fragments in the soil had negative relationship with grain yield ($Y = 48.47 - 1.69X - 0.005X^2$, $r = -0.376^{**}$). Slope ($Y = 33.08 - 2.88X$, $r = -0.396^{**}$) and erosion rating ($Y = 28.39 - 2.67X$, $r = -0.189^*$) had more of linear nature than quadratic (Fig. 31 and 32). The results are in conformity with the findings of Shivaramu and Niranjana (2010).

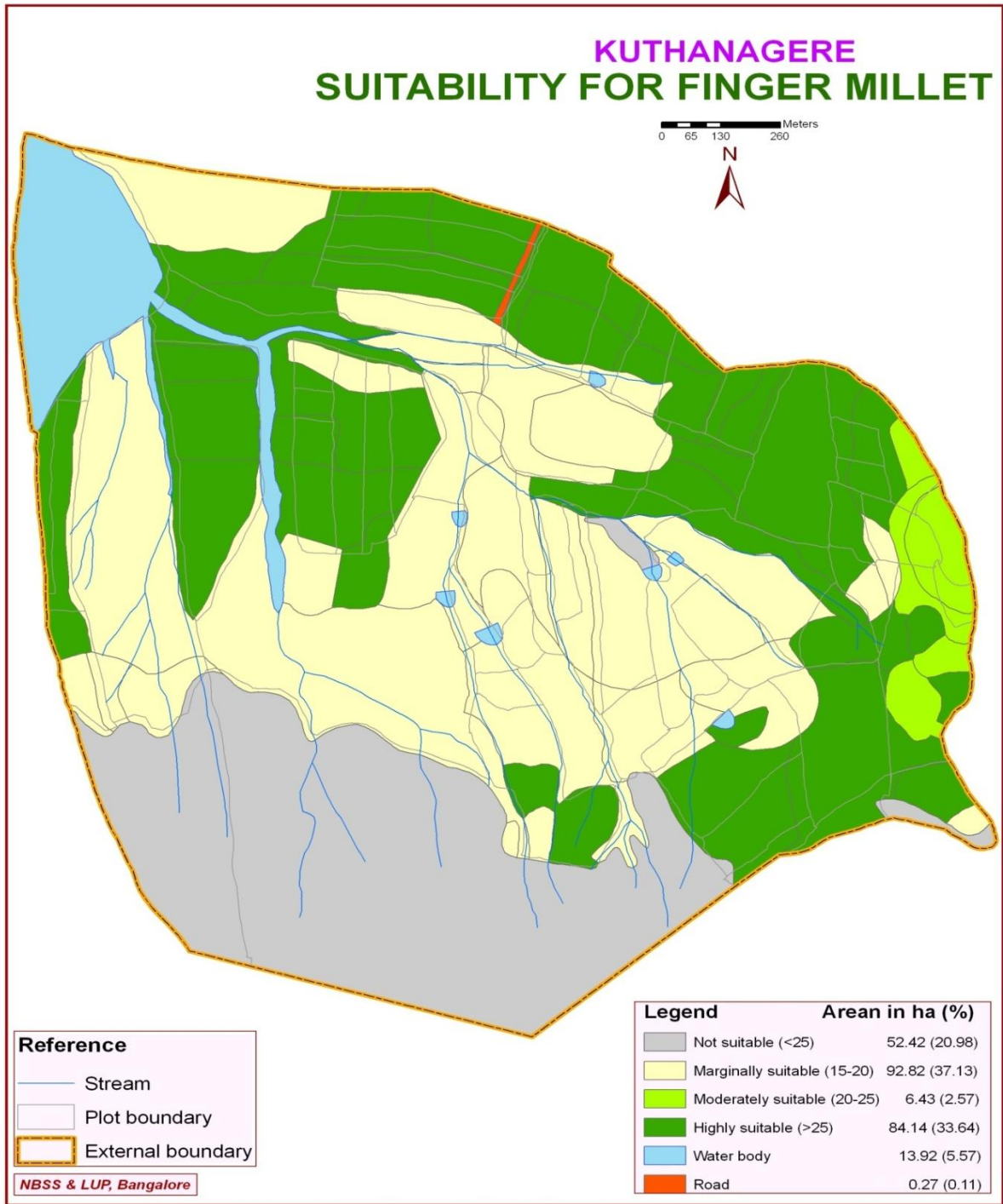


Fig. 29: Soil site suitability of finger millet in Kuthanagere watershed

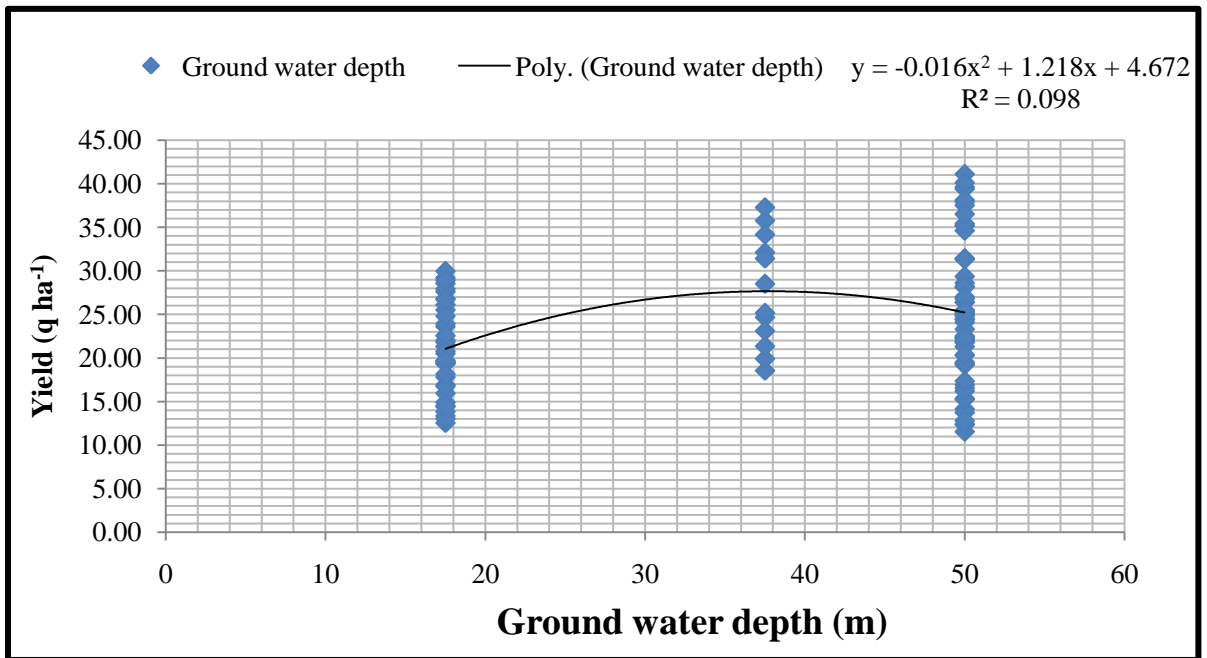


Fig. 30: Regression equation between ground water depth and grain yield of finger millet

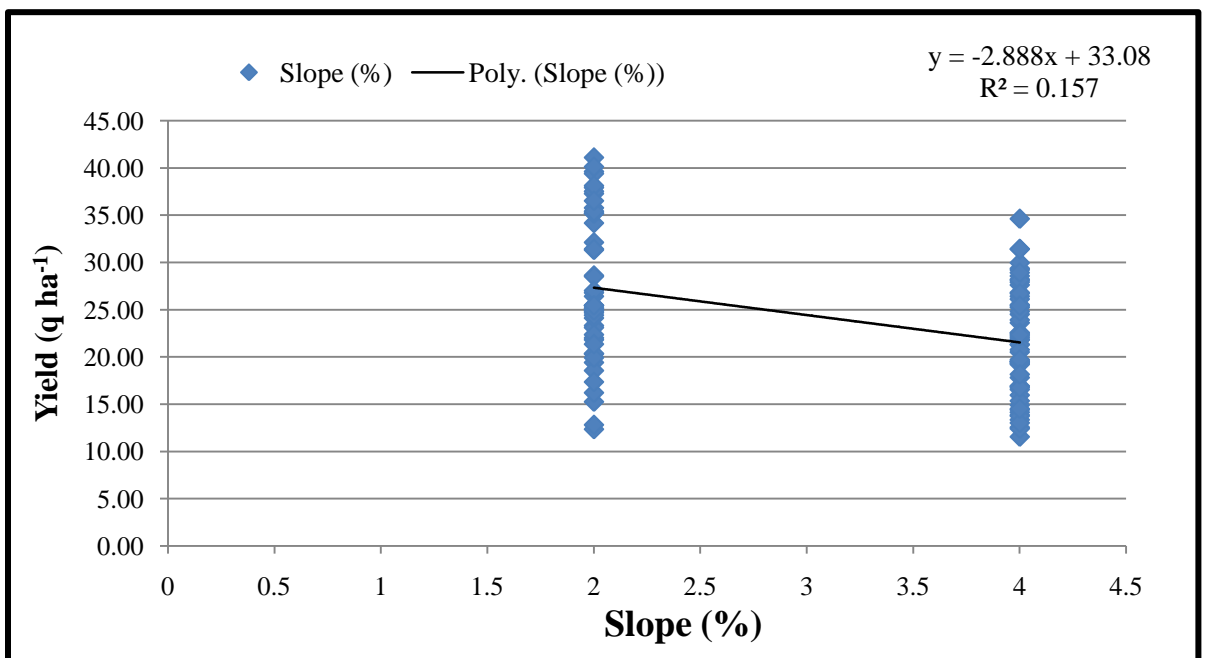


Fig. 31: Regression equation between slope and grain yield of finger millet

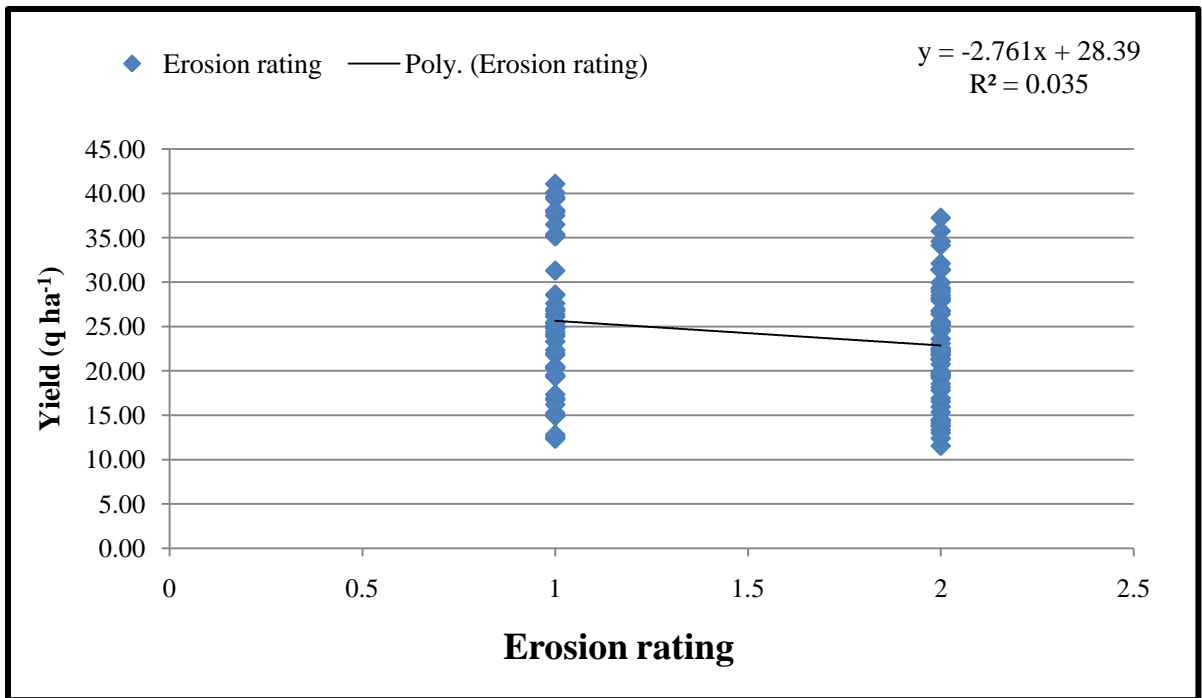


Fig. 32: Regression equation between erosion rating and grain yield of finger millet

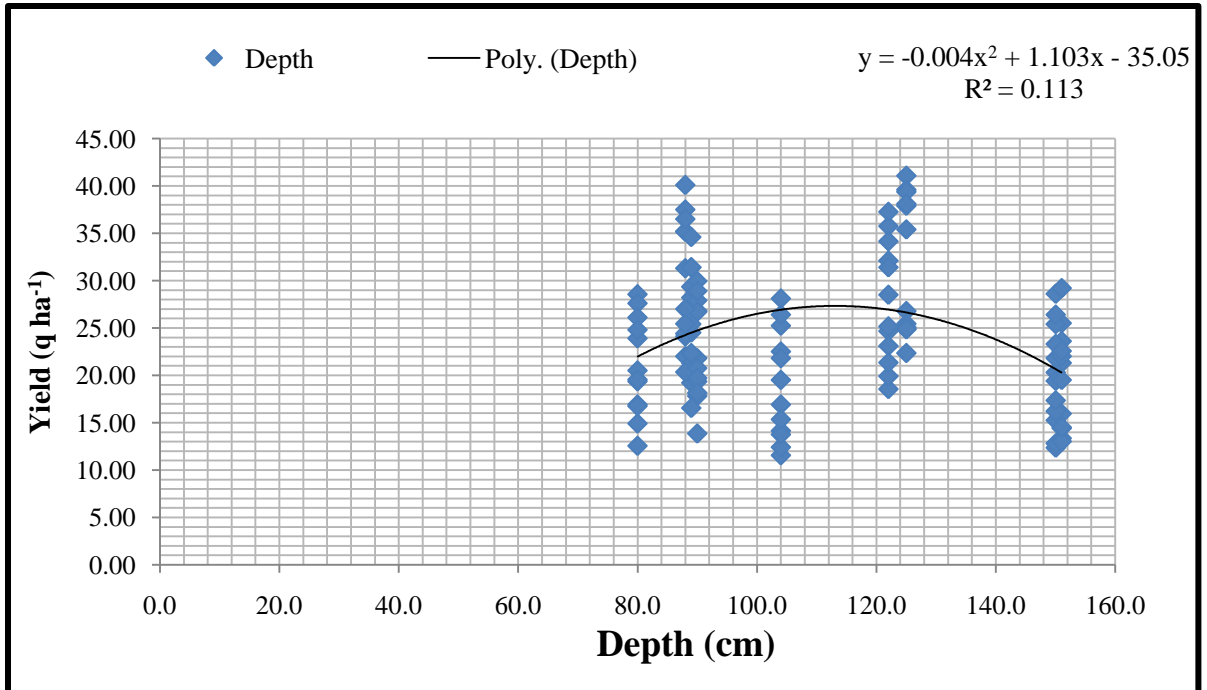


Fig 33: Regression equation between depth and grain yield of finger millet

Depth had negative correlation with grain yield ($Y=-35.06+1.10X-0.05X^2$, $r=-0.337^{**}$). The optimum soil depth from the fitted equation was observed to be around 1m (Fig. 33). The silt content had positive and prominently quadratic relationship with grain yield ($Y=-33.87+14.56X-0.13X^2$, $r=0.307^{**}$) and accordingly optimum content was worked to be 11 per cent. With an increase in clay from 22 per cent onwards, there was a steep increase in yield upto 30 per cent of clay ($Y=-41.34+4.40X-0.073X^2$, $r=0.187^{**}$). On the contrary, increase in sand above 54 per cent decreased the yield drastically. Thus, right proportion of sand (<54%, Fig. 34) and clay (22-30%, Fig. 36) keeping the optimum silt at 11 per cent (Fig. 35), play an important role in determining yield of finger millet. Shivaramu and Niranjana (2010) reported that sand (<35%), clay (>50%) and silt (16%) were optimum for higher yield of finger millet.

Electrical conductivity ($Y=44.69-770.05X+6685.91X^2$, $r=-0.262^{**}$ Fig. 37) and cation exchange capacity ($Y=99.98-26.17X+2.207X^2$, $r=-0.150$ Fig. 38) showed negative relationship with grain yield. Available nitrogen ($Y=11.35+0.06X+0.001X^2$, $r=0.335^{**}$ Fig. 39), available phosphorus ($Y=38.39-3.74X+0.21X^2$, $r=0.225^*$ Fig. 40) and available potassium ($Y=34.02-156.60X+525.30X^2$, $r=0.351^{**}$ Fig. 41) showed significant positive and quadratic relationship with finger millet yield showing the importance of balanced nutrition in finger millet. PAWC ($Y=13.70+0.14X-0.0002X^2$, $r=0.374^{**}$ Fig. 42) and LGP ($Y=60.80-0.55X+0.0018X^2$, $r=0.612^{**}$ Fig. 43) being the index of moisture storage capacity and moisture availability periods, respectively were positively correlated with finger millet with optimum values of more than 115mm and 240days, respectively. However, the optimum value of LGP depends mainly on the duration the crop rather than its yield potential.

From the correlation matrix, it was observed that ground water depth, sand, clay, silt content, PAWC and LGP and major nutrients were closely related with each other and altogether on grain yield (Shivaramu *et al.*, 1997). Therefore, instead of looking at their individual effects the overall interaction of different soil parameters on grain yield seemed to be appropriate and hence 16 multi linear regression equations (MLR) were worked out, of which 8 best models were presented in the Table 28. The significant R^2 values of these MLR equations ranged from 0.3846 in Model no. I when 8 parameters were regressed to 0.3746 Model No. VIII involving only PAWC. The two soil parameters

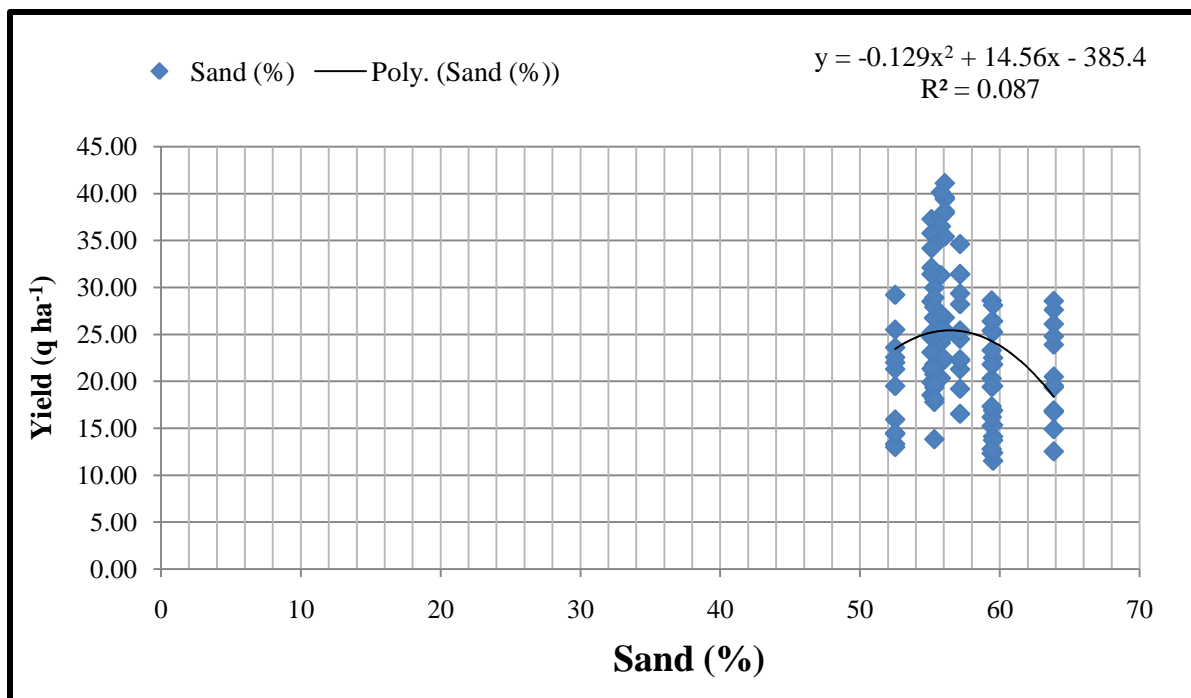


Fig 34: Regression equation between sand and grain yield of finger millet

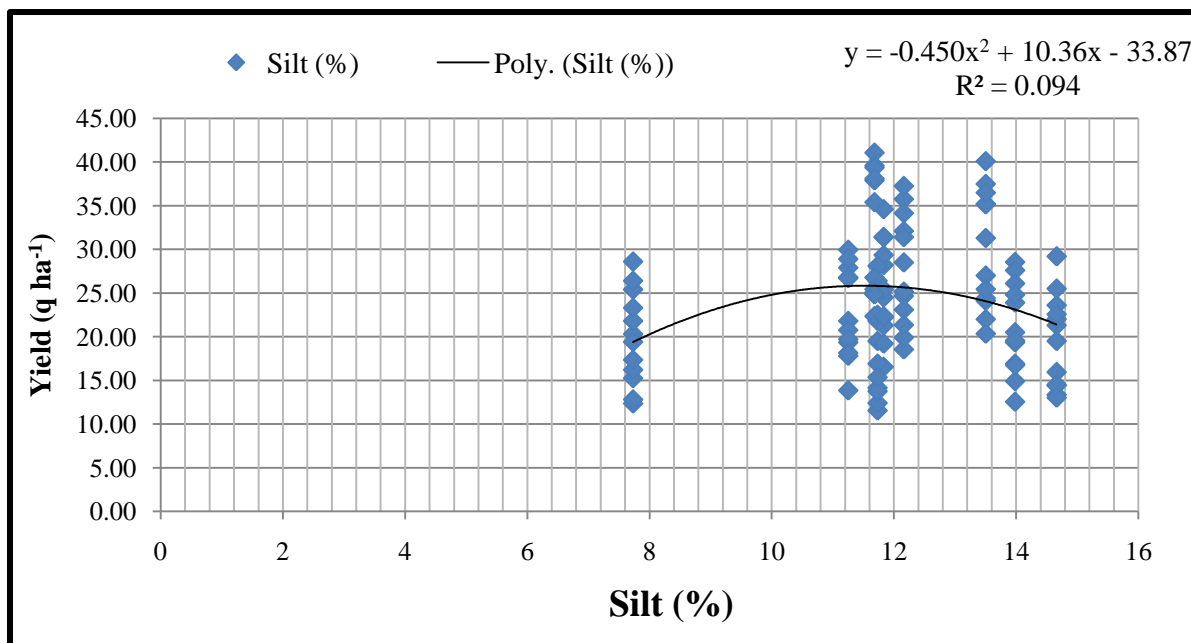


Fig 35: Regression equation between silt and grain yield of finger millet

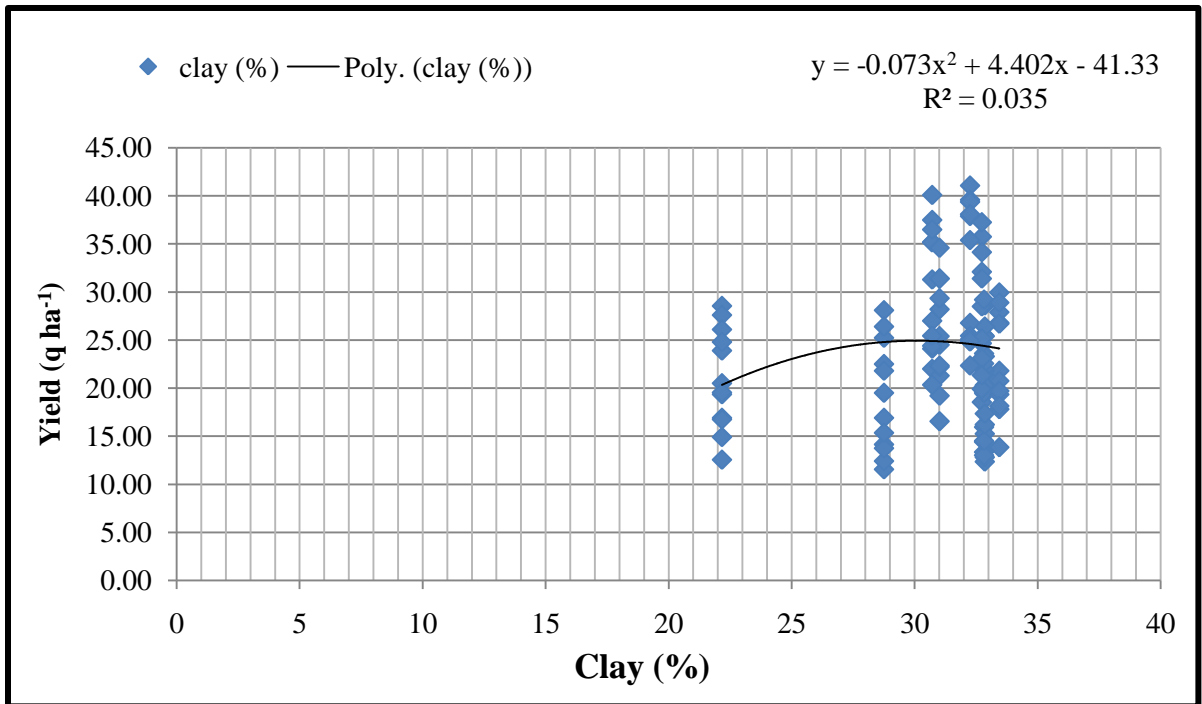


Fig. 35: Regression equation between clay and grain yield of finger millet

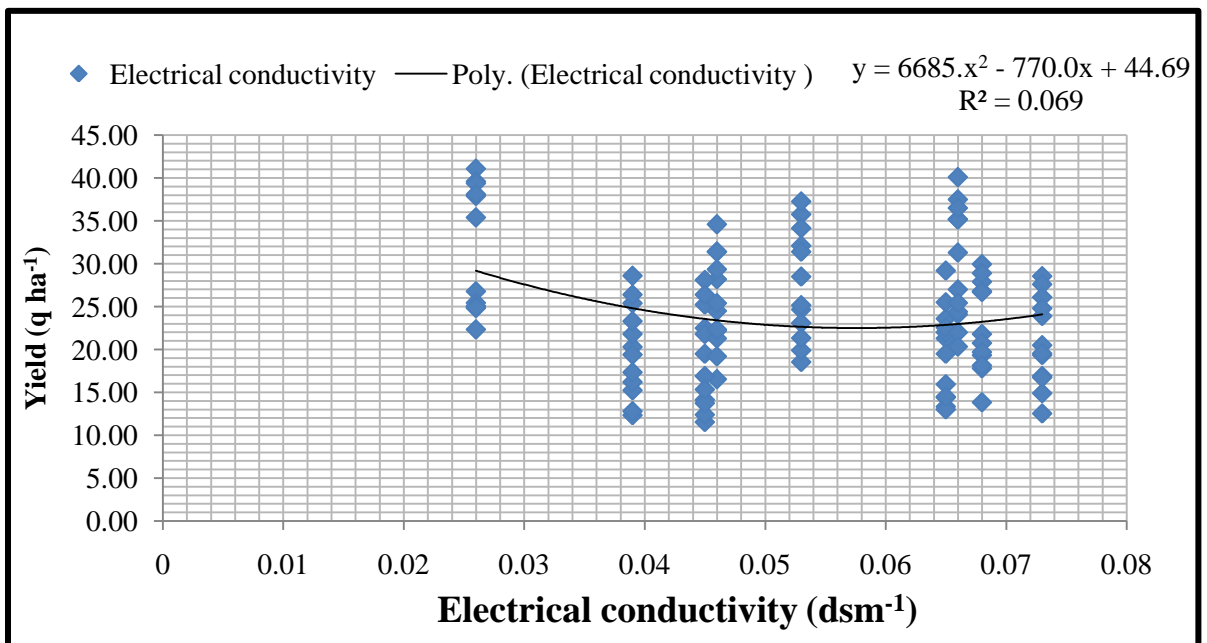


Fig. 37: Regression equation between electrical conductivity and grain yield of finger millet

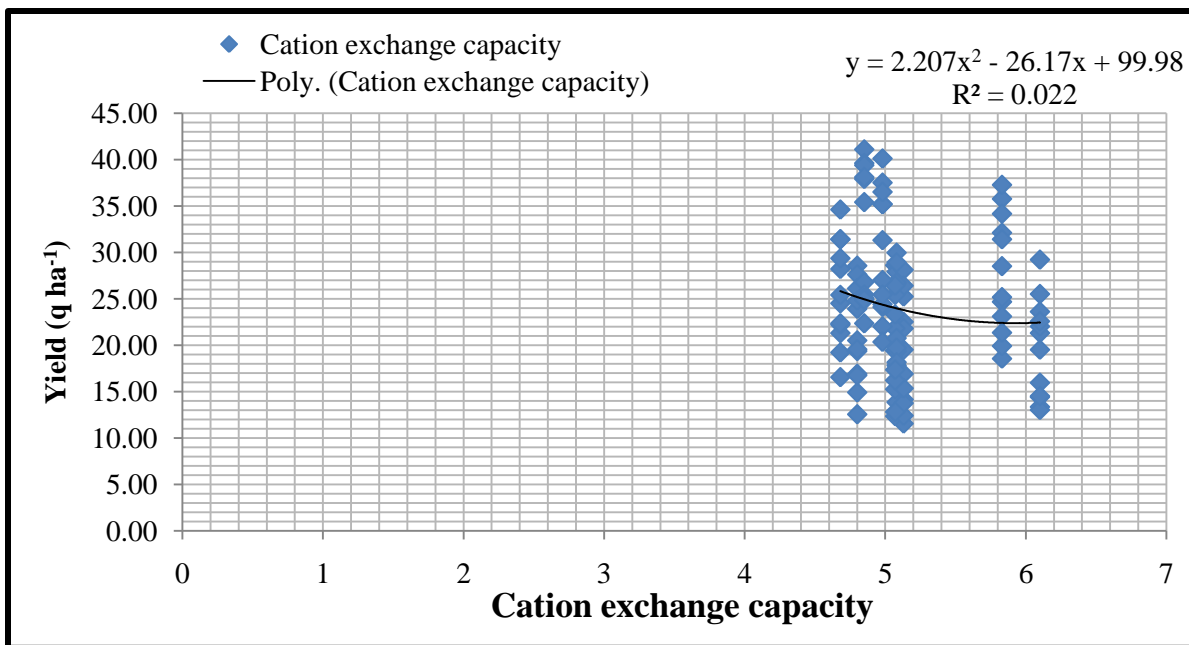


Fig. 38: Regression equation between cation exchange capacity and grain yield of finger millet

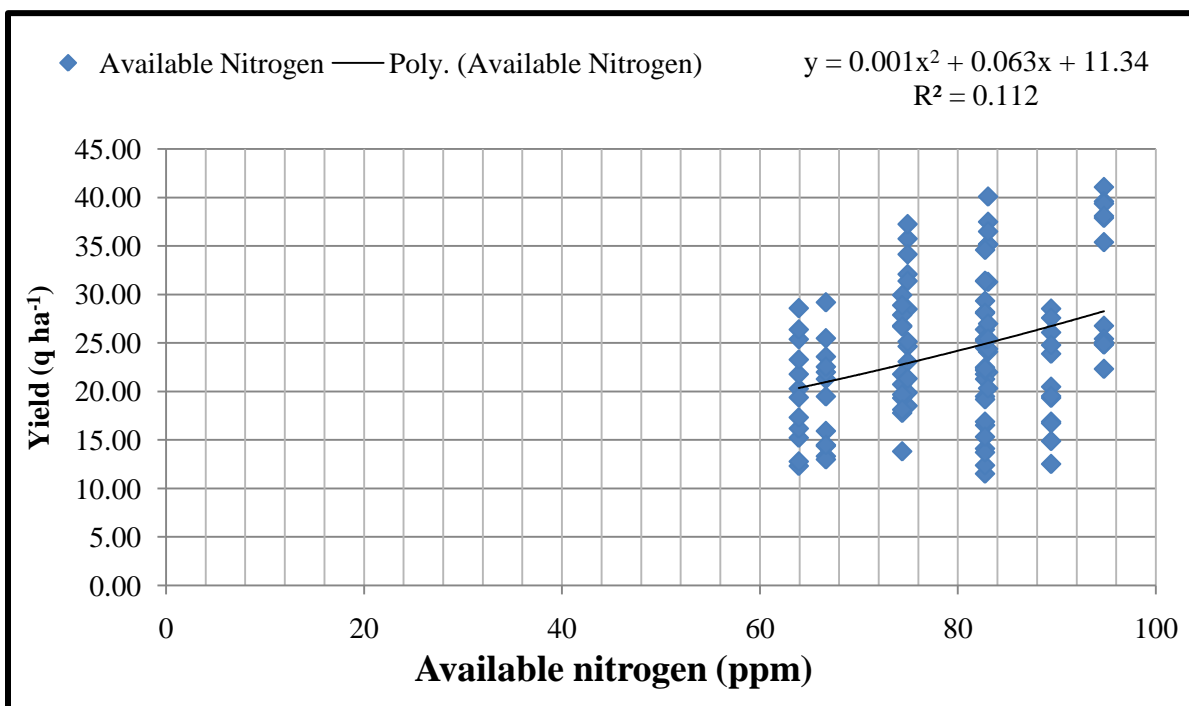


Fig. 39: Regression equation between available nitrogen and grain yield of finger millet

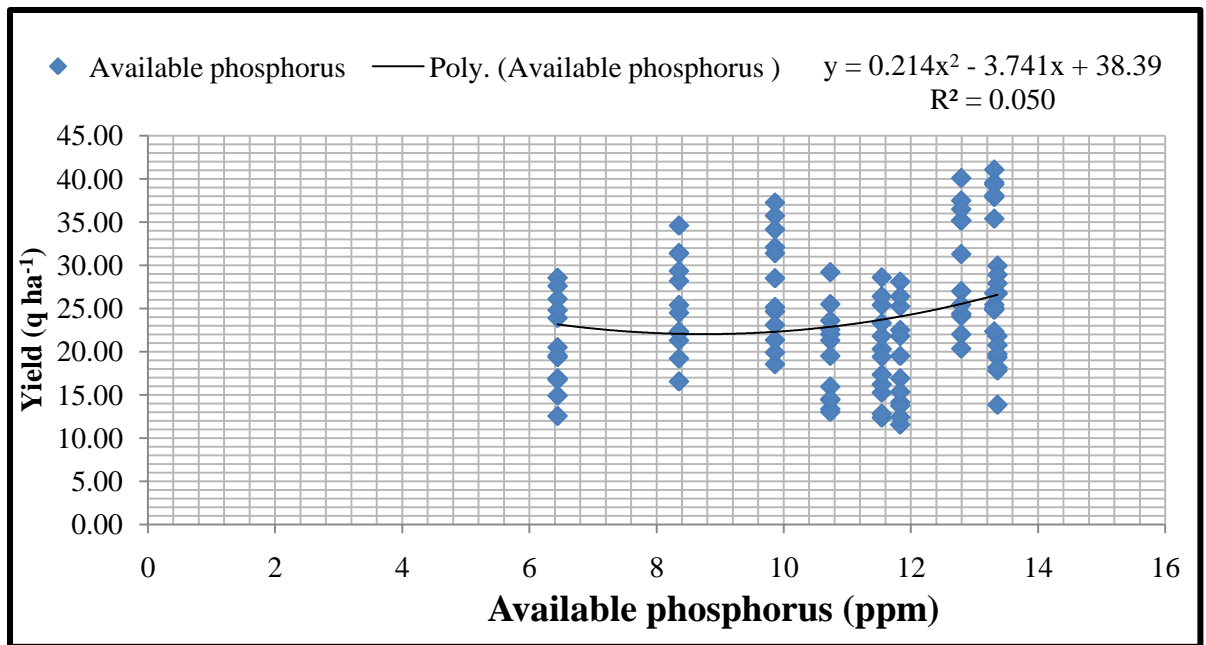


Fig. 40: Regression equation between available phosphorus and grain yield of finger millet

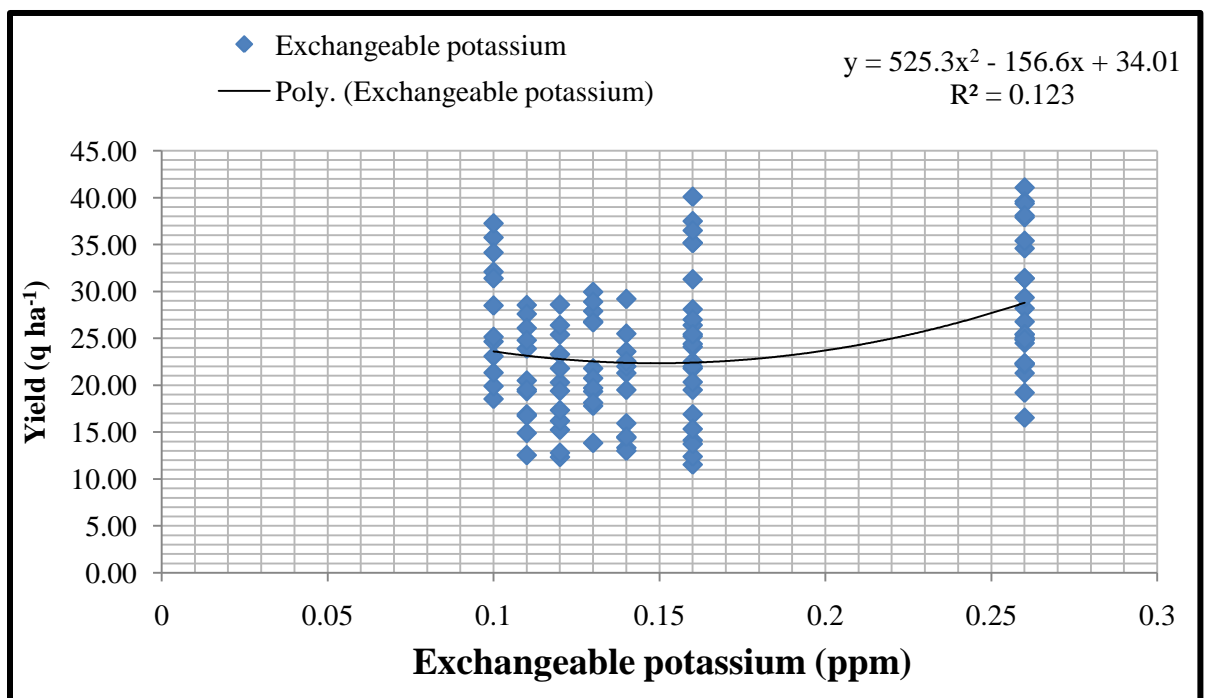


Fig.41: Regression equation between exchangeable potassium and grain yield of finger millet

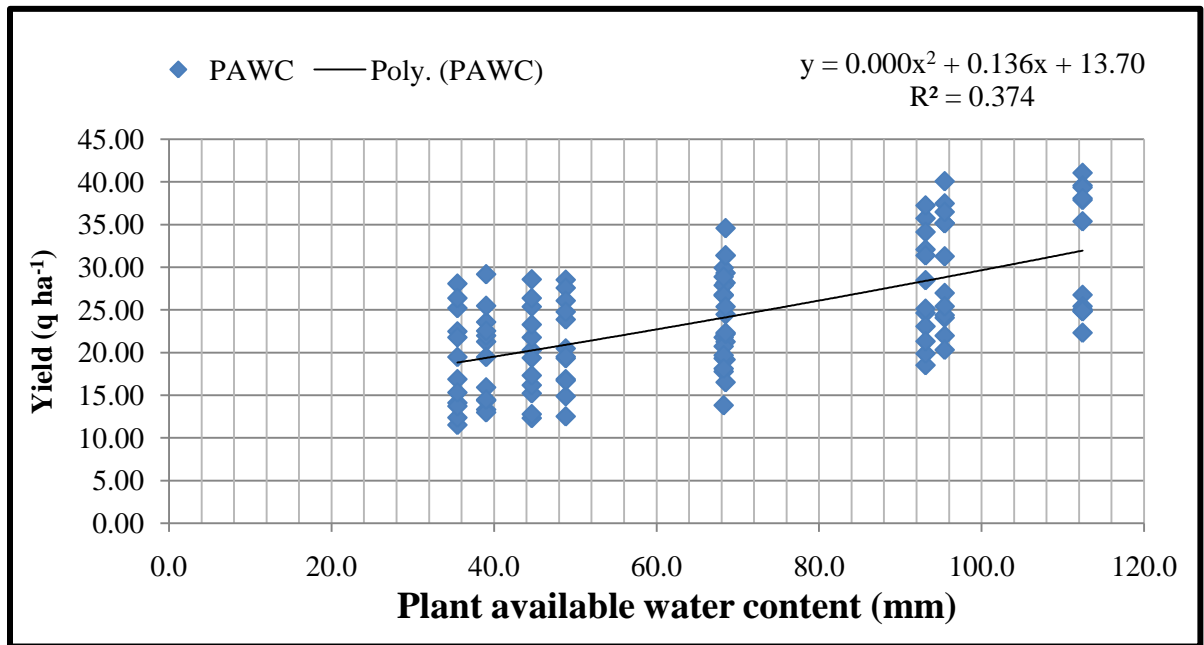


Fig. 42: Regression equation between plant available water content and grain yield of finger millet

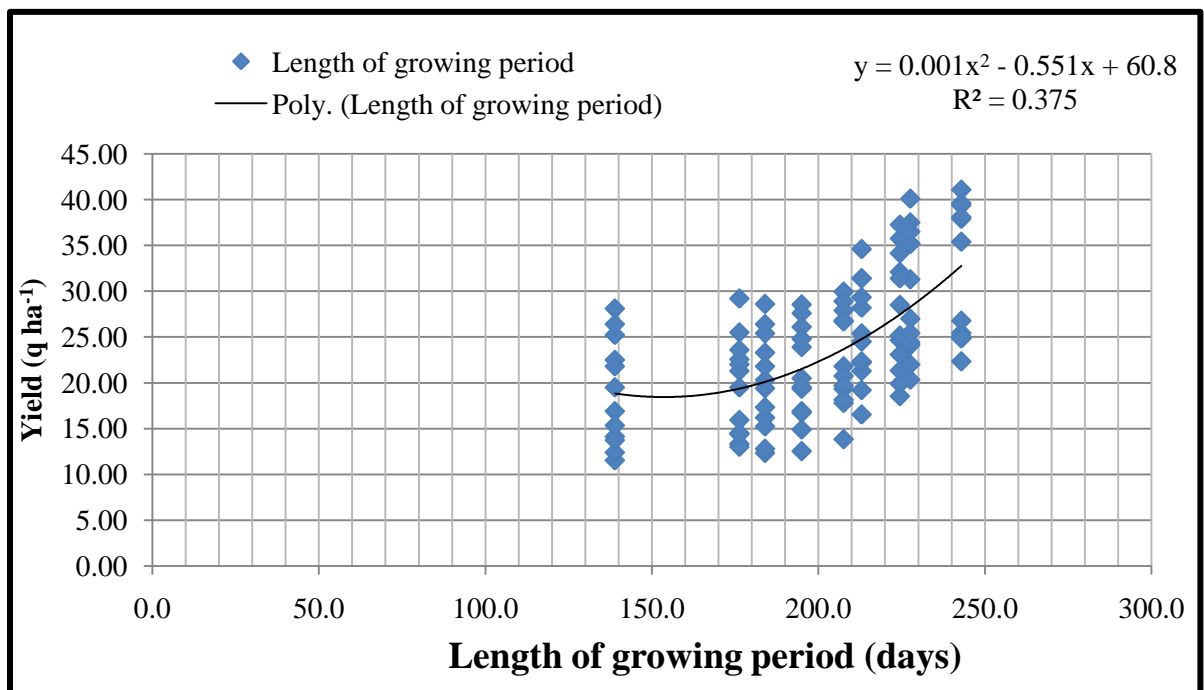


Fig. 43: Regression equation between length of growing period and grain yield of finger millet

viz., PAWC and LGP could explain 37 per cent of the variation in the grain yield ($R^2=0.3747^{**}$). Among these 8 models, the better models as per the setout criteria were found to be Model No. III ($R^2=0.3822^{**}$) followed by Model No. II ($R^2=0.3860^{**}$). However, one can use any of these models for judging the suitability of land depending on the information generated on soil site parameter and the management level of the crop but bearing the risk of associated standard error.

5.6 Characterization of surface samples for fertility status

After analysis of the below parameters soil series map of Kuthanagere watershed was developed (Fig. 44).

5.6.1 Soil reaction and Electrical conductivity

The pH and Ec values of the surface samples ranged from 4.7 to 7.6 and 0.023 to 0.195 dSm^{-1} . However, 19.71 ha area comes under very slightly acidic (4.5-5.1), 9.56 ha area under moderately acidic (5.1-5.5), 159.8 ha area under slightly acidic (5.6-6.5), 40.72 ha area was neutral (6.6-7.3), 6.02 ha area was under slightly alkaline (7.4-7.8) (Fig. 45).

The reasons for lower pH and Ec values were discussed at 5.3.3.1 and 5.3.3.2

5.6.2 Organic carbon

Organic carbon content in surface samples ranged from 0.44 to 0.73 per cent. Out of total study area of 250 hectares, 56.02 ha area having low OC (<0.5%), 179.79 ha area having medium OC (0.5-0.75%) (Fig. 46).

The reasons for low organic carbon content in these soils might be attributed to the prevalence of tropical condition, where the degradation of organic matter occurs at faster rate coupled with little or no addition of matter. Similar observations were also made by Nayak *et al.* (2002) in soils of Central Research Station, OUAT, Bhubaneswar.

5.6.3 Available nutrient status

5.6.3.1 Available nitrogen

The available nitrogen in the study area ranged from 67.16 ppm to 127.06 ppm and the values were low to medium. In Kuthanagere watershed, 171.06 ha falls under low nitrogen content (<125 ppm) content category and 64.75 ha area comes under medium nitrogen content (125-250) (Fig. 47). Major portion of nitrogen pool is contributed by organic matter. The low organic matter in these areas due to faster degradation and

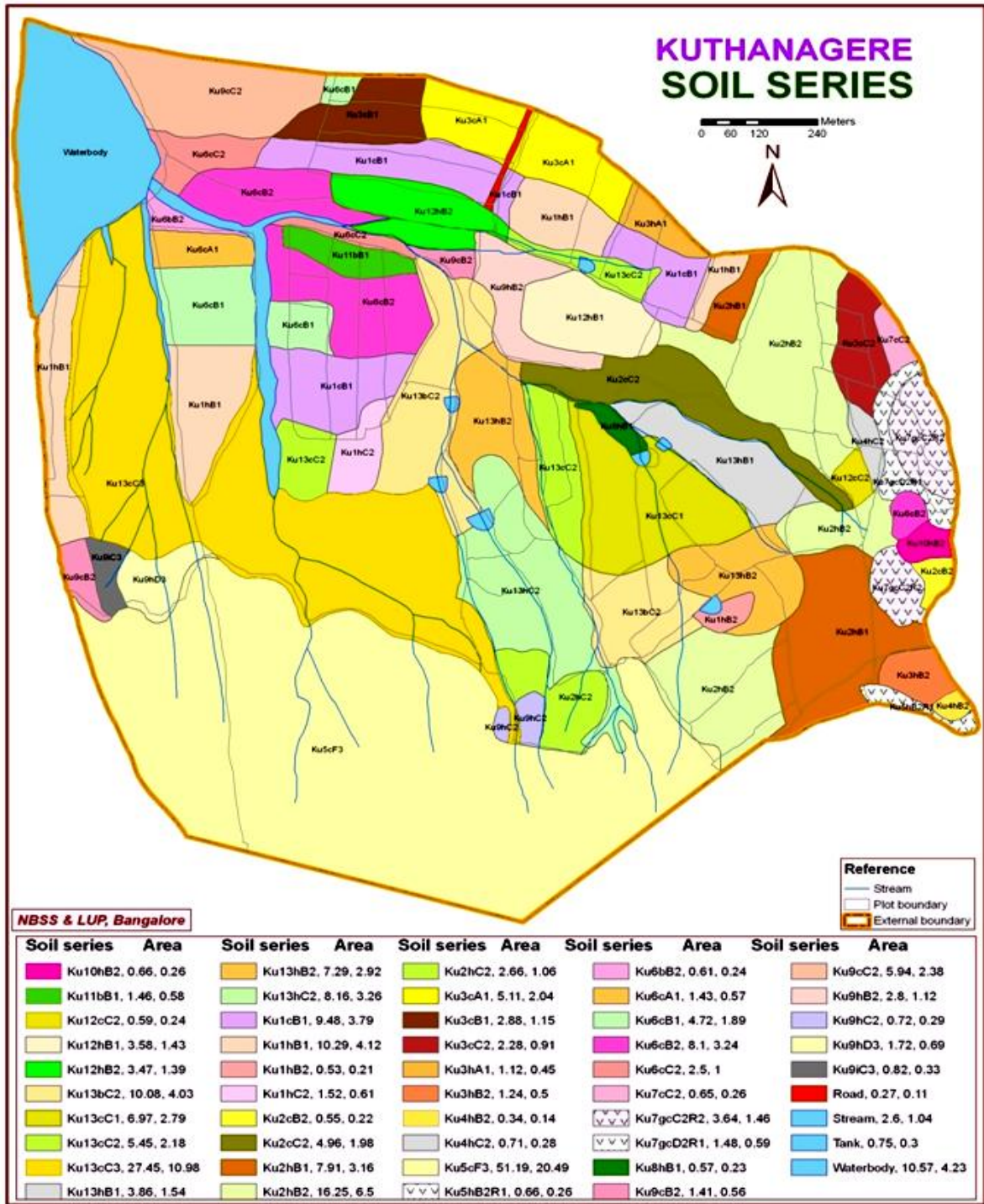


Fig. 44: Soil series map of Kuthanagere watershed

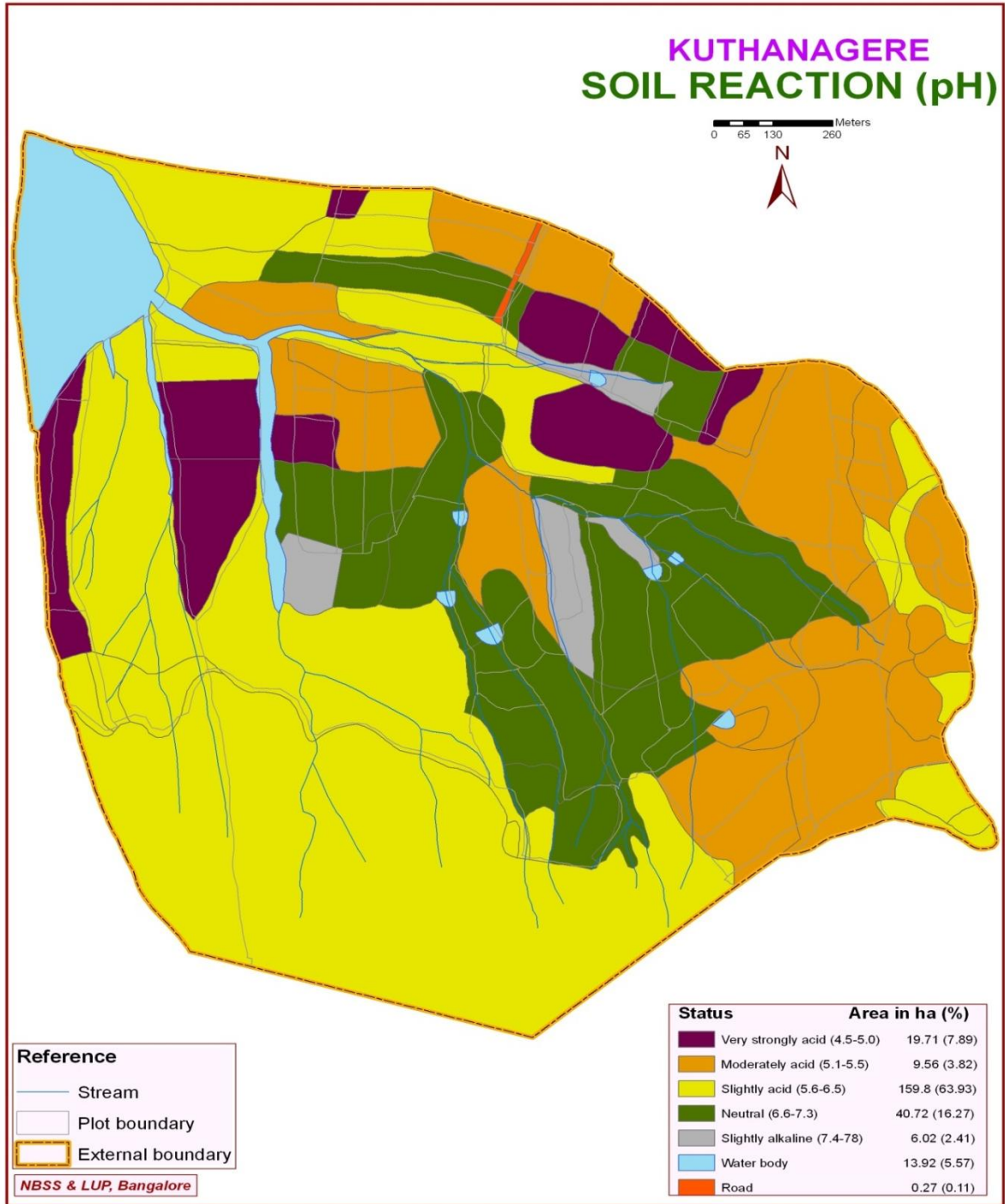


Fig. 45: Soil reaction status of Kuthanagere watershed

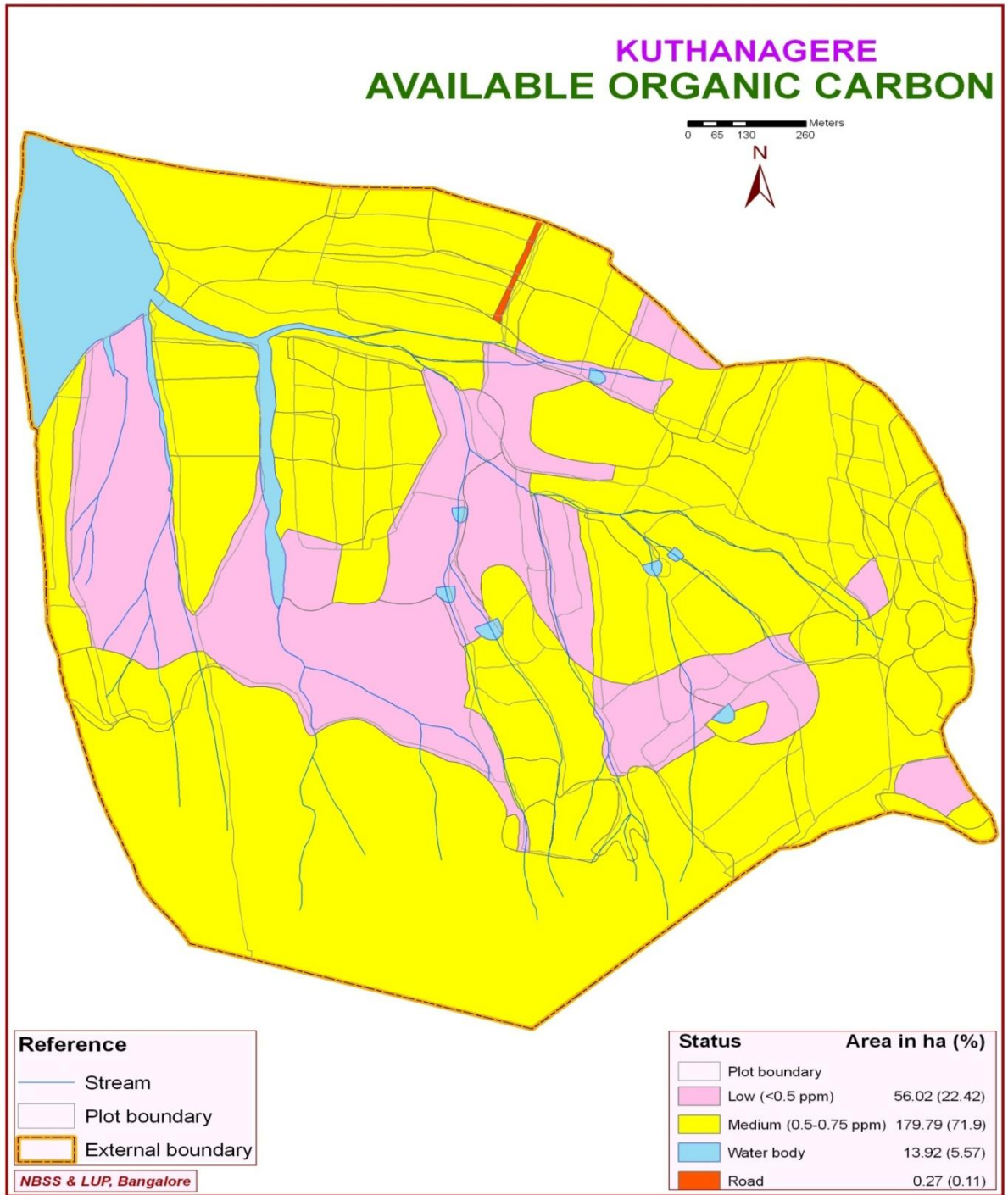


Fig. 46: Organic carbon (%) status of Kuthanagere watershed

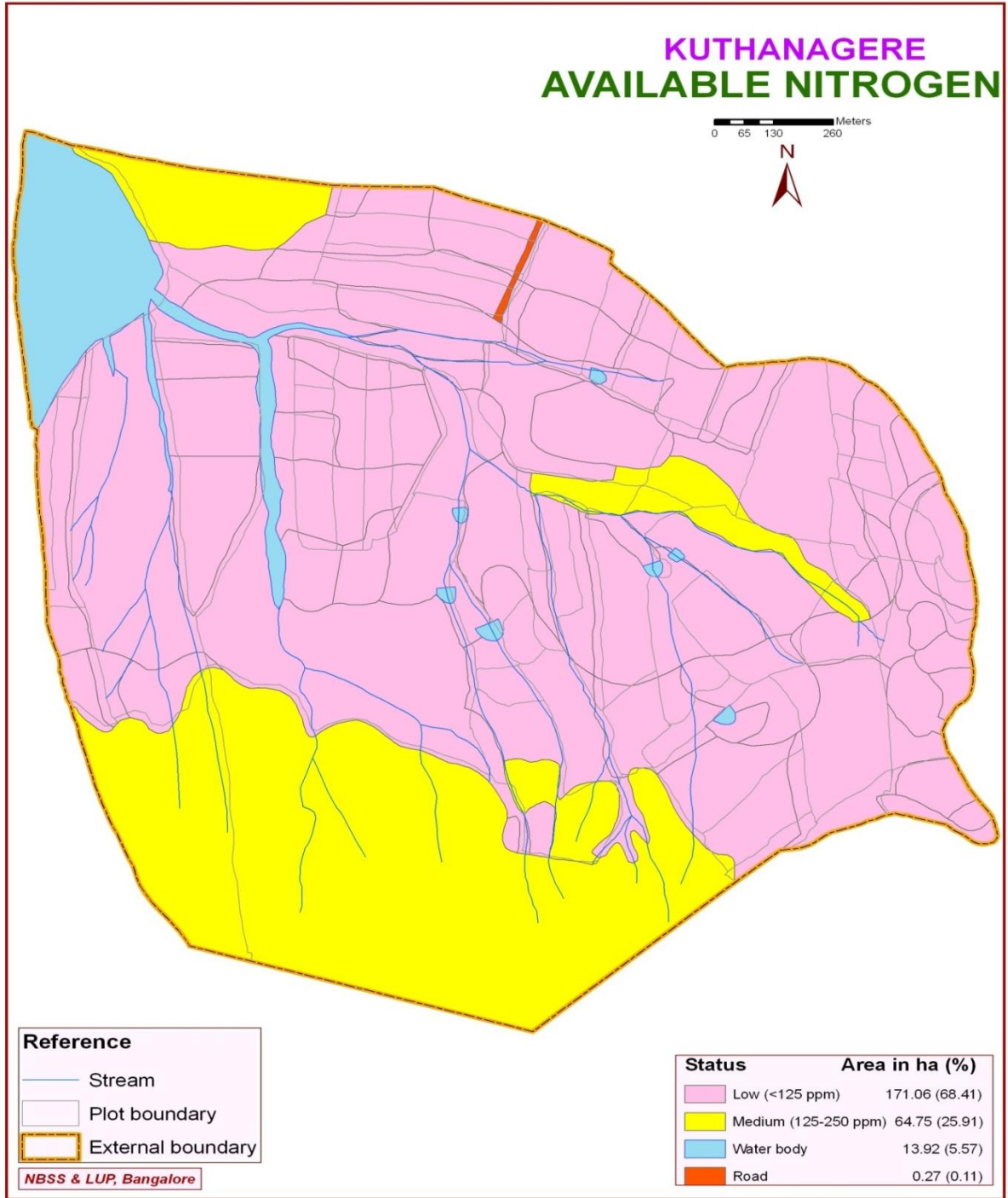


Fig. 47: Available nitrogen (ppm) status of Kuthanagere watershed

consequent removal of organic matter coupled with lesser nitrogen fertilization leading to nitrogen deficiency. The results obtained in the present study area are in agreement with the findings of Govindarajan and Biswas (1968).

5.6.3.2 Available phosphorus

The available phosphorus content ranged from 10.09 ppm to 19.83 ppm. In the study area, 3.92 ha area was found to have low phosphorus content (<10.2 ppm) and 231.89 ha area having medium phosphorus content (10.2-25.1 ppm) (Fig. 48). The low values of available phosphorus are due to low CEC, clay content and soil reaction of <6.5. The results are in conformity with the findings of Bopathi and Sharma (2006).

5.6.3.3 Available potassium

Available potassium in the study area ranged from 10.03 to 240 ppm. Major portion of study area was found to be medium in potassium content (115.72 ha) whereas, 15.01 ha area was found to be low in potassium content and 105.08 ha area was having higher amount of potassium content (Fig. 49). High values of potassium are due to predominance of potassium rich micaceous and feldspar minerals in parent material. Similar results were observed by Ravikumar (2004). Low category soils are seen due to lesser finer fractions in their soils.

5.6.4 Secondary nutrient

5.6.4.1 Exchangeable calcium and Magnesium

Exchangeable calcium was higher than magnesium in surface samples due to its mobility. From the distribution of Ca^{+2} and Mg^{+2} it is evident that Ca^{+2} show the strongest relationship with Mg^{+2} . The results are in conformity with findings of Sharma (1996a)

5.6.3.4 Available sulphur

All the surface soils were deficient in sulphur (Fig. 50) and the values ranged from 0.76ppm to 4.17 ppm. The low amount of sulphur in surface samples is mainly because of acid reaction and low electrical conductivity values. Similarly, Sharma and Gangwar (1997) noticed negative correlation between sulphur and pH and also between total sulphur and electrical conductivity.

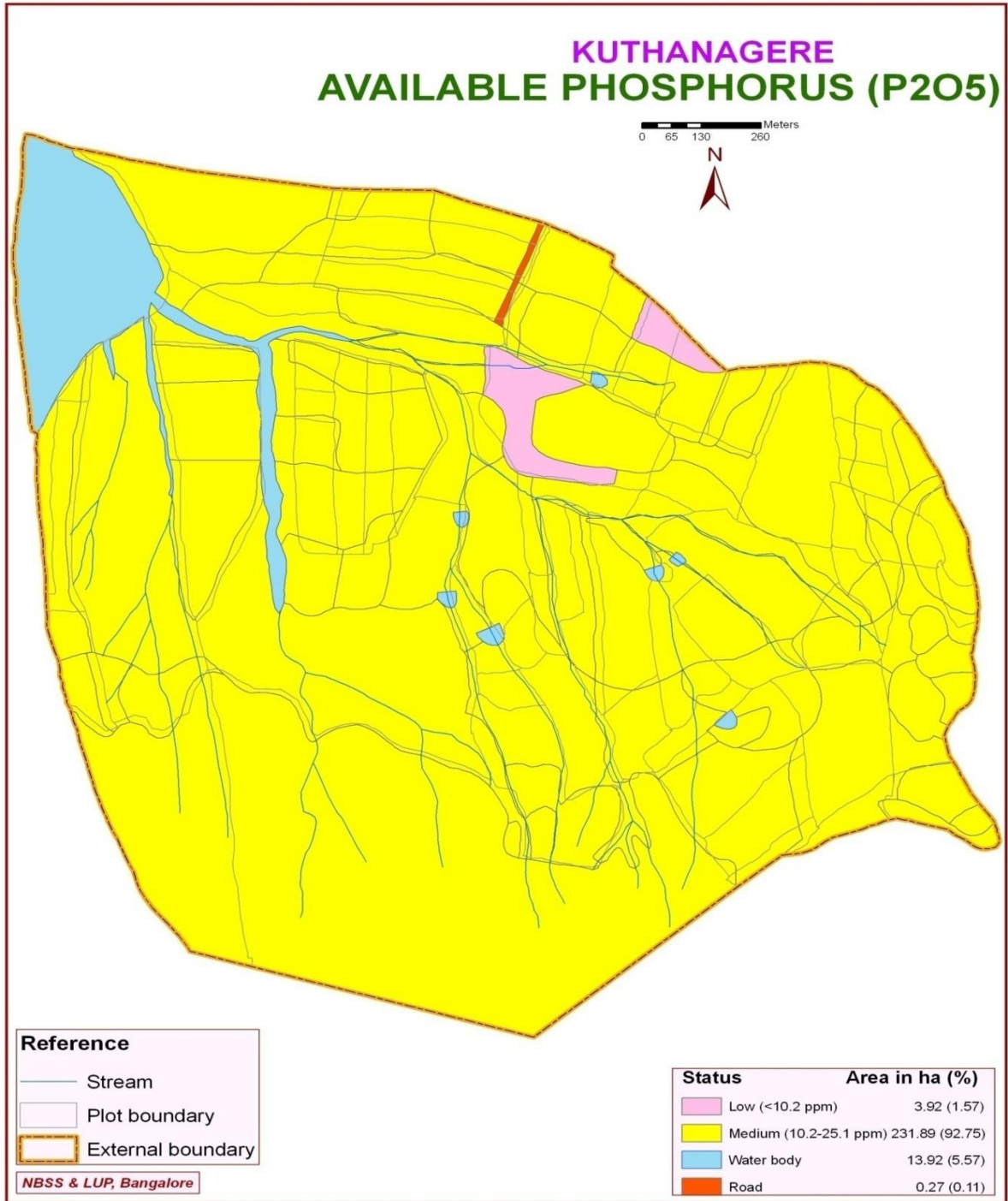


Fig. 48: Available phosphorus (ppm) content of Kuthanagere watershed

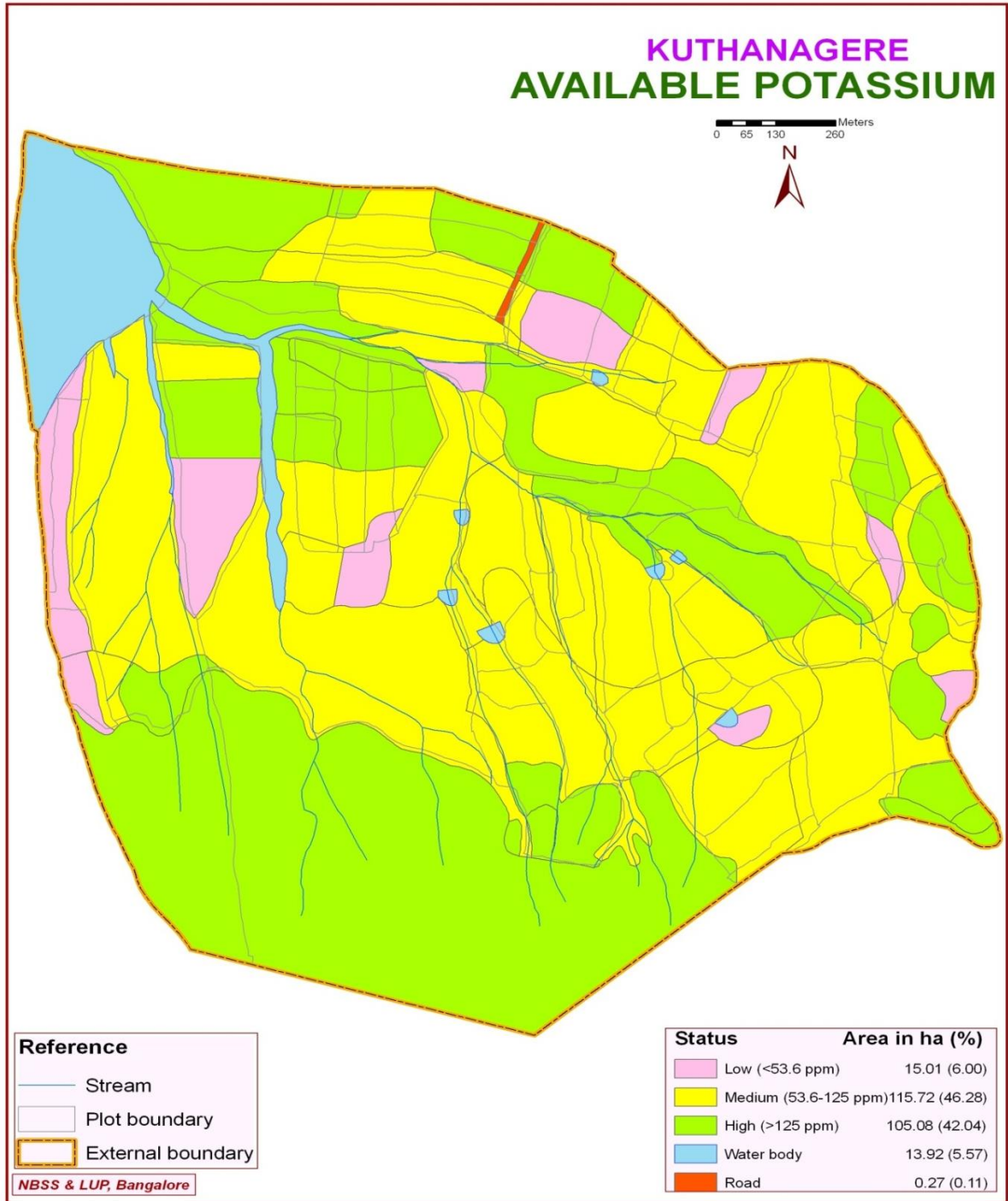


Fig. 49: Available potassium (%) status of Kuthanagere watershed

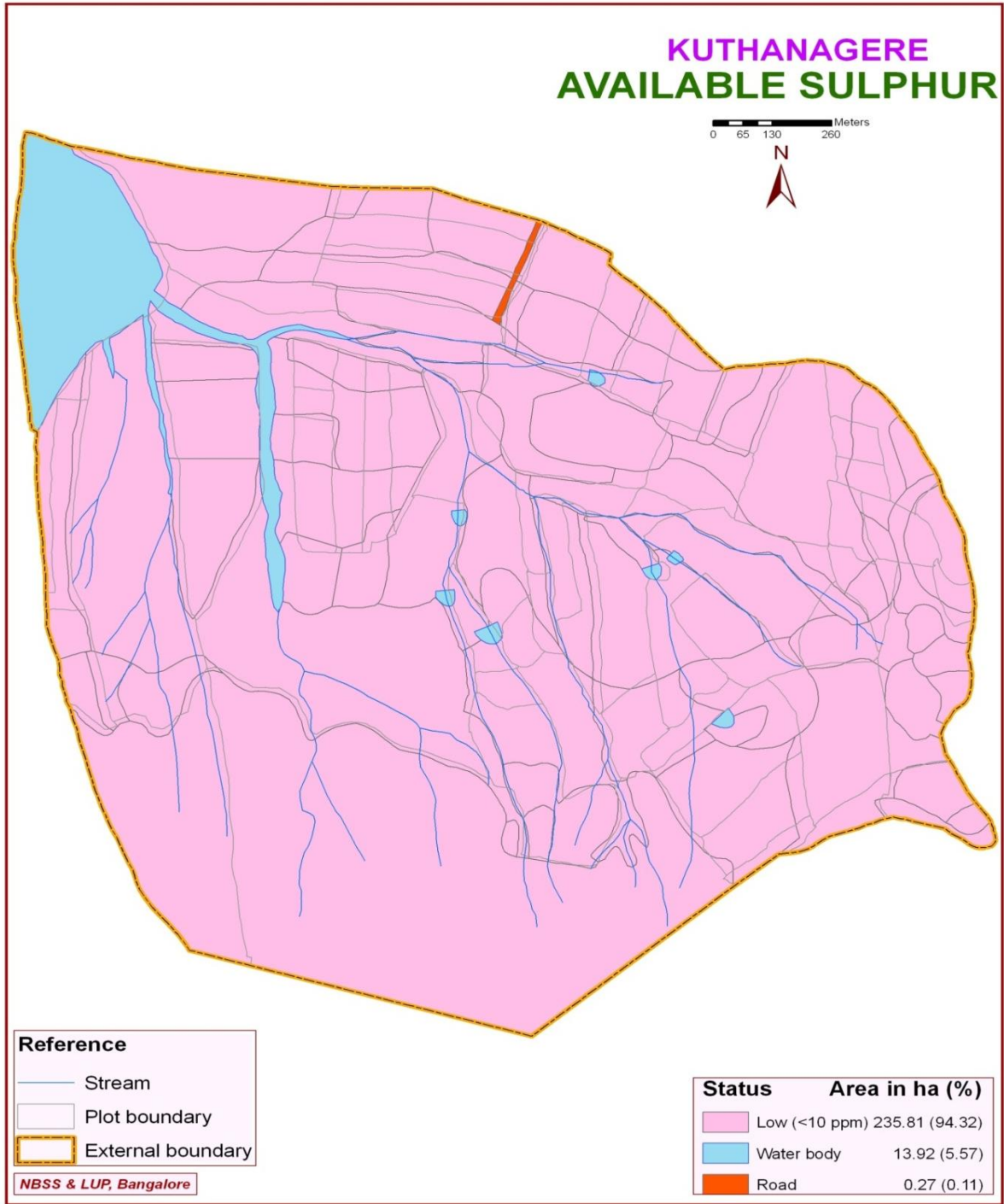


Fig. 50: Available sulphur (%) status of Kuthanagere watershed

5.6.5 Micronutrients

The data on micronutrient of soils revealed that Fe (Fig. 51), Zn (Fig. 52) Mn (Fig. 54), Cu (Fig. 53) and B (Fig. 55) varied from deficiency to toxicity level in surface samples.

High rainfall and high temperature in granite gneiss landscape and laterization assisted the accumulation of sesquioxides under redoximorphic condition favoring high concentration of Fe and Mn ions and sometimes Cu also. Porous nature of granite gneiss favored the fast leaching of Zn and boron from the solum either vertically or through laterally through seepage water. This has been reported by Anitha *et al.* (2011).

5.7 Comparison between the bench mark survey data with the results obtained during 2011 and 2012

Bird's eye view of the watershed before and after implementation at an interval of 10 years (2003 and 2013) of watershed showed conspicuous change in land use and land cover. Before implementation of watershed, land was shown to be severely eroded losing almost Ap horizon and part of B horizon with sparse or no vegetation cover (plate 21 and 22). Therefore alternate land use plan was developed and established based on the suitability of different soil sites and land forms in the watershed. Accordingly the systems developed were:

1. Agri-horticulture system with widely spaced (30 to 40 trees per ha.) Mango (*Mangifera indica*) intermixed with one or two other economical trees like curry leaves (*Murraya koenigii*), Cinnamon (*Cinnamomum zelanicum*), Pomogranate (*Punica granatus*), Jack fruit (*Artocarpus integrifolia*), Tamarind (*Tamarindus indica*) and tree like Castor
2. Silvi-pasture on scarp slopes of hill lock, foot hills, severely eroded gully lands and on field bunds. Contour V trenches of 0.25 m/sq. Cross section dug at 5 meter interval were planted with different trees species at high density of 2000 plants per ha considering the low survival rate of less than 50 per cent. The spaces between trenches were established with fodder legumes of *Styloxanthus* species. The tree species were *Acacia auriculiformis*, *Cassia siamia*, *Dalbergia sisso*, *Azadirachata indica*, *pongamia glabra*, *Lecana leucosecephala*, *ficus spp*, *Albezia*

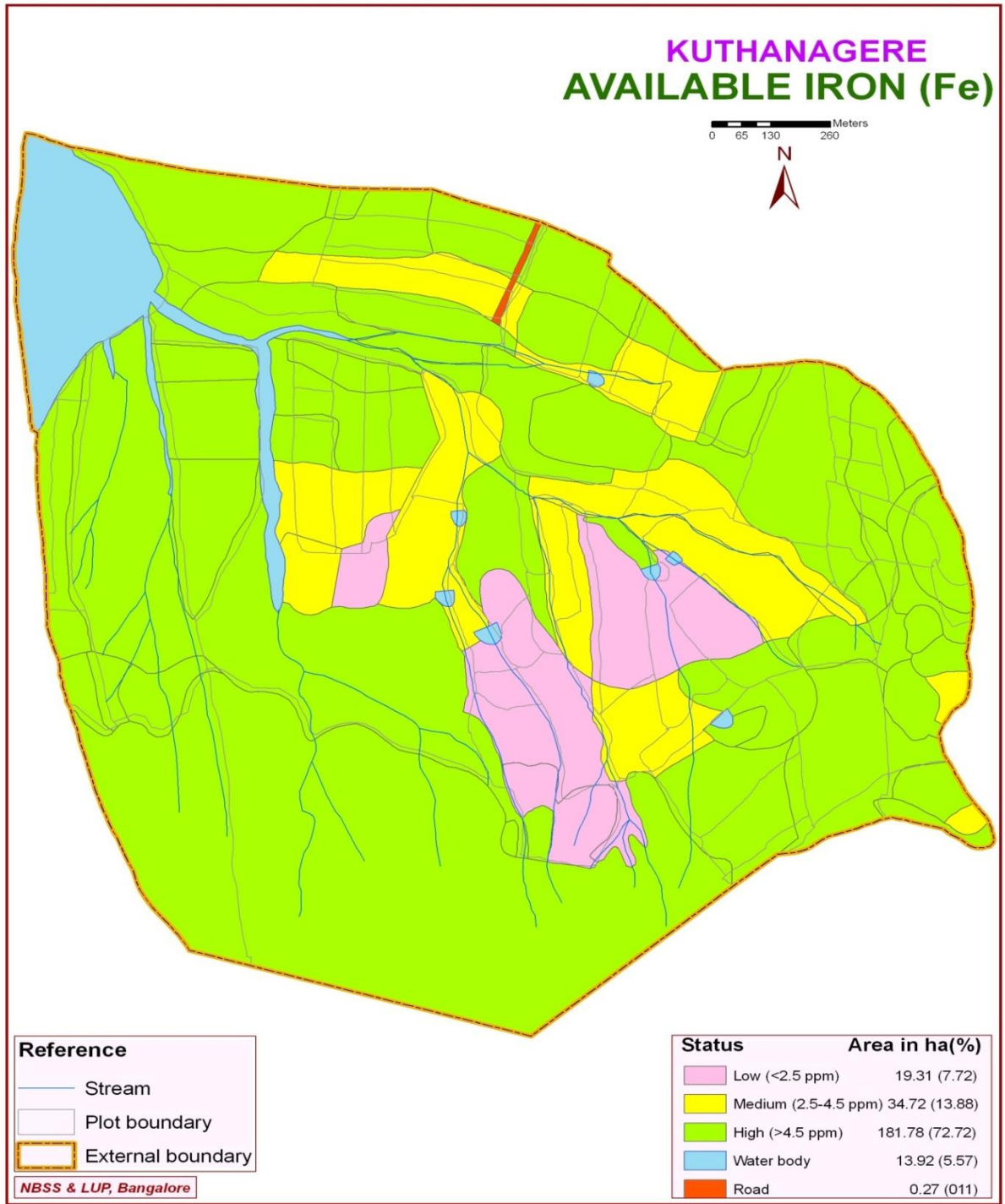


Fig. 51: Available iron (ppm) status of Kuthanagere watershed

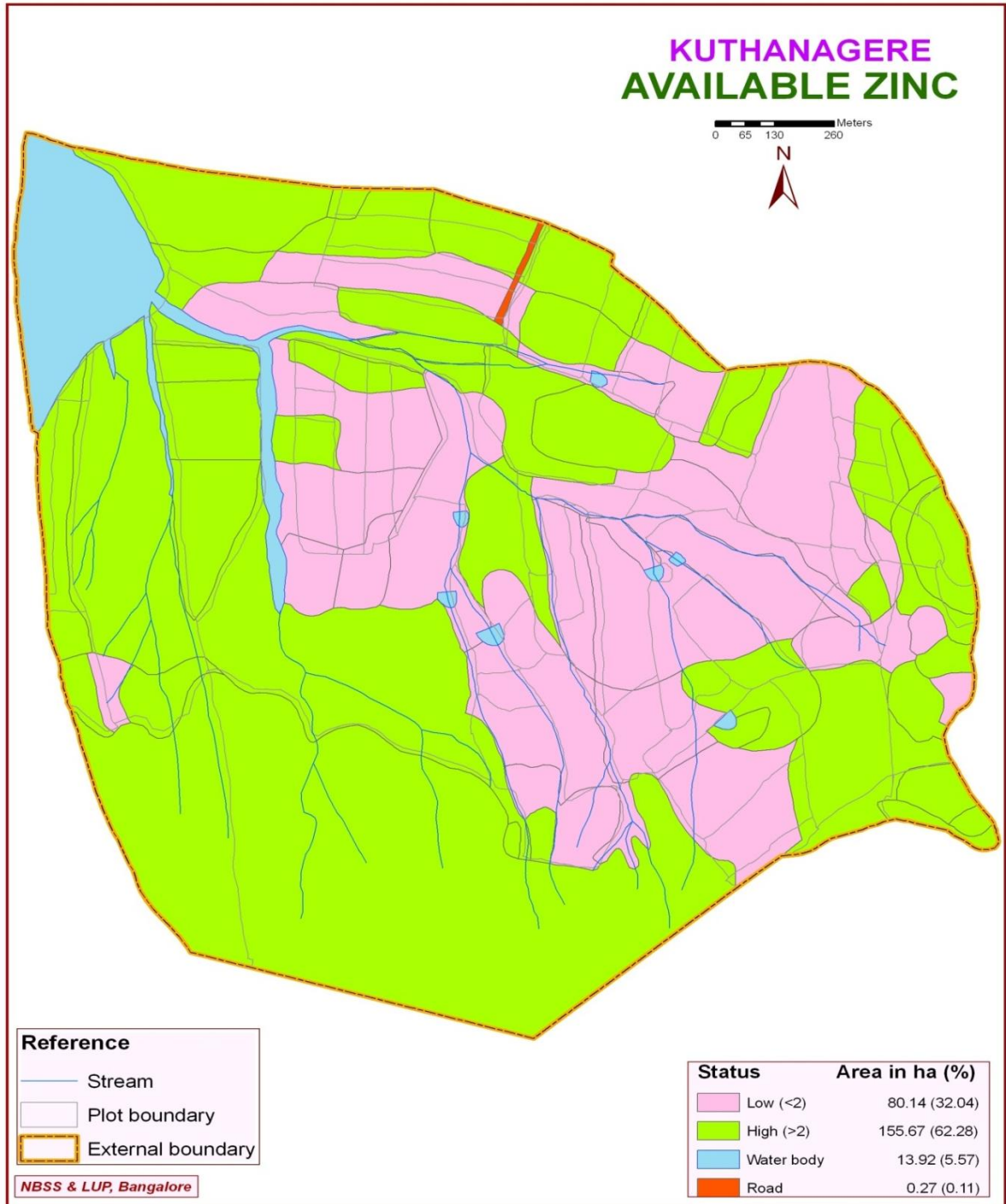


Fig. 52: Available zinc (ppm) status of Kuthanagere watershed

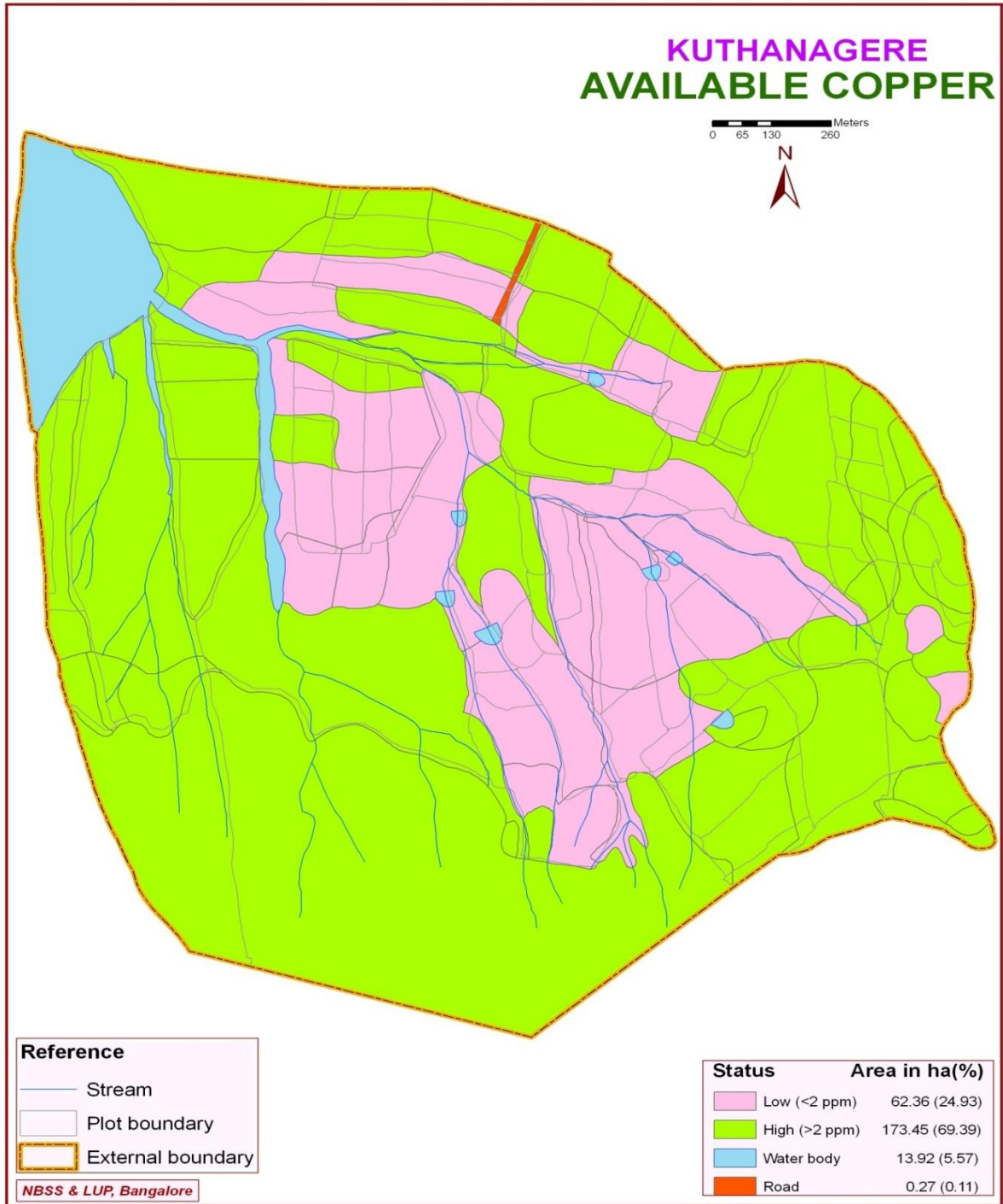


Fig. 53: Available copper (ppm) status of Kuthanagere watershed

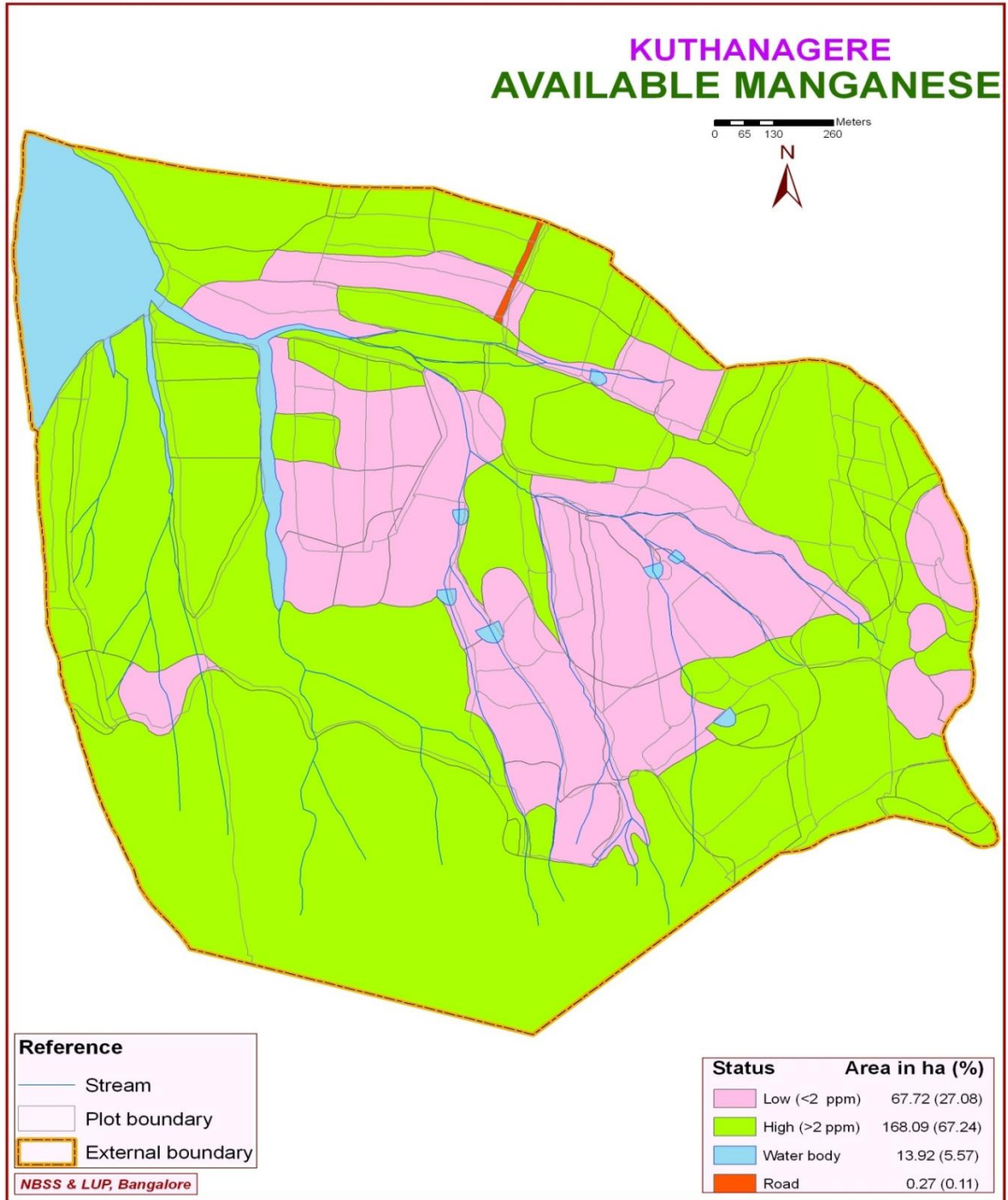


Fig. 54: Available manganese (ppm) status of Kuthanagere watershed

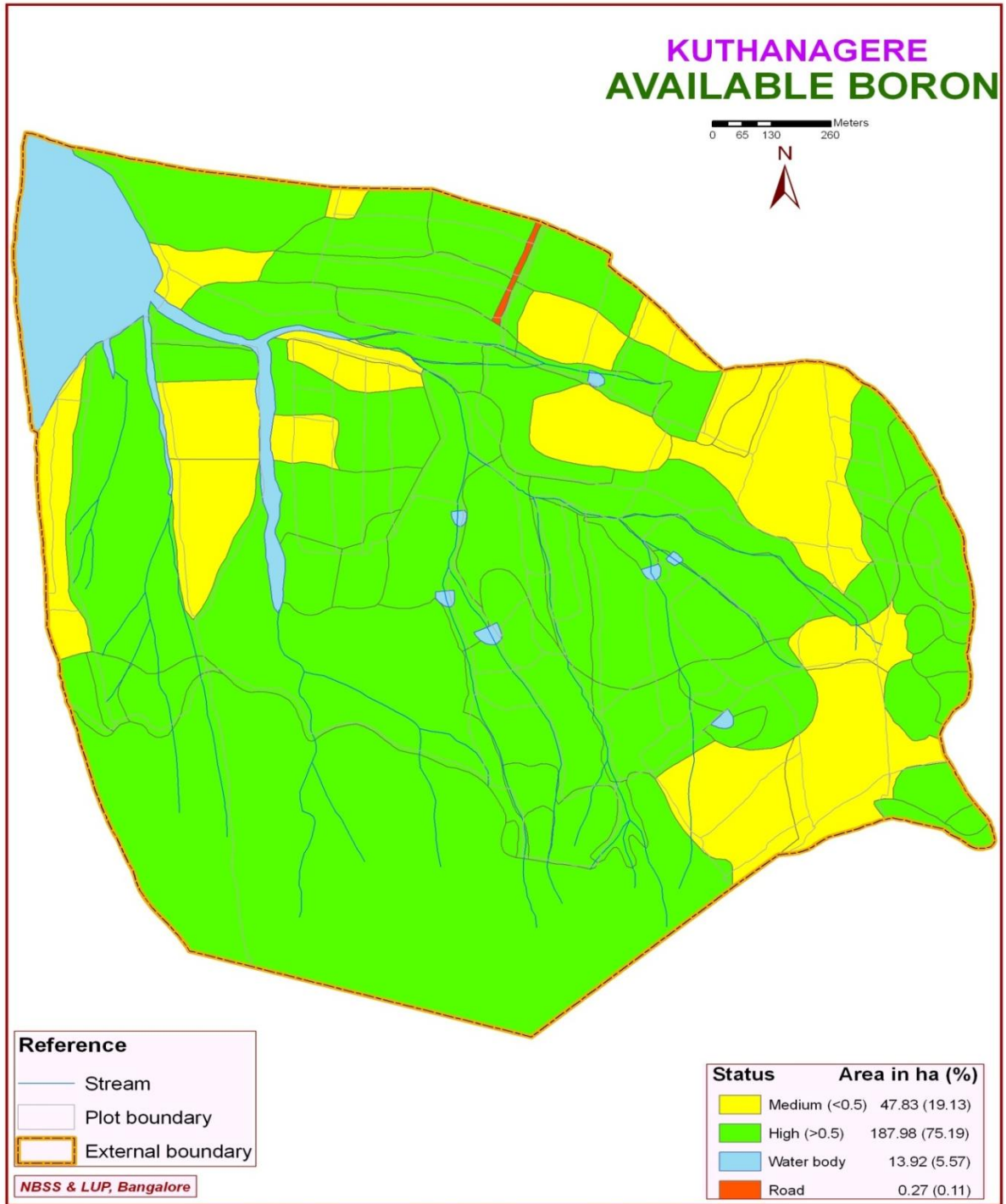


Fig. 55: Available boron (ppm) status of Kuthanagere watershed

lebbeck, bamboo and etc. along with fruits like *Phylanthus niroori, Annona scamosa, Emblica officinalis, Sisygium cumins etc.*

3. Water harvesting structures (either dug out or Nala bunds) and recycling harvested water to cultivate cash crops like chilli, tomatoes, and other vegetables.

Agri horticultural system: Plate 21 depicts bird's eye view of and a close up view of the Kuthanagere micro watershed (1992) before the watershed programme and plate 23 and 25 were the same representative, views after a lapse of 10 and 20 years showing the establishment of agri mango based mixed horticultural systems in class IV to VII lands. The improvement in land cover is clearly visible in ten years after the plantation. Besides, it generates employment and income in summer season due to mango fruit bearing in addition to the arable cropping in *kharif*. On the contrary, only arable cropping *viz.*, finger millet based akkadi system, sole pigeon pea or ground nut in only *kharif* was found less profitable and unstable due to already established prediction of a drought year once in every five years, on an average. Even in good years of S-W monsoon, the yield of arable crops on these class IV to VII lands were low compared to class II and III lands.

Due to inherent constraints of poor available water holding capacity, shorter length of crop growing periods and poor fertility status of these soils, present land use mapping (Plate 27) shows that the area under agri-horti system increased to 25.4 per cent and that of arable cropping decreased to 32 per cent in 10 years study, when compared to the past land use of 5.5 and 50.4 per cent, respectively. Further, it is certain in the improvement of standard of living and health due to more availability of balanced diet in terms of nutritive foods and spices from agri horti systems on these marginal lands, although it's difficult to measure in economic terms.

Silvi-pasture: It is nothing but growing of forest trees on lands not at all suitable for arable cropping. Plate 22 shows the partial view of watershed from north hill side taken before the establishment of Silviculture (May 1992) which looks as barren hillock and rock out crops. On these sharp slopes of the barren hillock dominant tree species of fodder, fuel, fruit, fibre, timber and green manure (*viz.*, *Aracia auriculiformis, Cassia siamea, Albeia lebbek, Delbergia sissoo, neem, tamarind, jamoon- amla, custard apple, bamboo, agave silk cotton, pongamia and etc.*) were planted on contour V ditches during



Plate 21: A bird's eye view of the Kuthanagere watershed from southern hill top before implementation of development (1992)



Plate 22: A partial view of the watershed taken from north hill side before initiation of its development (1992)



Plate 23: A bird's eye view of the Kuthanagere watershed from southern hill top after implementation of development (2003)

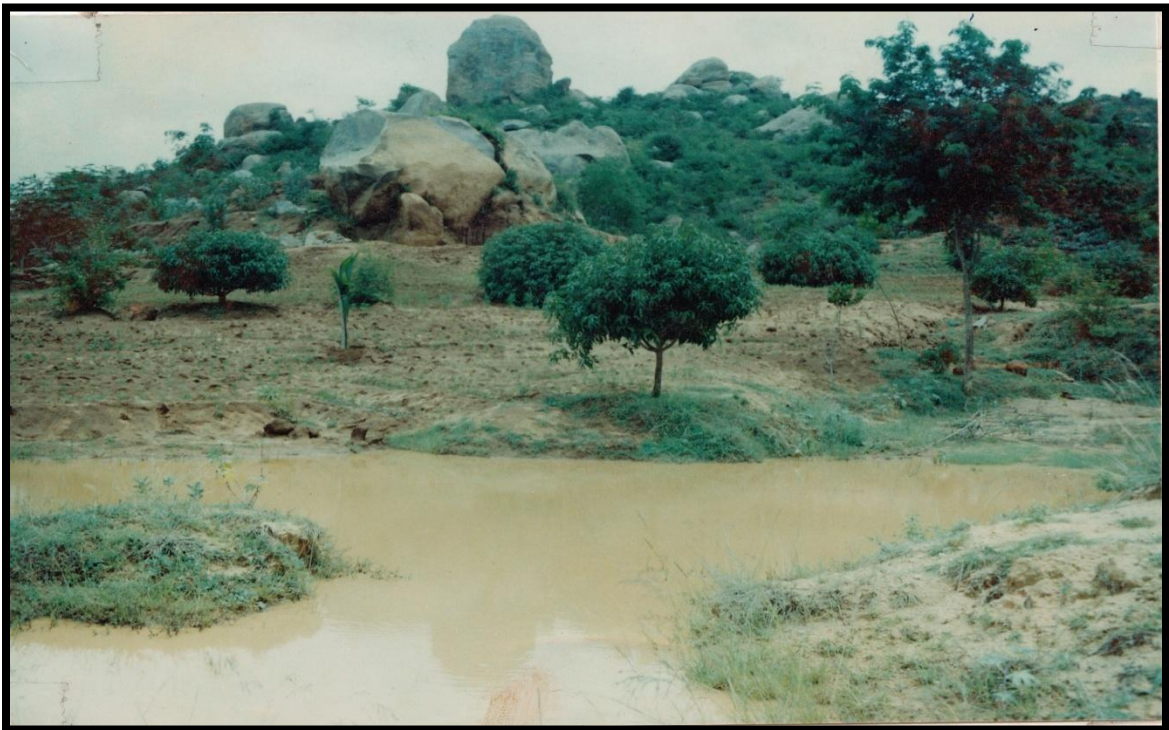


Plate 24: A partial view of the watershed taken from north hill side after initiation of its development (2003)



Plate 25: A bird's eye view of the Kuthanagere watershed from southern hill top after implementation of development (2013)



Plate 26: A partial view of the watershed taken from north hill side after initiation of its development (2013)

the onset of South west monsoon. After 10 and 20 years a lapse of silviculture (Plate 24 and 26) depicts the remarkable improvement in land cover with forest trees on scarp slopes, gullied lands and also seen are the horticultural trees.

Tree planting on field bunds with silver oak and casuarina, erect growing canopy spreading type were undertaken as agro forestry systems. These trees spp. had no shade effect on arable crops. The area under silviculture after 10 years of establishment on severely eroded gullies and on the barren hillocks increased 38.3 per cent of the watershed area

Cash cropping using harvested water in farm ponds: Pre and post monsoon contribute to nearly 40 per cent of total precipitation in most parts of southern Karnataka. These rains can be used efficiently to water the planted horticulture saplings and even to raise the summer vegetable like chillies which fetches a very price in the off season. Plate 21 depicts the partial view as highly eroded and exposed sub surface C horizon in 1992 when the watershed development programme was initiated. The same view in 2003 (Plate 24) and 2013 (Plate 26) demonstrates the luxurious growth of mixed horticultural plantation viz., Mango, Pomegranate, tamarind, guava, curry leaf and trees castor using the recycle water harvested in nala bunds. There are 12 such farm ponds constructed and being used for water harvesting and recycling in the watershed besides two check dams, six nala bunds and a big tank at the end of drainage outlet.

5.7.1 Plant available water content (PAWC) (mm), Length of growing period (days) and grain yield ($q\ ha^{-1}$) of finger millet

5.7.1.1 Plant available water content (PAWC) (mm)

PAWC was found to be higher in Kuthanagere-1 (112.4 mm) and Kuthanagere-7 (48.8 mm) soil series when compared to benchmark survey (41.1 and 43.9 mm, respectively). The increase in PAWC in Kuthanagere 1 and 7 soil series could be attributed to higher clay content as compared to benchmark survey resulting in higher water holding capacity which is available for plant uptake for longer period of time. High organic matter content in the soils has resulted in high PAWC. As organic matter content increase the volume of water held at field capacity increased at much higher rate. Hudson (1994) noticed highly significant positive correlation between organic matter and PAWC.

5.7.1.2 Length of growing period

Less number of growing days was noticed in Kuthanagere-4, 7, 9, 10 and 11 when compared to benchmark survey data. However more number of growing days was observed in Kuthanagere-1, 2, and 6 soil series when compared to benchmark results. Increase and decrease in LGP with respect to different soil series of Kuthanagere watershed can be attributed to the PAWC. Significantly high positive correlation was ($r^2=0.84^{**}$) was noticed between PAWC and LGP. Similar results are noticed by Shivaramu *et al.*, (2000) while working with soils of Kuthanagere watershed.

5.7.1.3 Grain yield ($q\ ha^{-1}$)

The grain yield of finger millet in all the soil series of Kuthanagere watershed was low as compared to benchmark yield. The per cent reduction of grain yield of finger millet in different soil series of Kuthanagere varied from 11.48 (Kuthanagere-1) to 24.66 (Kuthanagere-2). The reduction in the grain yield over a period of time was attributed to the change in cropping system from agriculture to Agri+Horti system wherein, mango is being grown in larger extent and ragi is taken as intercrop in the mango orchard (Plate 27). Shading of finger millet by mango component has a profound influence on growth and development resulting in reduced photosynthetic activity and dry matter production affecting the grain yield. Present results are in conformity with the results obtained by Lin *et al.* (1998). The reduction in the grain yield is also due to 42 per cent (485.9 mm) reduced rainfall in 2012 compared to normal rainfall (1027.6 mm) affecting the metabolic activities of plant. Similar observation was noticed by Govinda (2013) while studying the effect of precipitation on yield of millets. Soil moisture had an effect on the growth of both finger millet varieties. Drought reduced number of leaves per plant, dry matter accumulation, seed weight and yield of finger millet (Muhammad and Azam, 2007).

The grain yield of finger millet obtained during 2011 was found to be higher in all the soil series of Kuthanagere watershed compared to bench mark results. Highest percentage increase in grain yield was noticed in Kuthanagere-9 (24.96 %) followed by Kuthanagere-11 (21.50 %), Kuthanagere-7 (20.65 %) and least increase was noticed in Kuthanagere-3 (1.23 %). Higher grain yield of finger millet compared to benchmark yield can be attributed to improved depth due to watershed development activity resulting in higher plant available water content which intern increased the length of growing period of the crop.



Plate 27: Agri- horti cropping system seen in Kuthanagere watershed

5.7.2 Soil results

5.7.2.1 Physical properties

5.7.2.1.1 Sand

All the pedons showed decline in sand fractions except Kuthanagere-1, 4 and 10 which had accumulated sand over a period of time compared to bench mark survey.

5.7.2.1.2 Silt

When compared to bench mark survey slight increase in the silt content was noticed in the Ap horizons of Kuthanagere-1, 2, 3, 4, 7, 9, 10 and 13 pedons.

5.7.2.1.3 Clay

Over a period of time clay content decreased in Ap horizons of Kuthanagere-1, 4 and 10, however, accumulation of clay fractions was witnessed in Kuthanagere-2, 3, 5, 6, 7, 8, 9, 11, 12 and 13 pedons.

5.7.2.2 Chemical properties

5.7.2.2.1 Soil reaction

In Kuthanagere-1, 3, 4, 6, 7, 9, 10, 11 and 13 pedons soil has become acidic as compared to bench mark values. Reduction in the soil pH over a period of time may be attributed to use of acid forming fertilizers such as urea and DAP and also leaching of bases from surface to subsurface might be the reason for reduced pH.

5.7.2.2.2 Electrical conductivity

Among 13 pedons, in 5 pedons viz., Kuthanagere-1, 2, 4, 11 and 12, EC was found to be reduced when compared to bench mark survey.

5.7.2.2.3 Organic carbon

In all the surface soils organic carbon increased over a period of time except in Kuthanagere-4, 6 and 8. High organic carbon was mainly attributed to high vegetative cover due to agri- horticulture system resulted in lot of leaf fall from mango tree component.

5.7.2.2.4 Cation exchange capacity

The CEC of Kuthanagere-5, 8, 9, 11, 12 and 13 was found to be higher compared to bench mark survey report. The reason which may be attributed to the low CEC of the

soil is that dominance of 1:1 type of kaolinite clay and low clay content coupled with low vegetative cover.

5.7.2.2.5 Base saturation

Surface horizons of all the pedons recorded higher base saturation compared to bench mark survey except in Kuthanagere-5 and 9 which was found to be decreased over a period of time.

5.7.2.2.6 Exchangeable bases

Exchangeable sodium showed higher values in surface horizons of all pedons where as exchangeable calcium was found to be low in Kuthanagere-1, 4 and 6. Exchangeable potassium was found to be reduced in Kuthanagere-3, 6, 7, 11, 12 and 13 over a period of time. However, most of the pedons recorded lower values of exchangeable magnesium except Kuthanagere-11.

5.7.2.2.7 Available nitrogen

Majority of pedons recorded lower nitrogen content in the surface soils except in Kuthanagere-5, 7, 8, 11 and 13 which resulted in higher values compared to benchmark survey report. The reasons that could be attributed to the maximum nitrogen content observed in the surface horizon mainly is because of the fact that cultivation of crops are mainly confined to the surface horizon (rhizosphere) only and at the regular interval the depleting nitrogen content is supplemented by the external addition of fertilizer such as urea during crop cultivation. Accumulation and degradation of leaf litter over a period of time resulted in higher nitrogen content in surface horizon of forest pedon Kuthanagere-5.

5.7.2.2.8 Available phosphorus

Surface soils of all the pedons showed increased phosphorus content when compared to benchmark survey report. The reasons that could be attributed to the maximum phosphorus content observed in the surface horizon mainly is because of the fact that cultivation of crops are mainly confined to the rhizosphere only and at the regular interval the depleting phosphorus content is supplemented by the external addition of fertilizer such as diammonium phosphate during crop cultivation. Beside this acidic pH of the soil in the surface horizon was found to be another factor which causes phosphorus fixation and makes unavailable to plant uptake.

5.7.2.2.9 Micronutrient

Among micronutrient (Fe, Cu, Zn and Mn), Cu was found to be increased in all the pedons whereas, Fe was found to be increased on all the pedon Kuthanagere-12. Zn content was reduced in Kuthanagere-5, 8 and 12 soils however, surface soils of all the pedons showed reduced Mn content except Kuthanagere-12.

5.7.3 Soil depth

Soil conservation practices taken in Kuthanagere watershed had a profound influence on the depth of different soil series. Kuthanagere-1 showed 18 per cent increase in depth over bench mark survey. Similarly, Kuthanagere-4 recorded 104 per cent, Kuthanagere-5 recorded 82 per cent, Kuthanagere-6 recorded 49 per cent, Kuthanagere-8 recorded 23 per cent, Kuthanagere-10 recorded 17 per cent, Kuthanagere-12 recorded 14 per cent and Kuthanagere-13 recorded 130 percent increase in depth indicating higher accumulation of soil over a period of 20 years.

Practical utility of results

- Based on long term assessment of soil site suitability to finger millet, the most suitable soils were found to be Kuthanagere-1, 2, 3 and 6 yielding 25.50 to 31.74 q ha⁻¹. These soils were occurring on gently slopy (1-3 %) having common characteristics of deep to very deep soil depth (>90 to 150cms), well drained, sandy loam to sandy clay loam in texture with reddish brown to dark reddish brown B horizons having high moisture holding capacity (PAWC: 68-112 mm) and longer growing period (LGP: 213-243 days). The results can be extrapolated to all the existing Alfisols of Karnataka having the above characteristics.
- The long term assessment of soil fertility and yield of finger millet revealed an increase in PAWC in Kuthanagere 1 and 7 and longer growing period in Kuthanagere 1, 2 and 6 soil series compared to bench mark results due to increase in depth. However, these did not bring marked improvement in grain yield of finger millet due to introduction of mango crop as finger millet based agriculture-horticulture system.
- Among the 8 multi linear regression models established based on soil site characters, Model no. III (yield = -4.710 + 0.534 slope in percentage – 0.163 coarse fragment percentage (w/w) + 0.136 base saturation percentage + 0.116 available nitrogen in ppm + 0.098 plant available water content + 0.024 length of growing period in days) was found to be most reliable model in yield potentials in alfisols.
- Organic carbon content increased over a period of 20 years in most soil of Kuthanagere watershed.

Future line of work

- Overall impact assessment need to be assessed considering not only soil fertility and productivity of finger millet but also for other crops besides the changes in other parameters like flora and fauna, biodiversity, water table, land use land cover, land capabilities and socio economic status of the farmer.

Summary

VI. SUMMARY

Kuthanagere watershed adopted by the University of Agricultural Sciences, Bangalore was found to have thirteen soil series and forty soil phases through soil survey undertaken by the NBSS & LUP during 1992. The same watershed has been identified for the field experimentation in farmers field to study the long term effect of watershed development on changes in soil properties and productivity of finger millet and also to assess the soil site suitability for finger millet. The watershed lies at 13° 06' N latitude and 77° 11' E longitude at about 60 km West of Bangalore.

The finger millet crop was sown on nine different selected soil series in the watershed during *kharif* season in the month of August 2011 and 2012. The experiment was laid out in factorial randomized complete block design replicating thrice. Nine soil series existing on different landscape of the watershed were considered as main plots along with two varieties GPU-28 and MR-2 were considered as subplot treatments to know the performance of finger millet.

The results obtained from the investigation and the conclusions drawn are summarized in this chapter.

6.1 Performance of finger millet on different soil series

Finger millet registered significantly higher grain yield (31.74 q ha⁻¹) in Kuthanagere-1 soil series than other soil series except Kuthanagere-3. Kuthanagere-1 soil series recorded significantly more number of fingers (5.46 ear⁻¹) and more number of effective tillers at harvest (2.82). Higher yield and yield components were supported by higher growth component *viz.*, plant height, number of leaves, number of tillers and dry matter accumulation and distribution.

During entire crop growth period, the growth components *viz.*, plant height, number of leaves and tiller production were found to be significantly higher in Kuthanagere-1 soil series than with other soil series except with Kuthanagere-2.

6.2 Performance of finger millet varieties on different soil series

Higher grain yield of 25.11 q ha⁻¹ was obtained in GPU-28 compared to MR-2 (23.09 q ha⁻¹) and it was supported by higher yield attributes like 1000 grain weight, finger length, number of fingers ear⁻¹ and number of effective tillers hill⁻¹ at harvest

which were further associated with growth components such as total dry matter accumulation and distribution, number of leaves per plant and number of tillers per plant at different stages of crop growth.

6.3 Relationship of soil site characters with grain yield of finger millet

Among 25 soil site characters studied, 13 of them *viz.*, slope, erosion rating, ground water depth, coarse fragments, sand, base saturation, electrical conductivity, available nitrogen and phosphorus, exchangeable potassium, iron, copper, plant available water content and length of growing period had significant correlation with grain yield of finger millet. Among them the positive yield contributing soil parameters of finger millet were ground water depth, base saturation, available nitrogen, exchangeable potassium, plant available water content and length of growing period.

The negatively related soil parameters with grain yield of finger millet were observed to be slope, erosion rating, coarse fragments, sand, electrical conductivity, iron and copper.

6.4 Resource inventory of Kuthanagere watershed

Thirteen soil profiles representing the study area were selected based on the benchmark survey data. The soils were described in the field for their morphological properties and later characterized in the laboratory for their physical and chemical properties. Soil site suitability for finger millet was also evaluated in the watershed based on the yield of finger millet obtained during the period of experimentation (*Kharif* 2011 and 2012). In between profiles forty five surface samples were drawn from the field and analyzed for fertility status.

Depth of the soil ranged from shallow to very deep. The depth of upland pedons was comparatively less than that of the midland and lowland pedons in the study area.

The colour of the soils varied from dark reddish brown to dark red in Kuthanagere 1, 2, 3, 4, 5, 6 and 7 pedons. This was found to be mainly influenced by the type of parent material, low organic matter content and warmer temperature regime in the study area. The colour varied from dark yellowish brown to strong brown in Kuthanagere-8, 9, 10,

11, 12 and 13 pedons. This was influenced by topography and impeded drainage in the subsurface layer.

The texture of the soils was found to vary from sandy clay loam to sandy clay. Sand content was found to decrease with depth and with maximum value in Ap horizon. Whereas, clay content was found to increase with depth and stabilized at third horizon but, silt distribution followed irregular trend it was least in Bt1 and Bw2 horizons.

pH of the soil was acidic to neutral in nature. The pH was found to increase with depth whereas, electrical conductivity was found to decrease with depth indicating non-saline nature of the soils.

The organic carbon content in all the pedons varied from low to medium due to low vegetation cover (except in Kuthanagere-5 pedon). The soil erosion and warmer climate resulted in low accumulation of organic carbon in the study area.

Among exchangeable cations, calcium and sodium were dominant cations followed by magnesium and potassium. Cation exchange capacity of the soils was generally low in all the pedons.

The available nitrogen and phosphorus were low to medium. The low nitrogen content was attributed to the low organic carbon due to warmer climate and low vegetative cover with little nitrogen fertilization.

The surface soils of all the pedons were sufficient with Fe, where as Cu and Zn were found to be deficit in Kuthanagere-5, 8 and 12 pedons. Mn was found to be sufficient in surface horizons of all the pedons except in Kuthanagere-5, 8, 10 and 12.

The soil samples collected to study fertility status in the study area were analyzed for pH, electrical conductivity, organic carbon, available nitrogen, phosphorus and potassium, sulphur and micronutrients. The pH of the soils ranged from 4.7 to 7.6 indicating that soils were acidic to neutral in nature. Soil organic carbon was low to medium. Available nitrogen and phosphorus were low to medium however available potassium varied from low to high. Available sulphur was found to be deficit in all the surface soil samples. Micronutrients varied from deficit to sufficient range in the fertility samples.

6.4 Developing soil suitability mapping for finger millet in watershed

The different soils of Kuthanagere watershed have been tested for yield performance of finger millet and accordingly the suitability mapping has been done for finger millet crop integrating the earlier studies by Shivaramu *et al.* (2000).

6.5 Comparison between benchmark results and the results obtained during 2012

All the soil series showed reduced plant available water content compared to benchmark results except Kuthanagere 1 and 7.

Kuthanagere-4, 7, 9, 10 and 11 soil series showed lesser growing period compared to baseline results.

All the soil series of Kuthanagere watershed showed decline in yield compared to benchmark result. The reduction in the yield ranged from 13.68 to 25.60 percent.

Textural class of soils varied from sandy loam to sandy clay loam.

In most of the soil series pH is found to be reduced indicating increased acidic conditions of soil compared to benchmark pH

Organic carbon increased over a period of time in past of the soil series of Kuthanagere compared to benchmark result except in Kuthanagere-4, 6 and 8.

Out of thirteen soil series, seven soil series showed the decline trend compared to benchmark results.

All the soil series of Kuthanagere showed higher exchangeable sodium compared to benchmark report.

Among the major nutrients nitrogen content decreased over a period of time, however phosphorus was found to have accumulated resulting in higher phosphorus content compared to benchmark result. Potassium content was found to be high in Kuthanagere-1,2 4, 5, 8, 9 and 10 soil series.

Exchangeable calcium content was high in all the soil series of Kuthanagere compared to benchmark result except in Kuthanagere-1, 4 and 5 which recorded lower exchangeable calcium content. However, exchangeable magnesium content was found to lower in all the soil series except in Kuthanagere-11.

Among micronutrients, Fe was found to be low in Kuthanagere-12 and other soil series recorded higher Fe content over a period of time. Accumulation Cu was noticed over a period of time indicating higher amount compared to benchmark result. Kuthanagere-5, 8 and 12 soil series recorded lower Zn content compared to benchmark data whereas, other soil series resulted in higher Zn content. With respect to Mn all the soil series recorded lower values compared to benchmark data.

6.6 Variation in rainfall pattern in two years

The total annual rainfall was lower during crop growth period as compared to normal rainfall. The highest monthly rainfall was in August (197.7 mm) during 2011 as against 131.6 mm and October (161.4 mm) in the year 2012 as against 171 mm.

During the crop growth period the actual rainfall was lower than the normal rainfall in September and November (-127.8 and -26.9 mm) during 2011 whereas in 2012 the rainfall was lower in the month of July (-44.6 mm), August (-60.3 mm), September (-167.6mm), October (-9.6mm) and November (-49.6 mm).

Actual rainfall was more than the normal in the month of July, August and October (7.6, 66.1 and 2.4 mm, respectively) during 2011. However, during 2012 all the months recorded lower rainfall compared to normal.

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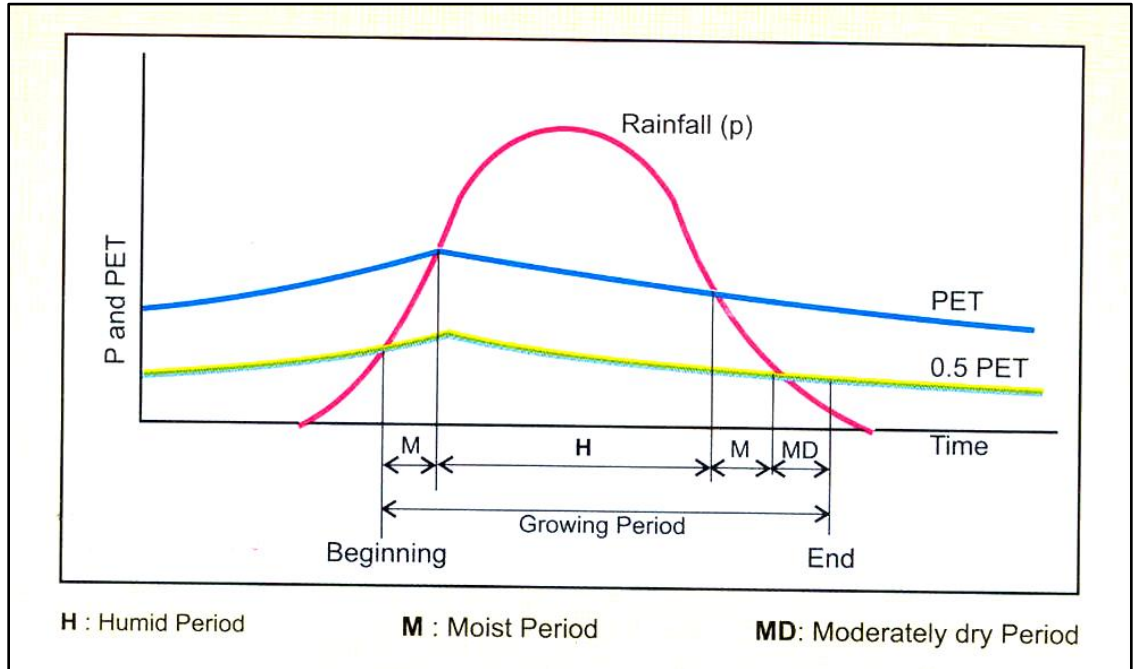
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Appendix

Appendix 1



Length of growing period

Appendix II

Critical limits of nutrients

Sl. No	Particulars	Low	Medium	High
1	pH	<6.5	6.5-8.5	>8.5
2	OC (%)	<0.5	0.5-0.75	>0.75
3	Avail. N (ppm)	<125	125-250	>250
4	Avail. P ₂ O ₅ (ppm)	<10.2	10.2-25.1	>25.1
5	Avail. K (ppm)	<53.6	53.6-125	>125
6	Avail. S (ppm)	<10	10.-20	>20
7	Zn (ppm)	<0.6	0.6	>0.6
8	Fe (ppm)	<2.5	2.5-4.5	>4.5
9	Mn (ppm)	<2	2	>2
10	Cu (ppm)	<2	2	>2
11	B (ppm)		<0.5	>0.5

Land suitability of finger millet based on yield

Class	Yield q ha ⁻¹
Not suitable	<15
Marginally suitable	15-20
Moderately suitable	20-25
Highly suitable	>25