CHARACTERIZATION OF THE SOILS OF KOLIYOOR MICRO WATERSHED USING GEOGRAPHIC INFORMATION SYSTEM.

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THESIS

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COLLEGE OF AGRICULTURE
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KERALA, INDIA

2012

DECLARATION

I hereby declare that this thesis entitled **"Characterisation of the soils of Koliyoor micro watershed using Geographic Information System"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University of Society.

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Certified that the thesis entitled **"Characterisation of soils of Koliyoor micro watershed using Geographic Information System"** is a record of research work done independently by **Mr.Appu M. G**., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

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Appu M. G.

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LIST OF ABREVIATIONS

µg	microgram
^{o}C	degree celsius
%	per cent
AAS	Atomic Absorption Spectrophotometer
ASTER	Advanced Space-borne Thermal Emission and Reflection Radiometer
Av.	Available
B	Boron
CAD	Computer Aided Design
Ca	Calcium
cm	centimeter
COA	College of Agriculture
Cu	Copper
DBMS	Database Management Software
deg.	degree
ESRI	Environmental Systems Research Institute
FACT	Fertilizers And Chemicals Travencore Ltd.
IDW	Inverse Distance Weighted
DEM	Digital Elevation Model

Def.	Deficient
dS/m	Deci Siemens per meter
EC	Electrical conductivity
et al	and others
EDTA	Ethylene Diamine Tetra Acetic Acid
e.g.	Example
Fe	Iron
Fig.	Figure
FYM	Farm Yard Manure
g/c.c	gram per cubic centimeter
GIS	Geographic Information System
GPS	Global Positioning System
ha	hectare
ID	Identity
K	Potassium
km	Kilo meter
KAU	Kerala Agricultural University
Kg/ha	Kilogram per hectare
L.U.	Land use
Mg	Magnesium
m	metre

Mg/m3	mega gram per meter cube
mm	millimeter
mm/day	millimeter per day
Mn	Manganese
Med.	Medium
N	Nitrogen
NASA	National Aeronautics And Space Administration
Sl. No.	Serial number
NWDPRA	National Watershed Development Program for Rainfed Area
Org	Organic
PC	Personal Computer
P	Phosphorus
ppm	Parts per million
Suff.	Sufficient
S	Sulphur
TIN	Triangular Irregular Network
Y/R	Yellow/Red
Zn	Zinc

Introduction

1. INTRODUCTION

Planning is the first step of management and it is a widely accepted way to handle complex problems of resource allocation and decision making. Planning finds its real viability only when it is done based on ecological/natural units. Watershed is the ideal natural unit for development planning. From the analytical and experiential knowledge, scientific community came out with the concept of watershed for the sustainable development. Watershed approach uses sound, scientifically based information from an array of disciplines to understand the factors influencing ecosystems, human health, and economic conditions of a particular resource. Watersheds reveal interconnections, so that relationships between biophysical and socio-cultural processes can be clarified. Because of these facts, it became the converging point of social development and ecological sustainability. Researchers have found that all types of natural resource management planning works best when it is on a watershed basis. Being a highly important ecological entity, soil must be managed on watershed basis so that we will be able to consider all the interactions and interdependencies that exist between soil and other ecosystem entities.

Formation of a comprehensive inventory, a database is the pre-requisite for a proper management plan. Agricultural land use decisions are often taken by arbitrary judgment principally due to the absence of reliable database on the soil resources. Extensive data collection and the proper handling of the data on soils are the essential steps in agricultural development planning. It is common that planners and policy makers will have to face the problems like large quantity of data, incompatibility within the data categories, its obsolescence, difficulties in data base upgradation, etc. It would make the planning a time consuming process as well as difficult.

The introduction of modern technologies has led to an increased use of computers and information technology in all aspects of data handling. The software technology used in this domain is GIS. There is vast scope for the use of geo-informatics in making the planning process more easy and efficient. Besides the common steps of data handling like collection and storage of data, GIS helps to analyze them and form secondary data from existing relationship between primary data. It has become an outstanding data management tool because of the facts like data is handled on spatial basis, conventional difficulties of data management are avoided, new vistas of data sharing and upgradation, etc. The technology is used for planning in several fields. Agriculturalists more than other profession, have an intimate relationship with the land spatial data management. The qualities of their land determine the quality of crops or the well being of their animals that in turn decides their livelihood. The farmer always has to think about how she or he is going to manage various parts of farm, because of their heterogeneity. That is, there is tremendous spatial variability in farmland and farmers need to understand the effects this will have on their crops and animals. Scientists encounter similar spatial variability in their field experiments and trials. It is not possible to formulate development plans for a larger area without a high expenditure in terms of time, economics and energy. Bringing all the data into the planning desk alone will ease the work. The policy makers and planners need to assess the data spatially and temporally for a large area. Therefore, these areas envisage the need of GIS as a planning tool.

This research work has been undertaken with the objective of characterization of the soils of Koliyoor micro watershed using Geographic Information System.

Review of Literature

2. REVIEW OF LITERATURE

Planning is a widely accepted way to handle complex problems of resource allocation and decision making. According to Clayton *et al.* (2002), it is about preparing for the future. A comprehensive data bank and resource mapping are the two pre-requisites for planning. It is well-known that data management is the most important aspect which decides the effectiveness of planning. Data management comprises the tasks of data capturing, data storage, updating and manipulation of data, data analysis and interpretation. In the case of regional development, planners and policy makers have to deal with large quantity of spatial and non-spatial data. The conventional data management tools and systems were unable to overcome various difficulties associated with the quantity and quality of the data and thus the planning process was not smooth. Advancement of computer related technologies helped to solve several age-old difficulties of all the aspects of life. In the domain of data management and planning, the computer related technology used is Geographic Information System (GIS). Relevant literature on the basics of GIS and its applications are collated hereunder.

2.1 GIS

GIS is a computerized spatial information system for supplying data or information for planning and policy making. According to the type and use of GIS, several definitions of GIS has been coined. GIS is a system of hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modeling and displaying of spatially referenced data for solving complex planning and management problems (Bernhardsen, 1999).

Clarke (2001) described GIS as an automated system for capture, storage, analysis and display of spatial data. Chang (2002) defined GIS as a computer system for capturing, storing, querying and displaying geographic data. Geographic information system is a computer system that can hold and use data describing places on earth's surface (Das, 2004). GIS can be defined as an organized collection of computer hardware and software designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information (ISSS, 2007).

GIS is a computerized data base management system for capturing, storing, validating, analyzing, displaying and managing spatially-referenced data sources (Seghal, 2008)

2.1.1 Data Sources for GIS

In the context of GIS, data means representations that can be manipulated using a computer. It can be obtained from various sources and are stored as a database in a GIS and enables future use of stored data for an effective and efficient manipulation of spatial and non-spatial data (Aravind and Rakesh, 2004).

Rao (2000) had suggested geographic data base requirement for GIS applications at different scales. Though topographical maps provide some spatial information about natural and cultural features of terrain, it is not enough for developmental planning.

Timely and reliable information on natural resources with respect to their potentials and limitations is a pre-requisite for sustainable development. Data sources for creating new data include remotely sensed data, GPS data and paper maps (Chang, 2002).

Any textural, tabular, graphical data that can be referenced to geographic feature serve as attribute data sources (Saifudeen, 2006). Hard copy maps, aerial photographs and remotely sensed imageries are the most commonly available spatial data sources (Saifudeen, 2006)

Among various data sources, remote sensing and GPS are the most important and popular nowadays.

2.1.1.1 Remote sensing

Remote sensing is the science of obtaining information about objects or phenomenon in the environment through the use of sensing devices located at a distance without there being any contact between the object and sensing device (ISSS, 2007). Generally remote sensing can be divided into two categories as ground-based and space based. Information about the object is derived from its characteristic spectral properties. Now a days, remote sensing is extensively used for data collection for various studies.

Liu *et al.* (2011) made use of remote sensed imagery to evaluate land use changes for calculating ecological service values of the landscape. Remote sensing has been utilized successfully for studying the environmental degradation of southern fringe area of Madurai city (Saravanan*et al.,* 2010).

Marathe and Chandrashekhar (2011) used remotely sensed imageries for studying the subsurface sediments to enquire the tectonic history of a coastal area located on the southern bank of BharjaRiver in Rathnagiri district of Mararshtra. Remotely sensed digital imageries have been identified as reliable tool for assessing potential impact of landscape change (Nie*et al.,* 2011).

Fugura*et al.* (2011) used RADARSAT-1 imagery for shoreline delineation by overcoming the conventional difficulties like cloud cover. Marshall *et al.* (2012) identified the potential of remote sensing techniques in combination with surface re-analysis for monitoring evapo-transpiration.

Remote sensing data were used to interpret the spatial land surface information and derive the model parameters for assessing the non-point source pollution for a watershed (Yang *et al.,* 2011). Mayilvaganan*et al* (2011) said that remote sensing and GIS techniques are very efficient and useful for identification of ground water potential.

Waring*et al.* (2011) used remote sensing for deriving patterns of large-scale disturbances n forests of Pacific North-West region in response to recent climatic change. Marinoni*et al.* (2011) found that combined remotely sensed imagery and census information even allow for the specification of a probability for individual land uses.

The combination of digital elevation model and remote sensing is a powerful way to examine the relationship between topography of land and it's spectral characteristics (Menon, 2000).

Rao, D.V.K.N. (2000) studied the reflectance of rubber along with teak and mixed forest in individual bands, false colour composite and Normalised Difference Vegetation Index images. GIS users can process satellite images and extract data for a variety of maps in vector format such as land use and land cover, hydrography, water quality and areas of eroded soils (Chang, 2002).

2.1.1.2 Global Positioning System

Global Positioning System (GPS) is a space based navigation and positioning system administered by U.S military, which helps to determine the exact position of an object on the earth surface in terms of geographical co-ordinates (French, 1996).

GPS is used extensively for GIS data collection (Pradeep, 2006). Apel*et al.* (2011) identified GPS based techniques are best for monitoring of river stages which is one of the basic observations required for understanding catchment hydrology and hydraulic systems. GPS technology was utilized for practicing site-specific irrigation that reduced the water loss significantly (Charles *et al*., 2011).

Palaniswami*et al.* (2011) identified the necessity for a change in farming system of sugarcane to incorporate controlled traffic, wider row spacing and permanent cropping beds with the aid of GPS guidance.

The usefulness of linking and integrating GIS with other precision agricultural technologies such as remote sensing (Markley *et al*., 2003; Schmidt *et al*., 2001), GPS (Fuelling and Wright, 1997) and base maps with agronomic data (Jhoty, 1995) makes GIS an attractive precision agricultural technology.

Tractor based RTK-GPS systems provide substantial savings in agro-chemical with associated environmental and economic advantages for sustainable agricultural production systems (Perez-Ruiz *et al.,* 2011).

2.2 APPLICATIONS OF GIS

In recent times, application of GIS in the management of natural resources is increasing at a fast pace.

2.2.1 Agricultural application of GIS

Pandey*et al.* (2003) integrated GIS with soil conservation service (SCS) model for estimation of runoff from Karso watershed of DamodarBarkar catchment in Hazaribagh district of Jharkhand state.

Singh *et al.*(2003) developed a suitable methodology for estimating crop area by integrating remote sensing and GIS based spatial sampling approach. Hegazy*et al.* (2003) described a method in using remotely sensed data and GIS for monitoring the land use of Gabal Elba area, South Eastern desert, Egypt.

Garg and Seth (2003) integrated the information on land use and cropping pattern that was extracted with the help of multi-data satellite imageries as well as existing records and stored as different layers in GIS in the form of spatial and non-spatial data.

Results of a GIS study gave clues to reasons behind high incidence of stunted disease in black pepper in some of important districts of Kerala where the incidence is surveyed and data plotted. Environmental factors like altitude, temperature and rainfall were also included to corroborate occurrence of vectors and the disease (Parthasarathy*et al.,* 2005).

2.2.2 Applications of GIS in Forestry

To control the forest degradation, the governments need to know where, when, how fast and why such degradations happen. Based on such knowledge, a general and sustainable management of these resources will be possible.

Jayakumar*et al.* (2002), in a case study to monitor the extent of degradation of forest in Kolli hills of Eastern Ghats using remote sensing and GIS obtained vital information for conservation and planning of resources. Saadi and Abolfazal (2003) used remote sensing and GIS for analysis and estimation of deforestation in forest area of Arasharan in North-West of Iran in the period of 1987 and 2001.

The GIS analysis of land use dynamics coupled with factors of regional development can reveal the status and reasons of deforestation (Bahadur, 2011). GIS was used heavily for tropical forest assessment (Singh *et al*., 2003).

GIS is having a very good utility in biodiversity conservation, assessment of deforestation, identifying the gaps in conservation and habitat selection (Menon and Bawa, 1997). Estimation of above ground biomass has been made by range of methods from field measurements to remote approaches using auxiliary data (Lu, 2006).

GIS technology was proved efficient for calculating net primary productivity of Italian forests (Chirici*et al.,* 2007).

2.2.3 Application of GIS in Environmental Monitoring

Raheja (2003) discussed an approach for the use of GIS based software application framework for environmental risk management due to need for displaying and analyzing a huge volume of spatial as well as non-spatial environmental hazards and exposure data, in a fast and accurate manner.

Banarjee*et al.* (2003) used GIS technology to integrate and compile the data from various sources to design an information system that evaluated environmental hazards of tea garden belt in Jalpaguri district.

GIS and satellite image processing was used to identify, locate, map and analyze the existing data on the district for modeling the Arsenic hazard zones in West-Bengal (Basu and Sili, 2003). GIS has been included as an analytical tool in a variety of natural resource management practices (Aravind and Rakesh, 2004).

Ramos and Gracia (2011) utilized GIS in combination with remote sensing data to map, recognize and assess the spatio-temporal change in channel morphology. Zhang *et al* (2011) applied a versatile GIS based spatial auto-regression (SAR) for assessing land salinisation in Yellow river delta.

Gasol*et al.* (2011) used GIS as an environmental analysis tool to provide an integrated methodology to find suitable areas of cultivating Brassica spp. Avtar*et al.* (2011) used GIS based model for erosion hazard zonation.

Prasannakumar*et al.* (2010) combined Revised Universal Soil Loss Equation (RUSLE) has been used in combination with remote sensing and GIS techniques to assess the spatial pattern and annual rate of soil erosion in Munnar forest division in Western Ghats. Ali *et al.* (2011) used GIS based methods to quantify the impacts of potential land use change on the storm-runoff generation in a river basin.

2.2.4 Application of GIS in disaster management

Sharma and Dubey (2003) attempted to develop an analytical object oriented model in GIS for flood plain zoning.

Pandey*et al.* (2003) prepared a map using GIS technology showing the recorded earthquake data and other derived parameters generated for a part of Delhi city, thus producing preliminary seismic micro-zoanation map for Delhi.

GIS technology was used for impact resection of water network in urban areas and to provide decision supported disaster management during earthquake in Iran (Mehrizi, 2003).

Emam*et al.* (2003) evaluated risk of desertification of Varamin plain, Iran using GIS. Ramos and Gracia (2011) identified remote sensing and GIS are key tools to map and monitor the geomorphologic change for flood management.

2.2.5 Application of GIS in Business

Ammana and Raina (2003) demonstrated the capability of GIS in planning strategy for business. Russel and Heidkamp (2011) used GIS methodology to analyze the detrimental effect of loss of a supermarket on geographical food access on the city's residents.

2.2.6 Applications of GIS in Socio-economy

GIS was used to monitor and solve some urban problems of overpopulation (Rao*et al*, 1999; Usha and Suresh, 2002)

The use of GIS in routing traffic and traffic control has been demonstrated in various parts of world (CESS, 2001; Chattopadhyay*et al*, 2002)

Ashwani*et al.* (2003) tried an automated GIS application to give general geographically related information desired by election commission of U.P.

2.3 WATERSHED MANAGEMENT AND GIS

The watershed is advocated as an appropriate unit for ecological planning (Steiner *et al*., 2000). GIS has been used in various aspects of watershed management. In India, integration remote sensing and GIS for prioritizing watershed has been done by CEE (2001); Khan (2002) and Gosain and Rao (2004).

According to Mohrana (2002), GIS provides tool to delineate watersheds and in tandem with remote sensing data, delineation of watershed had become easier.

Other operations of GIS in watershed management are its use in resource appraisal (Ram, 2002), evaluation of ground water potential (Sarkar*et al.,* 2001) and land use change detection (Bisht and Kothyari, 2001; Chakraborthy*et al.,* 2001).

Tomar*et al.* (2002) used integrated approach through remote sensing and GIS for generating site specific action plan for Shipra watershed, Meghalaya.

Amatya*et al.* (2011) said that, SWAT is a GIS based basin scale model widely used for characterization of hydrology and water quality of large, complex watersheds.

Using GIS software, geomorphology, soils, land use/land cover maps were combined to generate actions plans in a watershed. (Sidhu *et al.,*2000)

Mahajan*et al.* (2001) utilized the GIS applications to find the effect of topography on land use in AshwaniKhad watershed in Himachalpradesh

Jayakumar and Arockisamy (2003) in Tamilnadu, utilized GIS and remote sensing to study the land use/land cover changes. Dewidar (2004) conducted similar study in Nile delta of Egypt.

Rao and Fizee (2004) prepared detailed thematic maps of soil, land use/ land cover, hydro-morphological maps using satellite data of Katepurasa watershed in

Maharashtra. The critical areas for land treatment in selected micro-watershed were identified using GIS environment.

Kashiwar*et al.* (2009) made detailed thematic maps of soil, land use/ land cover of Salai watershed in Maharashtra. Roy *et al.* (2010) identified that Cartosat DEM can be used as an input for planning the development of watershed.

Sekhar and Rao (2002) identified soil erosion zones to suggest measures for control of soil erosion using remote sensing, GIS and conventional techniques in the PhulangVagu watershed in Sriramsagar catchment area of Andrapradesh.

Dineshkumar*et al.* (2007) utilized the GIS applications to delineate the ground water potential zones of Muvattupuzha river basin, Kerala along the South-West coast of India.

Chowdary*et al.* (2009) prepared detailed thematic maps of soils, land use and hydro-geomorphology of Mayurakshi watershed, India.

Praveen *et al.* (2010) used GIS technology for comparative assessment of runoff and annual silt load from micro-watersheds.

Survey of literature revealed that there is increasing number of studies reported on natural resource management using GIS techniques for integrated studies for optimal land use planning.

Materials and Methods

3. MATERIALS AND METHODS

The investigation under report was conducted at Koliyoor micro watershed, situated at about 12 km from ThiruvananthapuramCity, in Kerala state, during 2010-2012. The study was conducted using facilities of the department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani and the department of Soil Survey and Soil Conservation, Government of Kerala. Materials used for the study and methods adopted are explained hereunder.

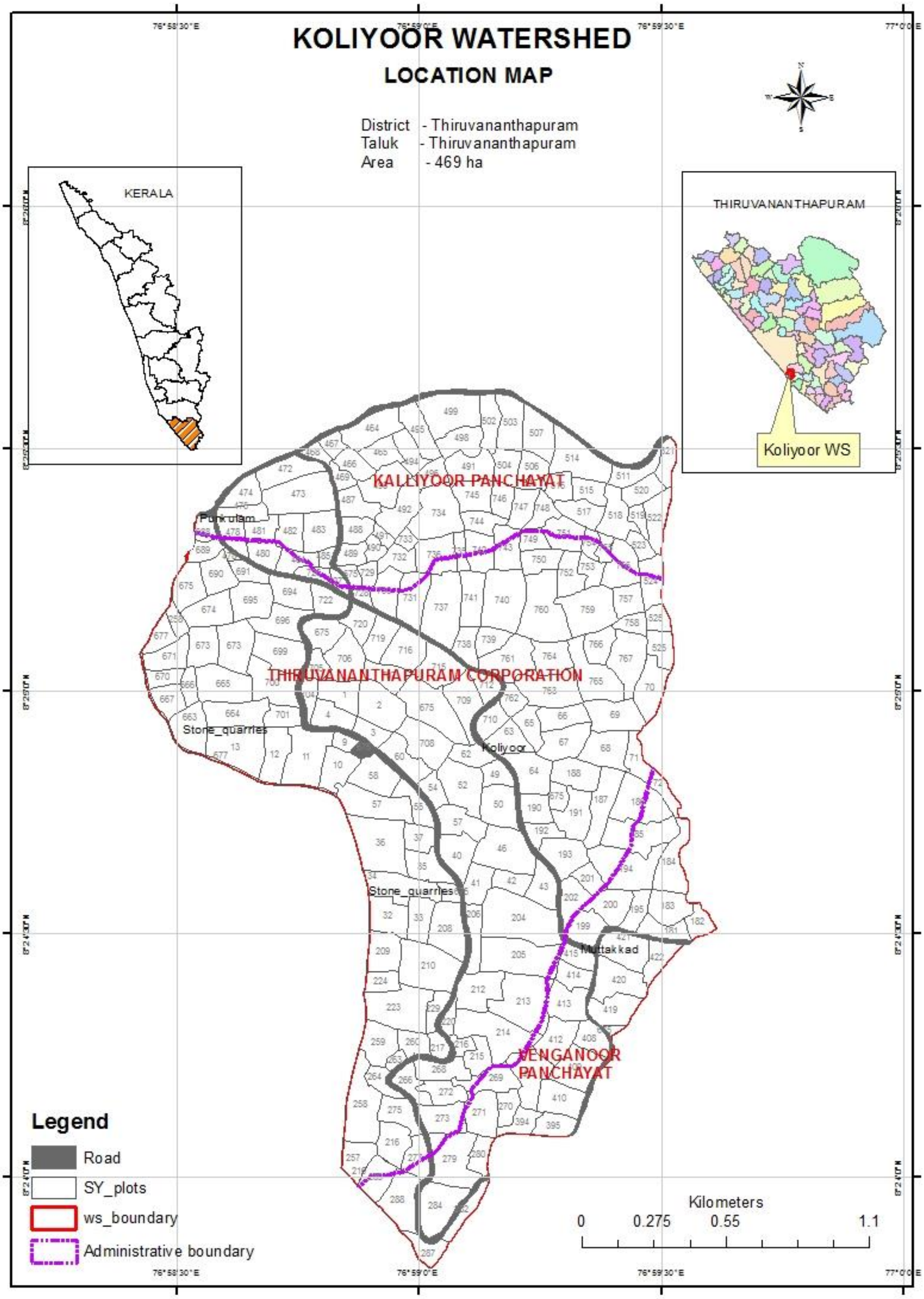
3.1 GENERAL DESCRIPTION OF THE AREA

Koliyoor micro watershed is located in the North-West side of Thiruvananthapuram district, which is 12 km away from the city. It is a part of Vellayani lake watershed. It is bound by Poonkulam-Kalliyoor road in the southern side, West poonkulam-Kovalam road (K.S. road) in the western side and the Poonkulam-Kalliyoor road in the northern side. The Vellayanilake acts as the eastern boundary as well as the outlet of water courses from the watershed. Total area of Koliyoor micro watershed is 469 ha. However, frequent inundation of survey plots near the lake has restricted the effective area into 421 ha. The important populated places within the Koliyoor micro watershed are, Kovalam junction, Azhakulam junction, Muttackad junction, Koliyoor junction, and Poonkulam junction. Koliyoor micro watershed comprises areas of Kalliyoorpanchayath, Venganoorpanchayath and Thiruvananthapuram Corporation. Fig. 1 shows the location map of Koliyoor micro watershed.

3.1.1 Natural vegetation

Abundance of perennial trees is spectacular in Koliyoor micro watershed. The plots are under a considerable coverage of weeds which include monocots as well as dicots.

Fig. 1. Location map of Koliyoor micro watershed



3.1.2 Land use

The whole area of Koliyoor micro watershed can be categorized into agricultural and non-agricultural areas. Agricultural plots can be further divided based on prominent land use of the plots. Three categories of plots were identified in this manner. They were the plots in converted paddy fields, plots having coconut based cultivation and the plots under homestead cultivation. However, it is very difficult in the case of majority of the plots, to precisely include them in a particular land use category because of extreme diversity of cultivation and land management.

Converted paddy fields are with the intensive cultivation of banana, cassava and vegetables. Some of these plots remain without any cultivation also. Plots under coconut based cultivation are having cassava, turmeric, etc as intercrops. A few plots are under good management. Most of the coconut fields are at slops. Various erosion control measures and water conservation measures were seen in the plots under scientific management. Majority of the area of Koliyoor micro watershed comes under homestead cultivation. These plots are dominated by perennial trees like mango, cashew, guava, jack fruit, etc. Soil in these plots is relatively undisturbed.

Non-agricultural plots are dominated by stone quarries. Most of them are near to the western ridgeline (K.S. road). Now a days, a lot of plots are being converted for non-agricultural purposes like construction works, mining, etc.

3.1.3 Water resources

Koliyoor micro watershed contains three main water streams which drain ultimately into Vellayanilake. Muttakkad stream originates from Valiyakulam and reaches the lake at Muttakkad. Koliyoor stream originates from Mekkolikulam and drains into Vellayani Lake near Koliyoor. The third stream is from an ephemeral source located near Channelkkara junction and drains into Vellayani Lake near the western end of Kakkamoola bund road. At present situation, it is very difficult to trace the exact flow-path of these streams because of large scale land changes.

Eastern side of the Koliyoor micro watershed is getting water for irrigation from the Vellayani Lake while the western region is supplied with the water stored in abandoned stone quarries.

3.1.4 Climate

The climate of the area is humid tropical with an average annual rainfall of 1680mm and temperature ranging from 19 to 31. Weather data recorded by meteorological observatory at College of Agriculture, Vellayani is presented in Appendix I.

3.2 BASE RESOURCE MATERIALS

Cadastral maps of the study area were available with the Department of Soil Survey and Soil Conservation and the same was used as basic resource material in this investigation. The map was at a scale of 1:5000. Other supplementary spatial data sources utilized in this study are Toposheets prepared by the Survey of India (1:50000), Digital Elevation Model (ASTER-30m) availed from the free data base of NASA and Google Earth imageries.

The GPS receiver units available with Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani were used for recording the geographical coordinates of the sampling locations. Various GIS operations were conducted with the help of facilities available at the Geomatics lab of Department of Soil Survey and Soil Conservation. ArcGIS (Version 9) was used for the whole GIS operations with the help of extensions viz. Spatial Analyst and Geostatistical Analyst for area calculations and terrain analysis respectively.

3.3 SPATIAL DATA INPUT

There is no single method of entering the spatial data into a GIS. The important data input methods are digitising, automatic scanning, coordinate geometry and conversion of existing digital data. In this study, digitising was followed.

Scanning is a digitizing method that converts an analog map into a scanned file, which is then converted to vector format through tracing (Verbyla and Chang, 1997). The cadastral map was scanned using A_0 scanner and saved in *.tiff format. Further it was georeferenced using the reference points taken using the GPS receiver unit. The ground control points used were Kovalam junction, Muttakkad junction, Poonkulam junction, Azhakulam junction and Channelkkara bus waiting shed. Digitisation was performed after georeferencing.

Digitisationwas performed using ArcGIS software. The digitized files were saved in *.prj format to be further exported to DXF format. The vectorised file was then imported into PC Arc/Info to make Arc/Info coverage and they were further transformed into shape files for further analysis**.** Thus the cadastral layer was created and it was used for all the GIS operations as the base thematic layer except the terrain analyses.

3.4 FIXING OF SAMPLE POINTS AND SAMPLE COLLECTION

The cadastral thematic layer was converted into '.kml' format for projecting it on the satellite imagery of Google earth. Thus the Google earth satellite imagery of the Koliyoor micro watershed on which the cadastral layer was overlaid was produced. Using the hard copy of this map, the sampling locations were fixed. Areas of settlements, buildings, quarries and other plots of non-agricultural uses were given minimum preference for taking the samples.

The sampling sites were marked using GPS receiver unit. Table 1 shows the GPS readings of geographical co-ordinates of sampling locations as well as sample numbers assigned to each soil sample. Fig. 2 shows the map of Koliyoor micro watershed on cadastral basis merged with the layer of sampling locations. About 500g soil were collected from each sample site in a polythene bag and

Table 1. GPS readings of geographical co-ordinates of sampling locations and sample numbers assigned to each soil sample in Koliyoor watershed

Sl. No.	Sample ID	GPS Location	Latitude (deg.)	Longitude (deg.)
1	S 1	2Ndoutlet	8.416053	76.989514
2	S 2	1	8.424408	76.989572
3	S 3	514	8.423893	76.990041
4	S 4	515	8.414406	76.976372
5	S 5	516	8.414454	76.97644
6	S 6	517	8.424856	76.986036
7	S 7	518	8.424332	76.986903
8	S 8	519	8.423936	76.984523
9	S 9	520	8.423385	76.983933
10	S 10	521	8.421373	76.981807
11	S 11	522	8.421308	76.981373
12	S 12	523	8.422789	76.980949
13	S 13	524	8.422719	76.98024
14	S 14	525	8.423101	76.978303
15	S 15	526	8.424824	76.979767
16	S 16	527	8.419777	76.982333
17	S 17	528	8.417989	76.981766
18	S 18	529	8.419596	76.983419
19	S 19	530	8.417065	76.983738
20	S 20	531	8.420051	76.985272
21	S 21	532	8.419191	76.985413
22	S 22	533	8.418458	76.986988
23	S 23	534	8.419671	76.987623
24	S 24	535	8.416846	76.990039
25	S 25	536	8.416814	76.985646
26	S 26	537	8.414501	76.985994
27	S 27	538	8.415044	76.983955
28	S 28	539	8.416581	76.982181
29	S 29	540	8.414277	76.984935
30	S 30	541	8.415269	76.986675
31	S 31	542	8.416045	76.987076
32	S 32	543	8.416767	76.989163
33	S 33	544	8.416422	76.991222
34	S 34	545	8.413974	76.987904
35	S 35	546	8.407708	76.988651
36	S 36	547	8.408554	76.989198
37	S 37	548	8.409462	76.988191
38	S 38	549	8.409852	76.991082
39	S 39	550	8.408199	76.991096
40	S 40	551	8.408285	76.990618
41	S 41	552	8.409108	76.991511
42	S 42	553	8.406225	76.987427
43	S 43	554	8.405484	76.988225
44	S 44	555	8.404273	76.98703
45	S 45	556	8.405296	76.985889

Table 1. GPS readings of geographical co-ordinates of sampling locations and sample numbers assigned to each soil sample in Koliyoor watershed (Continued..)

Sl. No.	Sample ID	GPS Location	Latitude (deg.)	Longitude (deg.)
46	S 46	557	8.426376	76.985773
47	S 47	558	8.426111	76.599855
48	S 48	559	8.425275	76.985634
49	S 49	560	8.424234	76.986013
50	S 50	561	8.424771	76.984809
51	S 51	562	8.425832	76.984426
52	S 52	565	8.415811	76.985165
53	S 53	566	8.413038	76.987874
54	S 54	567	8.412483	76.987921
55	S 55	568	8.421254	76.975273
56	S 56	570	8.418906	76.974462
57	S 57	571	8.417566	76.974616
58	S 58	572	8.415811	76.975214
59	S 59	573	8.414656	76.975935
60	S 60	574	8.413757	76.977734
61	S 61	575	8.403007	76.981403
62	S 62	576	8.400673	76.983706
63	S 63	577	8.401042	76.983197
64	S 64	578	8.401494	76.984574
65	S 65	579	8.401139	76.985406
66	S 66	580	8.399806	76.984961
67	S 67	581	8.398943	76.983484
68	S 68	582	8.397621	76.983716
69	S 69	583	8.402884	76.986714
70	S 70	584	8.416197	76.979414
71	S 71	585	8.415641	76.979012
72	S 72	586	8.415422	76.979834
73	S 73	587	8.415051	76.981318
74	S 74	588	8.413855	76.982574
75	S 75	589	8.413279	76.983903
76	S 76	590	8.411781	76.983932
77	S 77	591	8.411156	76.984449
78	S 78	592	8.409814	76.984796
79	S 79	593	8.408576	76.984799
80	S 80	594	8.406947	76.983516
81	S 81	595	8.410088	76.989422
82	S 82	596	8.411867	76.989814
83	S 83	597	8.412917	76.990008
84	S 84	598	8.412552	76.991383
85	S 85	599	8.411415	76.992129
86	S 86	600	8.410572	76.991613
87	S 87	601	8.414039	76.990241
88	S 88	602	8.425239	76.982191
89	S 89	603	8.424478	76.982035
90	S 90	604	8.413405	76.986112

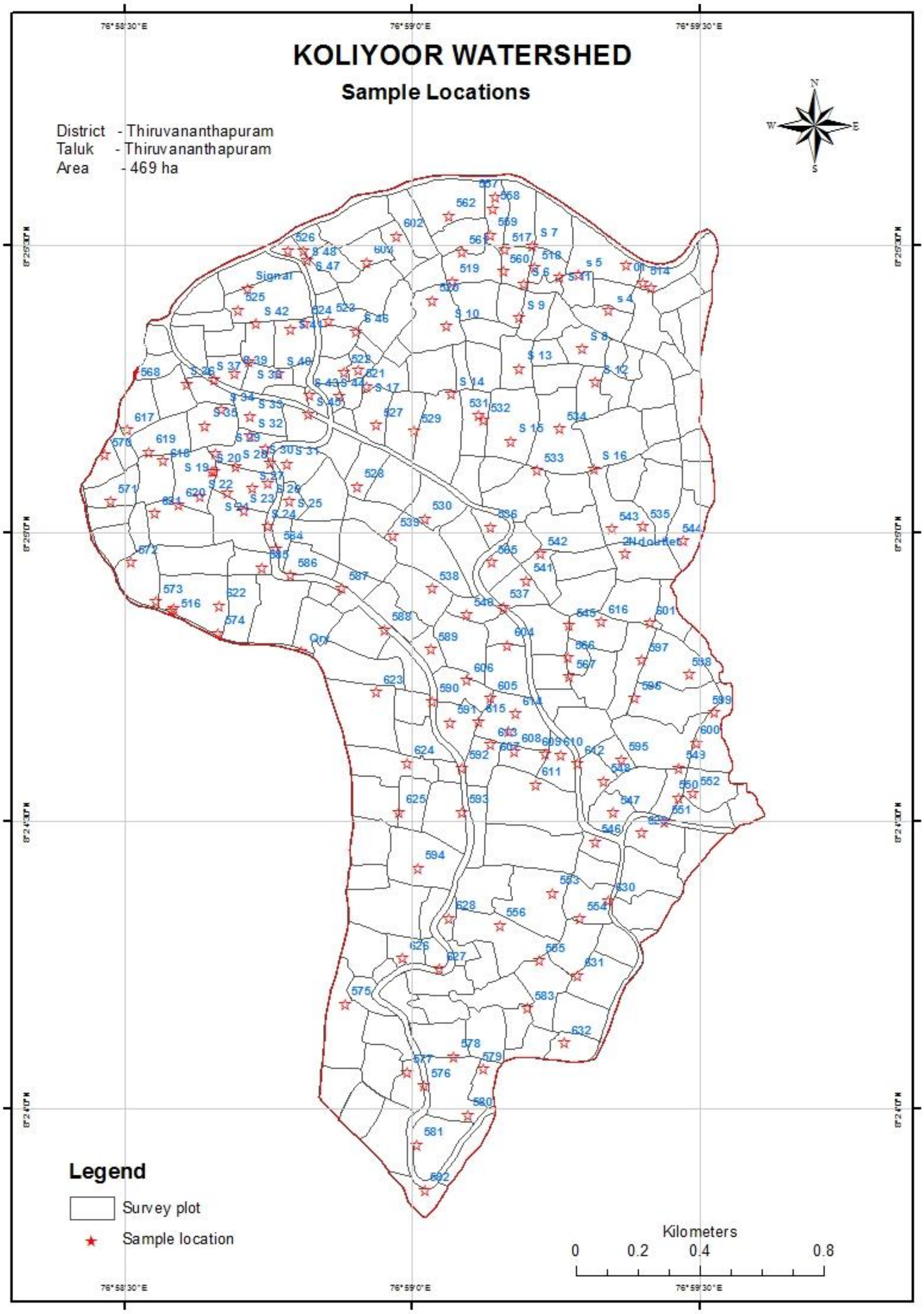
Table 1. GPS readings of geographical co-ordinates of sampling locations and sample numbers assigned to each soil sample in Koliyoor watershed (Continued..)

Sl. No.	Sample ID	GPS Location	Latitude (deg.)	Longitude (deg.)
91	S 91	605	8.411876	76.985636
92	S 92	606	8.412393	76.984947
93	S 93	607	8.410895	76.986147
94	S 94	608	8.410335	76.986316
95	S 95	609	8.410239	76.987215
96	S 96	610	8.410228	76.987654
97	S 97	611	8.409364	76.986936
98	S 98	612	8.409995	76.988115
99	S 99	613	8.410502	76.985634
100	S 100	614	8.411427	76.986342
101	S 101	615	8.411186	76.985273
102	S 102	616	8.414072	76.988837
103	S 103	617	8.419628	76.975088
104	S 104	618	8.418738	76.976123
105	S 105	619	8.418996	76.975739
106	S 106	620	8.417455	76.976578
107	S 107	621	8.417215	76.975892
108	S 108	622	8.414548	76.977773
109	S 109	623	8.412035	76.982307
110	S 110	624	8.409982	76.983218
111	S 111	625	8.408573	76.982970
112	S 112	626	8.404347	76.983063
113	S 113	627	8.404028	76.984114
114	S 114	628	8.405503	76.984422
115	S 115	629	8.407974	76.990011
116	S 116	630	8.406018	76.989051
117	S 117	631	8.403843	76.988142
118	S 118	632	8.401895	76.987774
119	S 119	Outlet Colleg	8.423765	76.990276
120	S 120	Qry	8.413227	76.980152
121	S 121	S 10	8.422630	76.984338
122	S 122	S 11	8.424047	76.987635
123	S 123	S 12	8.421024	76.988683
124	S 124	S 13	8.421411	76.986464
125	S 125	S 14	8.420671	76.984478
126	S 126	S 15	8.419309	76.986217
127	S 127	S 16	8.418515	76.98862
128	S 128	S 17	8.420875	76.982049
129	S 129	S 18 Coconut	8.418945	76.977641
130	S 130	S 19	8.418434	76.97763
131	S 131	S 20	8.418447	76.977554
132	S 132	S 21	8.417816	76.977992
133	S 133	S 22	8.417698	76.977223
134	S 134	S 23	8.417282	76.978496
135	S 135	S 24	8.416843	76.979181

Table 1. GPS readings of geographical co-ordinates of sampling locations and sample numbers assigned to each soil sample in Koliyoor watershed (Continued..)

Sl. No.	Unique ID	GPS Location	Latitude (deg.)	Longitude (deg.)
136	S 136	S 25	8.417558	76.97978
137	S 137	S 26	8.418085	76.979189
138	S 138	S 27	8.417951	76.978709
139	S 139	S 28	8.41857	76.978238
140	S 140	S 29	8.419108	76.97909
141	S 141	S 30	8.418687	76.979232
142	S 142	S 31	8.41865	76.979721
143	S 143	S 32	8.419466	76.978668
144	S 144	S 33	8.420018	76.97865
145	S 145	S 34	8.420221	76.977838
146	S 146	S 35	8.419764	76.977335
147	S 147	S 36	8.420966	76.976842
148	S 148	S 37	8.421096	76.977621
149	S 149	S 38	8.421623	76.978634
150	S 150	S 39	8.421269	76.978203
151	S 151	s 4	8.423083	76.989063
152	S 152	S 40	8.421251	76.979484
153	S 153	S 41	8.422556	76.979814
154	S 154	S 42	8.422711	76.978832
155	S 155	S 43	8.42063	76.980367
156	S 156	S 44	8.420619	76.981232
157	S 157	S 45	8.420076	76.980334
158	S 158	S 46	8.42248	76.981737
159	S 159	S 47	8.424552	76.980306
160	S 160	S 48	8.424811	76.980227
161	S 161	s 5	8.424118	76.988172
162	S 162	S 6	8.423846	76.986583
163	S 163	S 7	8.424969	76.986825
164	S 164	S 8	8.421981	76.988281
165	S 165	S 9	8.422885	76.986472
166	S 166	Signal	8.423728	76.97858
167	S 167	557	8.427397	76.985724
168	S 168	599	8.411353	76.993101
169	S 169	600	8.410475	76.993071
170	S 170	552	8.409157	76.993795
171	S 171	551	8.407945	76.993597
172	S 172	582	8.396648	76.983716
173	S 173	570	8.418906	76.973684
174	S 174	571	8.417615	76.973449

Fig. 2. Cadastral map of Koliyoor micro watershed showing sampling locations



labeled for transportation to laboratory. A total of 174 soil samples were finalized for analysis.

3.5 SAMPLE PROCESSING

The soil samples were transported to the laboratory. Samples were then air dried and powdered gently. Weighed samples were sieved through a 2mm sieve. Coarse fractions above 2mm were discarded after careful weighing in an analytical balance. Fine earth fractions were packed in plastic jars and arranged serially in samples racks for laboratory analysis.

3.6 LABORATORY ANALYSIS

Analytical methods followed in soil analysis are as follows:

	Character	Method	Reference
1	Physical properties		
	Mechanical composition	Hydrometric method	Piper, (1967)
	Bulk Density	Undisturbed core sample	Black *et al*, (1965)
	Water holding capacity	Undisturbed core sample	Black *et al.*, (1965)
	Porosity	Undisturbed core sample	Black *et al*, (1965)
2	Chemical properties		
	pH	pH Meter	Jackson, (1973)
	Electrical conductivity	EC meter	
	Organic carbon	Walkley and Black’s chromic acid wet digestion	Walkley and Black, (1934)

	Character	Method	Reference
	Available P	Bray No.1 extraction and ascorbic acid reduced molybdo-phosphoric blue color method	Bray and Kurtz, (1945)
	Available K	Neutral normal ammonium acetate extraction and flame photometry	Jackson, (1973)
	Available Ca and Mg	Neutral normal ammonium acetate extraction and titration with EDTA	Hesse, (1971)
	Available S	Extraction by CaHPO4	Chesnin and Yein, (1950)
	Available Fe, Mn, Zinc and Cu	AAS using 0.1N HClextractant	Sims and Johnson, (1991)
	Available B	Hot-Water extraction	Gupta, (1967)

3.7 INTEGRATION OF ATTRIBUTE DATA IN GIS

After the analysis of samples for various parameters, the data was entered into excel sheet and organised into rows and columns of respective parameters. The 'Join and Relate' functions available with the ArcGIS software was used for this purpose. After the data integration, data checking was performed in order to eliminate the slightest errors. In this way, all the survey plots were assigned with the corresponding survey numbers and all the sample points were attached to the soil attribute data obtained from the analysis.

3.8 USE OF THE GIS TECHNOLOGY

The GIS technology is developing at faster pace than many ICT tools. New innovations are forthcoming every now and then! A functional GIS generally integrates data on land features with the geography of corresponding place. However, the data used in GIS is the most important component and an erratic datum will render any GIS useless.

3.8.1 Data types in GIS

GIS technology utilizes two basic types of data. These are *spatial data* that describes the absolute and relative location of geographic features on the surface of earth and *attribute data* that describes the characteristics of the spatial features. These characteristics can be quantitative and/or qualitative in nature. Spatial data for the current study is the map of Koliyoor micro watershed and the attribute data are all the tabular data generated during the investigation.

3.8.2 Data Editing and Quality Assurance

Data editing and verification is performed to reduce the errors that arise during the encoding of spatial and non-spatial data. Several kinds of errors can occur during data input. They are incompleteness of the spatial data, location placement errors of spatial data, distortion of the spatial data, incorrect linkages between spatial and attribute data and incomplete or wrong attribute data. Data editing of this project was done in Arc GIS software.

3.8.3 Organizing Data for Analysing in GIS

Most GIS software organizes spatial data in a thematic approach that categorizes data in vertical and horizontal layers. This approach allows data to be input as separate themes and overlaid based on analysis requirements. Spatial data layers are commonly input one at a time and accordingly, attribute data are entered as one layer at a time. A variety of terms are used to define data layers in commercial GIS software. These include themes, coverage, layers, levels, objects, and feature classes. Most GIS projects integrate data layers to create derived themes or layers that represent the result of some calculation.

The results of chemical analysis of soil samples and other information about the watershed were organised as thematic layers for further processing.

3.8.4 Data Analysis in GIS

The chief advantage of using GIS software is that the analytical functions are totally integrated with the DBMS component which is the basis for all analysis techniques. Most GIS's provide the capability to build complex models by combining primitive analytical functions. Aronoff (1989) identified four categories of GIS analysis functions. The range of analysis techniques in these categories is very large.

3.8.4.1 Retrieval, reclassification and Generalization

Reclassification involves looking at an attribute, or a series of attribute, for a single data layer and classifying the data layer based on the range of values of the attribute. Accordingly, features adjacent to one another that have a common value but differ in other characteristics will be treated and appear as one class. In a vector based GIS, boundaries between polygons of common reclassed values are dissolved to create a cleaner map of homogenous continuity. The ability and process for displaying the results of reclassification, a map or report, will vary depending on the GIS software.

3.8.4.2 Topological overlay

Topological overlay is predominantly concerned with overlaying point data in polygon, line data in polygon, and polygon on polygon. By combining multiple layers in a topological fashion complex queries can be answered concerning attributes of any layer.

In this investigation, all the maps were produced by over laying fertility status layer on cadastral layer because; it is the most useful type of map at farmers' level. Map showing NPK status of soils of Koliyoor micro watershed was generated by overlaying individual layers of available N, available P and available K. Similarly, over laying technique was utilized for assessing area and the location of specific survey plots in the different slope gradient classes.

3. 8.4.3 Neighborhood Operations

Neighborhood operations evaluate the characteristics of an area surrounding a specific location. Neighborhood operations include interpolation and buffering. The important interpolation methods available with ESRI GIS software packages are Kriging, IDW, Triangulation, Spline and Trend.

In this study, Inverse distance weighted (IDW) interpolation has been used for geostatistical analysis and map preparation. IDW interpolation technique determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a locationally dependent variable.

This method assumes that the variable being mapped decreases in influence with distance from its sampled location. Thus, the soil fertility reading at a sampling location decreases in influence with distance.

3.9 PROJECTION OF DIGITIZED SPATIAL DATA

The transformation from the geographic grid to a co-ordinate system is referred to as Map projection (Chang, 2002; Kumar, 2004). The digitized map was projected using ground control points with known co-ordinates by the projection utility available with ArcVIEW. The digitised contours were projected using the reference grid traced from the Topographical sheet of Survey of India. Albers equal-area projection system was followed as the projection for the current study.

3.10 OUTPUTS FROM THE GIS

One of the main advantages of GIS software is the provision for well laid out thematic maps after required analysis of attribute data. In the current investigation, the soil parameters of Koliyoor micro watershed were spatially analysed at cadastral level and related to other terrain features namely slope, slope direction, etc. Various maps were generated on single and multiple themes that are presented in the results and discussion chapters.

Results

4. RESULTS

Characterisation of Koliyoor micro watershed in terms of soil parameters was accomplished through analysis of 174 soil samples from the watershed for various parameters. The results of soil analysis were organized as a soil database and the same was linked to the corresponding locations in the spatial database using appropriate GIS tools. Thus, a soil information system for Koliyoor micro-watershed was developed using GIS technology and maps showing the spatial variation of various soil parameters were generated.

4.1 TEXTURAL VARIATIONS

The textural values of soil samples (feel method) from Koliyoor micro watershed are given in Table 2 and Table 3 presents the mechanical composition of soil samples collected on grid basis.

Textural analysis revealed that the soil samples taken fell into two textural classes, Sandy Clay Loam and Sandy Loam. When the samples were assessed by feel method, 13 % of samples showed grittiness, an average ribbon length of 18 mm with medium sand visible, which indicate that they belong to the Sandy Loam textural class. Among these samples,three representative samples were subjected to hydrometric analysis and they showed Sandy Loam texture which confirmed the finding through feel method. 87 % of the samples showed moderate grittiness and strong coherence at sticky point. Average ribbon length was 30 mm and medium sand particles were visible, which are the attributes of Sandy Clay Loam textural class. All the 12 samples, which showed Sandy Clay Loam status in laboratory analysis, belong to this group.

Among the Sandy Clay Loam Class, maximum variation was seen in sand content and the least in silt content. The minimum sand content (51.86 %) was recorded from the sample, ‘S 33’ which was from the 70th survey plot situated near the lake. From the same site, highest clay content (29.41 %) was recorded. The lowest clay content (23.76 %) was recorded from the sample, ‘S 57’ which was taken from the 671st survey plot. Maximum sand content (64.84 %) was found at the sample ‘S 27’ which

Table 2. Textural classes of soil samples from Koliyoor micro watershed

Sl. No.	Sample ID	Textural class	Sl. No.	Sample ID	Textural class
1	S 1	Sandy clay loam	27	S 27	Sandy loam
2	S 2	Sandy clay loam	28	S 28	Sandy clay loam
3	S 3	Sandy clay loam	29	S 29	Sandy clay loam
4	S 4	Sandy clay loam	30	S 30	Sandy clay loam
5	S 5	Sandy clay loam	31	S 31	Sandy clay loam
6	S 6	Sandy clay loam	32	S 32	Sandy clay loam
7	S 7	Sandy clay loam	33	S 33	Sandy clay loam
8	S 8	Sandy clay loam	34	S 34	Sandy clay loam
9	S 9	Sandy loam	35	S 35	Sandy clay loam
10	S 10	Sandy clay loam	36	S 36	Sandy clay loam
11	S 11	Sandy clay loam	37	S 37	Sandy clay loam
12	S 12	Sandy clay loam	38	S 38	Sandy clay loam
13	S 13	Sandy clay loam	39	S 39	Sandy clay loam
14	S 14	Sandy loam	40	S 40	Sandy clay loam
15	S 15	Sandy clay loam	41	S 41	Sandy clay loam
16	S 16	Sandy clay loam	42	S 42	Sandy Clay loam
17	S 17	Sandy loam	43	S 43	Sandy clay loam
18	S 18	Sandy clay loam	44	S 44	Sandy Clay loam
19	S 19	Sandy loam	45	S 45	Sandy loam
20	S 20	Sandy clay loam	46	S 46	Sandy clay loam
21	S 21	Sandy clay loam	47	S 47	Sandy clay loam
22	S 22	Sandy clay loam	48	S 48	Sandy clay loam
23	S 23	Sandy loam	49	S 49	Sandy clay loam
24	S 24	Sandy clay loam	50	S 50	Sandy clay loam
25	S 25	Sandy clay loam	51	S 51	Sandy clay loam
26	S 26	Sandy clay loam	52	S 52	Sandy clay loam

Table 2. Textural classes of soil samples from Koliyoor micro watershed (Continued...)

Sl. No.	Sample ID	Textural class	Sl. No.	Sample ID	Textural class
53	S 53	Sandy clay loam	79	S 79	Sandy clay loam
54	S 54	Sandy clay loam	80	S 80	Sandy loam
55	S 55	Sandy clay loam	81	S 81	Sandy clay loam
56	S 56	Sandy clay loam	82	S 82	Sandy clay loam
57	S 57	Sandy loam	83	S 83	Sandy clay loam
58	S 58	Sandy clay loam	84	S 84	Sandy clay loam
59	S 59	Sandy clay loam	85	S 85	Sandy clay loam
60	S 60	Sandy loam	86	S 86	Sandy clay loam
61	S 61	Sandy clay loam	87	S 87	Sandy clay loam
62	S 62	Sandy clay loam	88	S 88	Sandy clay loam
63	S 63	Sandy clay loam	89	S 89	Sandy clay loam
64	S 64	Sandy clay loam	90	S 90	Sandy clay loam
65	S 65	Sandy clay loam	91	S 91	Sandy clay loam
66	S 66	Sandy clay loam	92	S 92	Sandy clay loam
67	S 67	Sandy clay loam	93	S 93	Sandy loam
68	S 68	Sandy clay loam	94	S 94	Sandy clay loam
69	S 69	Sandy clay loam	95	S 95	Sandy loam
70	S 70	Sandy clay loam	96	S 96	Sandy clay loam
71	S 71	Sandy clay loam	97	S 97	Sandy clay loam
72	S 72	Sandy clay loam	98	S 98	Sandy clay loam
73	S 73	Sandy clay loam	99	S 99	Sandy clay loam
74	S 74	Sandy clay loam	100	S 100	Sandy clay loam
75	S 75	Sandy clay loam	101	S 101	Sandy clay loam
76	S 76	Sandy clay loam	102	S 102	Sandy clay loam
77	S 77	Sandy clay loam	103	S 103	Sandy clay loam
78	S 78	Sandy clay loam	104	S 104	Sandy clay loam

Table 2. Textural classes of soil samples from Koliyoor micro watershed (Continued...)

Sl. No.	Sample ID	Textural class	Sl. No.	Sample ID	Textural class	Sl. No.	Sample ID	Textural class
105	S 105	Sandy clay loam	131	S 131	Sandy clay loam	157	S 157	Sandy loam
106	S 106	Sandy loam	132	S 132	Sandy clay loam	158	S 158	Sandy clay loam
107	S 107	Sandy clay loam	133	S 133	Sandy clay loam	159	S 159	Sandy clay loam
108	S 108	Sandy clay loam	134	S 134	Sandy clay loam	160	S 160	Sandy clay loam
109	S 109	Sandy clay loam	135	S 135	Sandy clay loam	161	S 161	Sandy clay loam
110	S 110	Sandy clay loam	136	S 136	Sandy clay loam	162	S 162	Sandy clay loam
111	S 111	Sandy clay loam	137	S 137	Sandy loam	163	S 163	Sandy clay loam
112	S 112	Sandy clay loam	138	S 138	Sandy loam	164	S 164	Sandy clay loam
113	S 113	Sandy clay loam	139	S 139	Sandy clay loam	165	S 165	Sandy clay loam
114	S 114	Sandy clay loam	140	S 140	Sandy clay loam	166	S 166	Sandy clay loam
115	S 115	Sandy clay loam	141	S 141	Sandy clay loam	167	S 167	Sandy clay loam
116	S 116	Sandy clay loam	142	S 142	Sandy clay loam	168	S 168	Sandy clay loam
117	S 117	Sandy clay loam	143	S 143	Sandy clay loam	169	S 169	Sandy clay loam
118	S 118	Sandy clay loam	144	S 144	Sandy loam	170	S 170	Sandy clay loam
119	S 119	Sandy clay loam	145	S 145	Sandy clay loam	171	S 171	Sandy clay loam
120	S 120	Sandy loam	146	S 146	Sandy clay loam	172	S 172	Sandy clay loam
121	S 121	Sandy clay loam	147	S 147	Sandy loam	173	S 173	Sandy clay loam
122	S 122	Sandy clay loam	148	S 148	Sandy Clay loam	174	S 174	Sandy clay loam
123	S 123	Sandy clay loam	149	S 149	Sandy Clay loam			
124	S 124	Sandy clay loam	150	S 150	Sandy Clay loam			
125	S 125	Sandy clay loam	151	S 151	Sandy Clay loam			
126	S 126	Sandy loam	152	S 152	Sandy Clay loam			
127	S 127	Sandy loam	153	S 153	Sandy Clay loam			
128	S 128	Sandy clay loam	154	S 154	Sandy Clay loam			
129	S 129	Sandy loam	155	S 155	Sandy Clay loam			

Table 3. Mechanical composition of soil samples from Koliyoor micro watershed

Sl. No.	Sample ID	Sand (%)	Silt (%)	Clay (%)	Textural class
1	S 166	60.62	15.47	23.76	Sandy Clay Loam
2	S 89	55.64	13.82	24.18	Sandy Clay Loam
3	S 8	57.13	15.98	25.40	Sandy Clay Loam
4	S 122	56.11	15.44	28.19	Sandy Clay Loam
5	S 3	56.87	15.40	28.85	Sandy Clay Loam
6	S 31	56.98	16.45	27.81	Sandy Clay Loam
7	S 86	54.32	16.85	28.64	Sandy Clay Loam
8	S 36	55.64	15.43	27.64	Sandy Clay Loam
9	S 44	55.24	14.86	27.40	Sandy Clay Loam
10	S 33	51.86	15.12	29.41	Sandy Clay Loam
11	S 64	56.46	16.35	25.84	Sandy Clay Loam
12	S 72	56.44	15.80	28.44	Sandy Clay Loam
13	S 57	52.94	13.00	16.00	Sandy Loam
14	S 80	60.11	14.20	18.00	Sandy Loam
15	S 27	64.84	12.22	17.10	Sandy Loam

was taken from the 671st survey plot. Maximum sand content (64.84%) was found at the sample 'S 27' which was taken from the 708th survey plot.

The samples which showed Sandy Clay Loam textural class ranged in their sand content from 51.86 to 60.62 % with a mean value of 56.01 %. These samples showed a range of 13.82 to 16.85 % for their silt content with a mean value of 15.6 %. The mean clay content of the samples of 'Sandy Clay Loam' category was 27.13 % with a range of 23.76 to 29.41 %. The samples which showed 'Sandy Loam' textural status varied in their sand content from 52.94 to 64.84 % with a mean value of 59.3 %. The range regarding their silt content was from 12.22 to 13 % with an average value of 13.14 %. They showed mean clay content of 17.33 % within a range of 16 to 18 %.

4.2 ELECTROCHEMICAL PROPERTIES

The electrochemical properties of soil that will affect the availability of nutrients to plants were also analysed. These properties are getting importance when we aim to enhance the chemical fertility of soil.

4.2.1 Soil Reaction

Table 4 shows soil reaction of samples from Koliyoor micro watershed. In general, soils were acidic with pH ranging from 5.3 to 6.6, in 1:2.5 soil water suspensions with a mean value of 6.02 and mode value of 6. When the entire range was divided based on the field manual of soil survey staff during mapping, four pH classes were obtained. Fig 3 shows the distribution of these four pH classes over the entire area of Koliyoor micro watershed.

Most of the samples were in Medium Acid class and the least in Neutral class. The lowest pH (5.3) was found in the sample, 'S 50' which was taken from 498th survey plot, located at northern boundary of watershed. The highest value of pH (6.6) was recorded from the Sample 'S 53' which was taken from 675th survey plot.

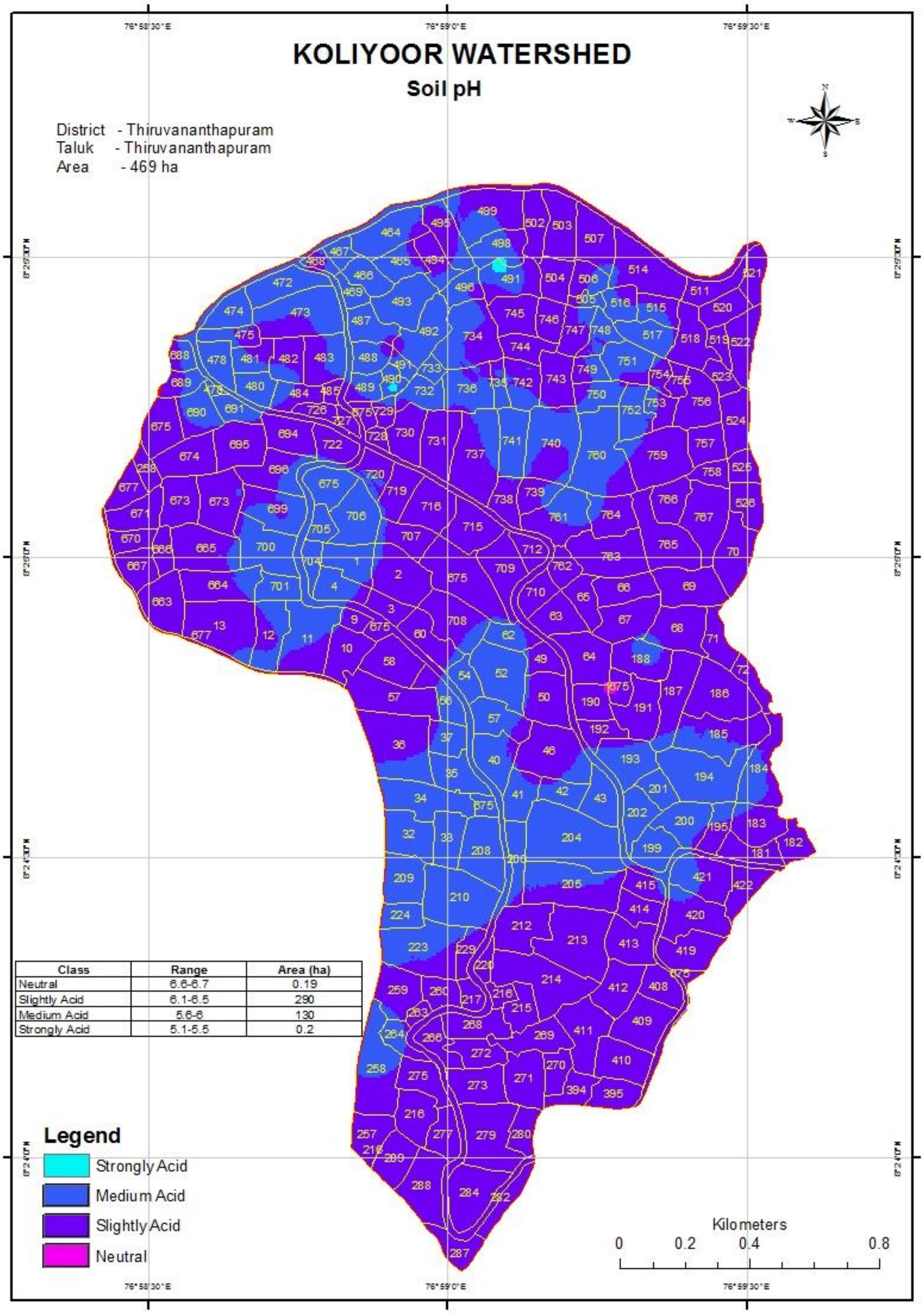
Table 4. Soil reaction of samples from Koliyoor micro watershed

Sl. No	Sample ID	pH	pH Class	Sl. No	Sample ID	pH	pH Class
1	S 1	6.2	Slightly Acid	45	S 45	6.1	Slightly Acid
2	S 2	6.0	Medium Acid	46	S 46	6.0	Medium Acid
3	S 3	6.0	Medium Acid	47	S 47	6.0	Medium Acid
4	S 4	6.1	Slightly Acid	48	S 48	6.3	Slightly Acid
5	S 5	6.4	Slightly Acid	49	S 49	6.0	Medium Acid
6	S 6	6.4	Slightly Acid	50	S 50	5.3	Strongly Acid
7	S 7	6.2	Slightly Acid	51	S 51	6.0	Medium Acid
8	S 8	6.2	Slightly Acid	52	S 52	6.3	Slightly Acid
9	S 9	5.9	Medium Acid	53	S 53	6.6	Neutral
10	S 10	5.4	Strongly Acid	54	S 54	6.2	Slightly Acid
11	S 11	5.7	Medium Acid	55	S 55	6.1	Slightly Acid
12	S 12	5.7	Medium Acid	56	S 56	6.2	Slightly Acid
13	S 13	5.7	Medium Acid	57	S 57	6.0	Medium Acid
14	S 14	6.0	Medium Acid	58	S 58	6.0	Medium Acid
15	S 15	6.1	Slightly Acid	59	S 59	6.0	Medium Acid
16	S 16	6.0	Medium Acid	60	S 60	5.9	Medium Acid
17	S 17	6.0	Medium Acid	61	S 61	5.9	Medium Acid
18	S 18	6.2	Slightly Acid	62	S 62	6.4	Slightly Acid
19	S 19	6.3	Slightly Acid	63	S 63	6.3	Slightly Acid
20	S 20	5.7	Medium Acid	64	S 64	6.3	Slightly Acid
21	S 21	6.0	Medium Acid	65	S 65	6.2	Slightly Acid
22	S 22	5.8	Medium Acid	66	S 66	6.0	Medium Acid
23	S 23	5.8	Medium Acid	67	S 67	6.0	Medium Acid
24	S 24	6.0	Medium Acid	68	S 68	6.1	Slightly Acid
25	S 25	6.0	Medium Acid	69	S 69	6.0	Medium Acid
26	S 26	6.0	Slightly Acid	70	S 70	6.0	Medium Acid
27	S 27	6.0	Medium Acid	71	S 71	5.8	Medium Acid
28	S 28	6.3	Slightly Acid	72	S 72	6.0	Medium Acid
29	S 29	5.8	Medium Acid	73	S 73	6.1	Slightly Acid
30	S 30	6.0	Medium Acid	74	S 74	6.1	Slightly Acid
31	S 31	6.1	Slightly Acid	75	S 75	5.9	Medium Acid
32	S 32	6.2	Slightly Acid	76	S 76	5.9	Medium Acid
33	S 33	6.2	Slightly Acid	77	S 77	6.0	Medium Acid
34	S 34	6.0	Medium Acid	78	S 78	6.0	Medium Acid
35	S 35	6.1	Slightly Acid	79	S 79	6.0	Medium Acid
36	S 36	5.8	Medium Acid	80	S 80	5.9	Medium Acid
37	S 37	5.6	Medium Acid	81	S 81	5.9	Medium Acid
38	S 38	5.6	Medium Acid	82	S 82	6.0	Medium Acid
39	S 39	6.1	Slightly Acid	83	S 83	6.0	Medium Acid
40	S 40	6.4	Slightly Acid	84	S 84	6.1	Slightly Acid
41	S 41	6.2	Slightly Acid	85	S 85	6.0	Medium Acid
42	S 42	6.2	Slightly Acid	86	S 86	6.0	Medium Acid
43	S 43	6.4	Slightly Acid	87	S 87	6.1	Slightly Acid
44	S 44	6.0	Medium Acid	88	S 88	6.1	Slightly Acid

Table 4. Soil reaction of samples from Koliyoor micro watershed (Continued…)

Sl. No	Sample ID	pH	pH Class	Sl. No	Sample ID	pH	pH Class
89	S 89	6.0	Medium Acid	133	S 133	6.1	Slightly Acid
90	S 90	6.0	Medium Acid	134	S 134	5.7	Medium Acid
91	S 91	6.1	Slightly Acid	135	S 135	5.9	Medium Acid
92	S 92	5.9	Medium Acid	136	S 136	5.6	Medium Acid
93	S 93	6.1	Slightly Acid	137	S 137	5.8	Medium Acid
94	S 94	6.0	Medium Acid	138	S 138	6.1	Slightly Acid
95	S 95	6.0	Medium Acid	139	S 139	6.1	Slightly Acid
96	S 96	5.7	Medium Acid	140	S 140	6.0	Medium Acid
97	S 97	5.7	Medium Acid	141	S 141	5.7	Medium Acid
98	S 98	5.9	Medium Acid	142	S 142	5.7	Medium Acid
99	S 99	6.0	Medium Acid	143	S 143	6.1	Slightly Acid
100	S 100	6.0	Medium Acid	144	S 144	6.2	Slightly Acid
101	S 101	6.0	Medium Acid	145	S 145	6.0	Medium Acid
102	S 102	5.9	Medium Acid	146	S 146	6.3	Slightly Acid
103	S 103	6.1	Slightly Acid	147	S 147	5.7	Medium Acid
104	S 104	6.1	Slightly Acid	148	S 148	5.8	Medium Acid
105	S 105	6.0	Medium Acid	149	S 149	5.9	Medium Acid
106	S 106	6.0	Medium Acid	150	S 150	5.9	Medium Acid
107	S 107	6.0	Medium Acid	151	S 151	5.9	Medium Acid
108	S 108	6.1	Slightly Acid	152	S 152	6.0	Medium Acid
109	S 109	6.1	Slightly Acid	153	S 153	6.1	Slightly Acid
110	S 110	5.9	Medium Acid	154	S 154	6.5	Slightly Acid
111	S 111	5.7	Medium Acid	155	S 155	6.4	Slightly Acid
112	S 112	6.0	Medium Acid	156	S 156	6.5	Slightly Acid
113	S 113	6.0	Medium Acid	157	S 157	6.2	Slightly Acid
114	S 114	6.1	Slightly Acid	158	S 158	6.1	Slightly Acid
115	S 115	5.8	Medium Acid	159	S 159	5.7	Medium Acid
116	S 116	6.1	Slightly Acid	160	S 160	5.8	Medium Acid
117	S 117	6.0	Medium Acid	161	S 161	6.1	Slightly Acid
118	S 118	6.3	Slightly Acid	162	S 162	6.0	Medium Acid
119	S 119	6.4	Slightly Acid	163	S 163	6.1	Slightly Acid
120	S 120	6.1	Slightly Acid	164	S 164	6.0	Medium Acid
121	S 121	6.1	Slightly Acid	165	S 165	6.0	Medium Acid
122	S 122	5.6	Medium Acid	166	S 166	5.8	Medium Acid
123	S 123	6.0	Medium Acid	167	S 167	6.0	Medium Acid
124	S 124	6.1	Slightly Acid	168	S 168	6.0	Medium Acid
125	S 125	6.0	Medium Acid	169	S 169	6.0	Medium Acid
126	S 126	6.1	Slightly Acid	170	S 170	6.2	Slightly Acid
127	S 127	6.3	Slightly Acid	171	S 171	6.4	Slightly Acid
128	S 128	6.1	Slightly Acid	172	S 172	6.1	Slightly Acid
129	S 129	6.3	Slightly Acid	173	S 173	6.2	Slightly Acid
130	S 130	6.2	Slightly Acid	174	S 174	6.0	Medium Acid
131	S 131	5.9	Medium Acid				
132	S 132	5.9	Medium Acid				

Fig. 3. Map of distribution of pH classes over Koliyoor micro watershed



4.2.3 Electrical conductivity

Table 5 presents the electrical conductivity of the soils samples from Koliyoor micro watershed. The data on electrical conductivity (EC) showed that all the samples were with very low conductivity with the mean value of 0.08 dS/m. It ranged from 0.01 to 0.26 dS/m and showed little variation among the samples. Thus, all the soil samples fell into the Non-Saline category. Therefore, only unrated map is generated for EC (Fig.4). When the land use based categories of soil samples were compared, those from plots of homestead cultivation showed highest mean electrical conductivity (0.11 dS/m). The survey plots from non-agricultural area showed lowest mean electrical conductivity (0.06 dS/m). The lowest value was obtained from the sample, 'S 80' which was taken from 210th survey plot. Highest EC value was shown by the sample, 'S 123' from 737th survey plot.

4.3 AVAILABLE NUTRIENTS

The status of available nutrients in the soil is an important parameter as far as productivity of soil is considered. Knowledge about the presently existing amount will help to decide the quantity and type of fertilizer to be applied. For getting a general view, the distribution of point data with respective range, mean and mode values of available nutrients are presented in Table 6. The distribution of point data over the fertility classes of each nutrient is given Table 7. Table 8 presents the range and mean values of parameters when the samples were categorized into four classes based on predominant land use prevailing in the area. Table 9 presents the distribution of area of watershed into the different fertility classes.

4.3.1 Available Major Nutrients

4.3.1.1 Organic carbon

Organic carbon content of the samples ranged from 0.1 to 2 % with a mean value of 0.72 % and mode of 0.45 %. The maximum value, 2 % was

Table 5. Electrical conductivity of the soil samples from Koliyoor micro watershed

Sl. No.	Sample ID	EC (dS/m)	Sl. No.	Sample ID	EC (dS/m)
1	S 1	0.11	45	S 45	0.11
2	S 2	0.1	46	S 46	0.07
3	S 3	0.12	47	S 47	0.1
4	S 4	0.08	48	S 48	0.12
5	S 5	0.08	49	S 49	0.07
6	S 6	0.11	50	S 50	0.1
7	S 7	0.05	51	S 51	0.13
8	S 8	0.03	52	S 52	0.06
9	S 9	0.14	53	S 53	0.05
10	S 10	0.1	54	S 54	0.08
11	S 11	0.11	55	S 55	0.06
12	S 12	0.1	56	S 56	0.13
13	S 13	0.07	57	S 57	0.08
14	S 14	0.03	58	S 58	0.05
15	S 15	0.1	59	S 59	0.08
16	S 16	0.05	60	S 60	0.04
17	S 17	0.06	61	S 61	0.07
18	S 18	0.08	62	S 62	0.1
19	S 19	0.05	63	S 63	0.11
20	S 20	0.08	64	S 64	0.08
21	S 21	0.1	65	S 65	0.05
22	S 22	0.07	66	S 66	0.06
23	S 23	0.05	67	S 67	0.09
24	S 24	0.08	68	S 68	0.11
25	S 25	0.12	69	S 69	0.11
26	S 26	0.15	70	S 70	0.08
27	S 27	0.07	71	S 71	0.08
28	S 28	0.05	72	S 72	0.06
29	S 29	0.04	73	S 73	0.1
30	S 30	0.05	74	S 74	0.06
31	S 31	0.08	75	S 75	0.04
32	S 32	0.12	76	S 76	0.05
33	S 33	0.09	77	S 77	0.04
34	S 34	0.05	78	S 78	0.05
35	S 35	0.06	79	S 79	0.09
36	S 36	0.03	80	S 80	0.01
37	S 37	0.05	81	S 81	0.07
38	S 38	0.07	82	S 82	0.04
39	S 39	0.11	83	S 83	0.06
40	S 40	0.07	84	S 84	0.1
41	S 41	0.09	85	S 85	0.09
42	S 42	0.13	86	S 86	0.05
43	S 43	0.06	87	S 87	0.1
44	S 44	0.08	88	S 88	0.11

Table 5. Electrical conductivity of the soil samples from Koliyoor micro watershed (Continued…)

Sl. No.	Sample ID	EC (dS/m)	Sl. No.	Sample ID	EC (dS/m)
89	S 89	0.07	133	S 133	0.13
90	S 90	0.09	134	S 134	0.13
91	S 91	0.1	135	S 135	0.06
92	S 92	0.08	136	S 136	0.03
93	S 93	0.07	137	S 137	0.03
94	S 94	0.09	138	S 138	0.07
95	S 95	0.11	139	S 139	0.09
96	S 96	0.08	140	S 140	0.07
97	S 97	0.08	141	S 141	0.09
98	S 98	0.09	142	S 142	0.05
99	S 99	0.11	143	S 143	0.03
100	S 100	0.09	144	S 144	0.09
101	S 101	0.08	145	S 145	0.05
102	S 102	0.06	146	S 146	0.06
103	S 103	0.08	147	S 147	0.06
104	S 104	0.1	148	S 148	0.04
105	S 105	0.05	149	S 149	0.09
106	S 106	0.03	150	S 150	0.12
107	S 107	0.11	151	S 151	0.04
108	S 108	0.08	152	S 152	0.11
109	S 109	0.07	153	S 153	0.11
110	S 110	0.1	154	S 154	0.08
111	S 111	0.11	155	S 155	0.05
112	S 112	0.09	156	S 156	0.13
113	S 113	0.08	157	S 157	0.08
114	S 114	0.1	158	S 158	0.15
115	S 115	0.08	159	S 159	0.09
116	S 116	0.07	160	S 160	0.09
117	S 117	0.09	161	S 161	0.06
118	S 118	0.03	162	S 162	0.03
119	S 119	0.04	163	S 163	0.11
120	S 120	0.04	164	S 164	0.09
121	S 121	0.1	165	S 165	0.08
122	S 122	0.05	166	S 166	0.09
123	S 123	0.26	167	S 167	0.07
124	S 124	0.04	168	S 168	0.09
125	S 125	0.11	169	S 169	0.05
126	S 126	0.05	170	S 170	0.09
127	S 127	0.06	171	S 171	0.07
128	S 128	0.05	172	S 172	0.11
129	S 129	0.09	173	S 173	0.13
130	S 130	0.03	174	S 174	0.08
131	S 131	0.07			
132	S 132	0.1			

Fig.4. Map of spatial distribution of electrical conductivity over Koliyoor micro watershed

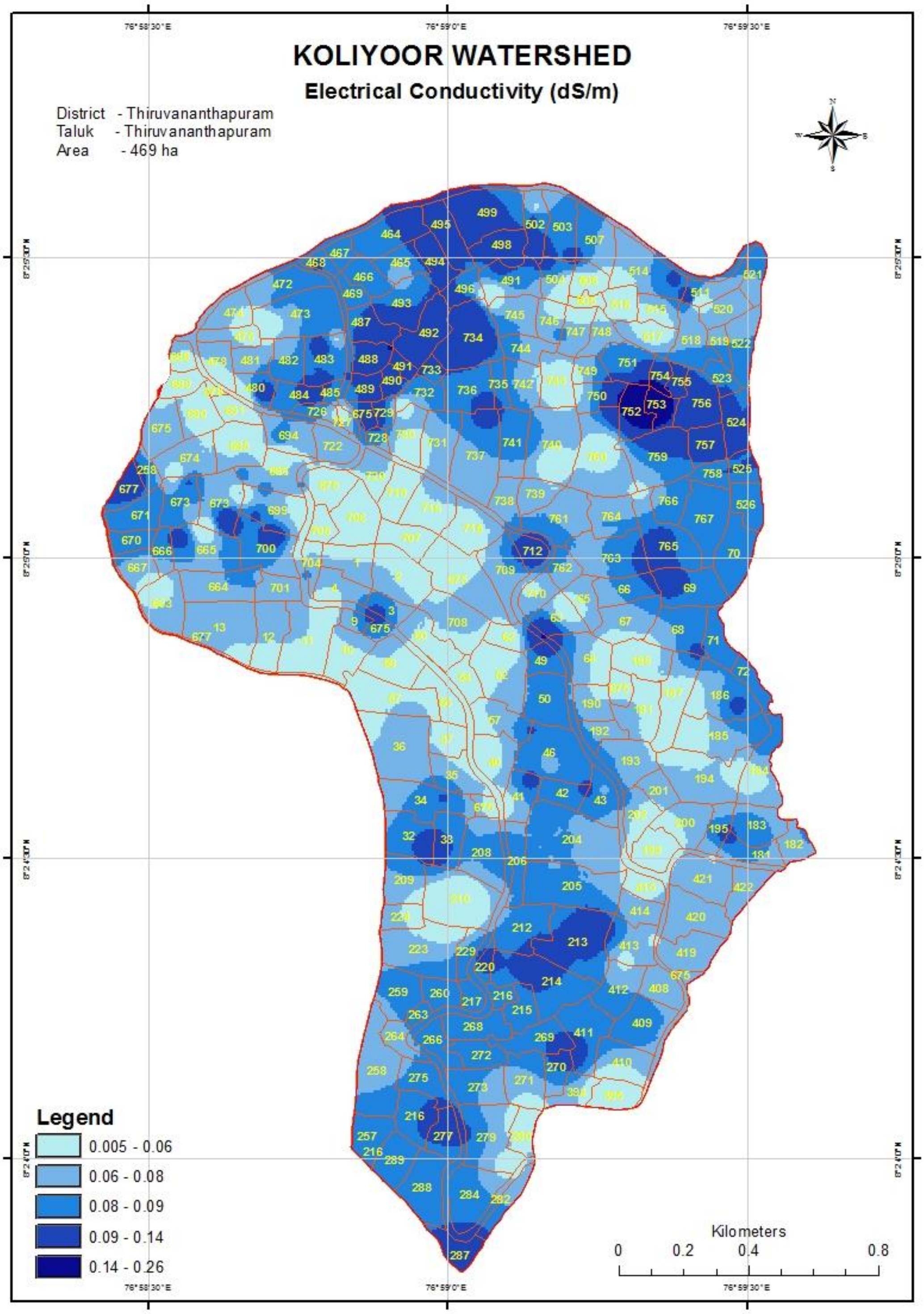


Table 6.The mean, mode and range values of available nutrients of the soil samples from Koliyoor micro watershed.

Sl. No.	Parameter	Mean	Mode	Range
1	Organic Carbon (%)	0.72	0.45	0.10-2.00
2	Available Phosphorus (kg/ha)	22.10	16.20	3.10-59.10
3	Available Potassium (kg/ha)	196.55	217.28	20.16 - 481
4	Available Sulfur (kg/ha)	30	37.50	8.93 – 71.4
5	Available Ca (ppm)	337.33	245	75 - 900
6	Available Mg (ppm)	49.47	42	12 – 167
7	Available Iron (ppm)	49.62	67.72	4.60 - 164
8	Available Copper (ppm)	3.47	0.80	0.01 – 8.66
9	Available Manganese (ppm)	32.00	26.41	5.50 – 95.30
10	Available Boron (ppm)	0.27	0.35	0.01-0.66
11	Available Zinc (ppm)	0.71	1.01	0.03 – 4.97

recorded from the sample 'S 90' which was taken from the 50th survey plot. The least organic carbon content was recorded from the sample, 'S 84' taken from 10th survey plot near western ridgeline.

Out of the total number of 174 samples taken for analysis, 48 samples (27.6 %) showed low organic carbon status. 49 samples (28.2 %) showed medium status while 77 samples (44.2 %) showed high organic carbon status.

Plots of homestead cultivation showed maximum range (0.7 to 1.9 %) and mean value (0.82 %) of organic carbon content followed by the plots having coconut based cultivation. Least organic carbon content was recorded from the plots of non-agricultural area especially which are dominated by stone quarries. There, it ranged from 0.1 to 0.8% with the lowest mean value of 0.21 %.

Table 7.Distribution of point data over the fertility classes of nutrients.

Sl. No.	Fertility class	Critical range	No. of Samples
Org. C (%)	Low	(Less than 0.5)	48 (27.6 %)
	Medium	(0.5 – 0.75)	49 (28.2 %)
	High	(More than 0.75)	77 (44.2 %)
Av. P (kg/ha)	Low	(Less than 9.85)	85 (48.9 %)
	Medium	(9.85 – 24.6)	23 (13.2 %)
	High	(Greater than 24.6)	66 (37.9 %)
Av. K (kg/ha)	Low	(Less than 92.96)	30 (17.2 %)
	Medium	(92.96 – 232.4)	96 (55.2 %)
	High	(Greater than 232.4)	48 (27.6 %)
Av. S (kg/ha)	Low	(Less than 11)	50 (28.9 %)
	Medium	(11 – 22)	116 (66.9 %)
	High	(Greater than 22)	8 (4.2 %)
Av. Ca (ppm)	Sufficient	(Greater than 300)	167 (96 %)
	Deficient	(Less than 300)	7 (4 %)
Av. Mg (ppm)	Sufficient	(Greater than 120)	7 (4 %)
	Deficient	(Less than 120)	167 (96 %)
Av. Fe (ppm)	Sufficient	(Greater than 5)	171 (98 %)
	Deficient	(Less than 5)	3 (2 %)
Av. Cu (ppm)	Sufficient	(Greater than 1)	154 (88.5 %)
	Deficient	(Less than 1)	20 (11.5 %)
Av. Mn (ppm)	Sufficient	(Greater than 1)	174 (100 %)
	Deficient	(Less than 1)	0 (0 %)
Av. Zn (ppm)	Sufficient	(Greater than 1)	3 (2 %)
	Deficient	(Less than 1)	171 (98 %)
Av. B (ppm)	Sufficient	(Greater than 0.5)	1 (0.6 %)
	Deficient	(Less than 0.5)	173 (99.4%)

When the point data were interpolated, the low organic carbon status was shown by 0.2 ha area (0.05 %), medium status was seen over 395 ha (94.2 %) and 25.8 ha (6.1 %) area showed high organic carbon status. Fig.5 shows the distribution of fertility classes of organic carbon over Koliyoor micro watershed.

Organic carbon status was used as an index for rating of available nitrogen. So the above mentioned statistics are applicable for available nitrogen also.

Table 8. Land use wise range and mean values of available nutrients in the soil samples from Koliyoor micro watershed

Land Use→	L.U 1*	L.U 2*
Number of Samples	18	45
Organic Carbon (%)	Range 0.5 – 0.9 Mean 0.6	Range 0.2 – 1.1 Mean 0.63
Available Phosphorus (kg/ha)	Range 12.4 – 43.8 Mean 25.5	Range 25.2 – 59.1 Mean 23.7
Available Potassium (kg/ha)	Range 33 – 192 Mean 210	Range 20.16 – 192 Mean 132.1
Available Sulfur (kg/ha)	Range 21 - 71.4 Mean 38	Range 15 – 34.2 Mean 31.4
Available Calcium (ppm)	Range 266 – 893 Mean 428.5	Range 243 – 612 Mean 366
Available Magnesium (ppm)	Range 75 – 161 Mean 91	Range 20 – 85 Mean 32.8
Available Iron (ppm)	Range 33 – 151 Mean 69	Range 40.4 – 151 Mean 66.3
Available Copper (ppm)	Range 1.9 – 8.6 Mean 4.1	Range 0.98 – 3.8 Mean 2
Available Manganese (ppm)	Range 21.7 – 30.1 Mean 23.4	Range 10 – 50.1 Mean 29.4
Available Boron (ppm)	Range 0.03 – 0.66 Mean 0.28	Range 0.01 – 0.4 Mean 0.22
Available Zinc (ppm)	Range 0.03 – 0.1 Mean 0.53	Range 0.1 – 1.1 Mean 0.89

* L.U 1= Converted Paddy Fields; L.U 2= Coconut based cultivation

Table 8. Land use wise range and mean values of available nutrients in the soil samples from Koliyoor micro watershed (Continued…)

Land Use →	L.U 3*	L.U 4*
Number of Samples	105	6
Organic Carbon (%)	Range 0.7 – 1.9 Mean 0.82	Range 0.1 – 0.8 Mean 0.21
Available Phosphorus (kg/ha)	Range 15 – 35.4 Mean 21.6	Range 3.1 – 33.2 Mean 20.1
Available Potassium (kg/ha)	Range 71 – 481 Mean 101.4	Range 40 – 280 Mean 199
Available Sulfur (kg/ha)	Range 27 – 60.5 Mean 39.2	Range 8.9 – 27 Range 12.1
Available Calcium (ppm)	Range 75 – 841 Mean 374	Range 200 - 541 Mean 301.1
Available Magnesium (ppm)	Range 50 – 71 Mean 63.2	Range 12 – 140 Mean 38. 7
Available Iron (ppm)	Range 34.7 – 53 Mean 46.6	Range 539 – 58 Mean 41.03
Available Copper (ppm)	Range 0.9 – 2.8 Mean 1.9	Range 0.01 – 3.15 Mean 1.1
Available Manganese (ppm)	Range 31.1 – 95.3 Mean 40.01	Range 5.56 – 33.9 Mean 21.33
Available Boron (ppm)	Range 0.22 – 0.51 Mean 0.36	Range 0.29 – 0.66 Mean 0.43
Available Zinc (ppm)	Range 0.7 – 4.1 Mean 1.01	Range 0.06 – 1.9 Mean 0.67

* L.U 3 = Homestead Cultivation; L.U 4 = Non agricultural Area

Fig. 5.Map of distribution of fertility classes of organic carbon over

Koliyoor micro watershed

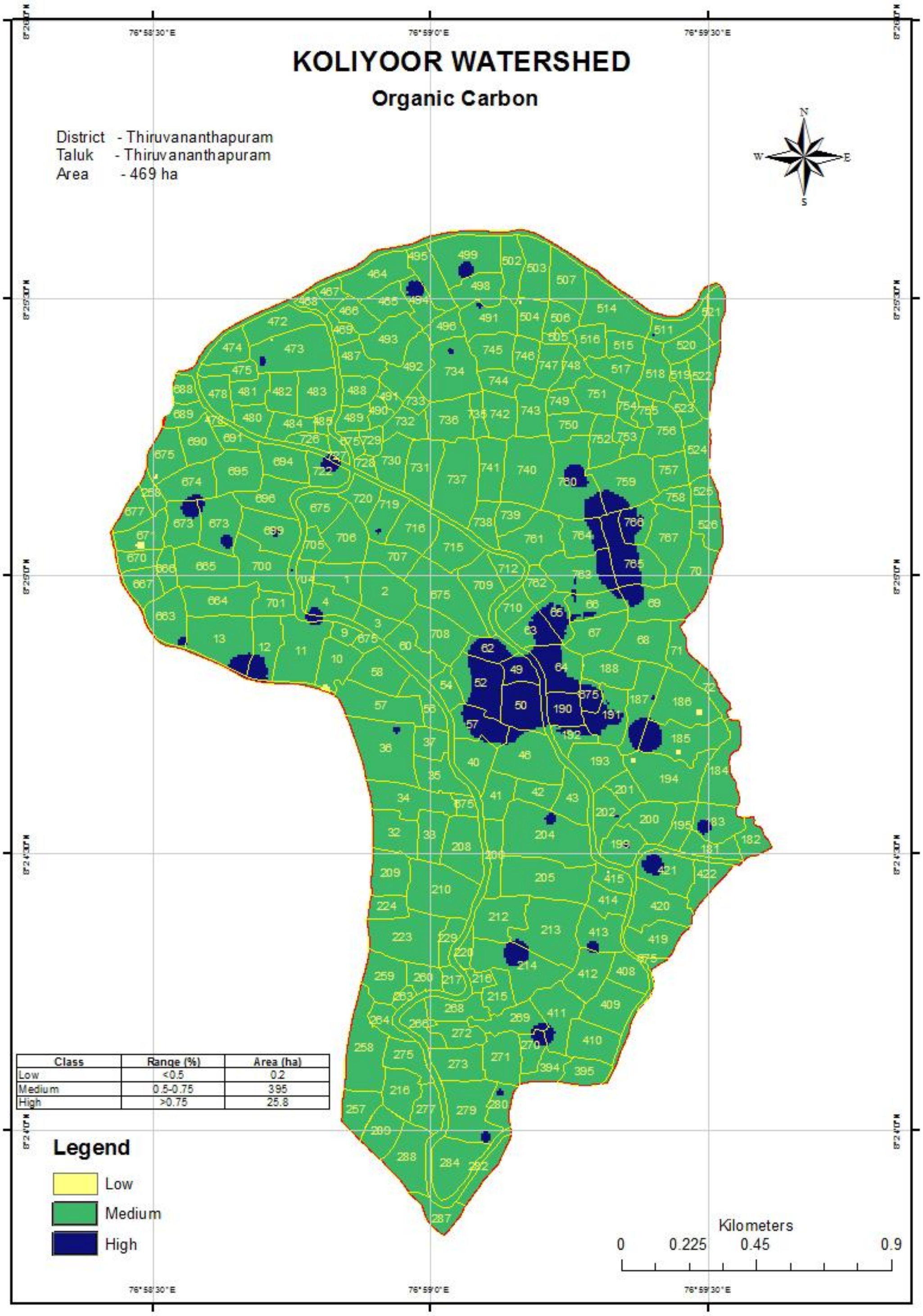


Table 9.Area of Koliyoor micro watershed under different fertility classes.

Nutrients	Area (ha)		
	Low	Medium	High
Org.Carbon	0.2 (0.05 %)	395 (94.2 %)	25.8 (6.1 %)
Av. P	12.5 (3 %)	279.6 (66 %)	128.9 (31 %)
Av. K	13.1 (3 %)	318.8 (75.7 %)	89.01 (23 %)
Av. S	1.2 (0.3 %)	29.8 (6.7 %)	370 (93 %)
	Deficient	Sufficient	
Av. Ca	110 (26 %)	311 (74 %)	
Av. Mg	420.06 (99.9%)	0.4 (0.1 %)	
Av. Fe	0.4 (0.1%)	420.6 (99.9 %)	
Av. Mn	0	421 (100 %)	
Av. Cu	1.1 (0.3 %)	419.9 (99.7 %)	
Av. Zn	391 (93 %)	29.8 (7 %)	
Av. B	420.01 (99.8)	0.99 (0.2 %)	

4.3.1.2 Available Phosphorus

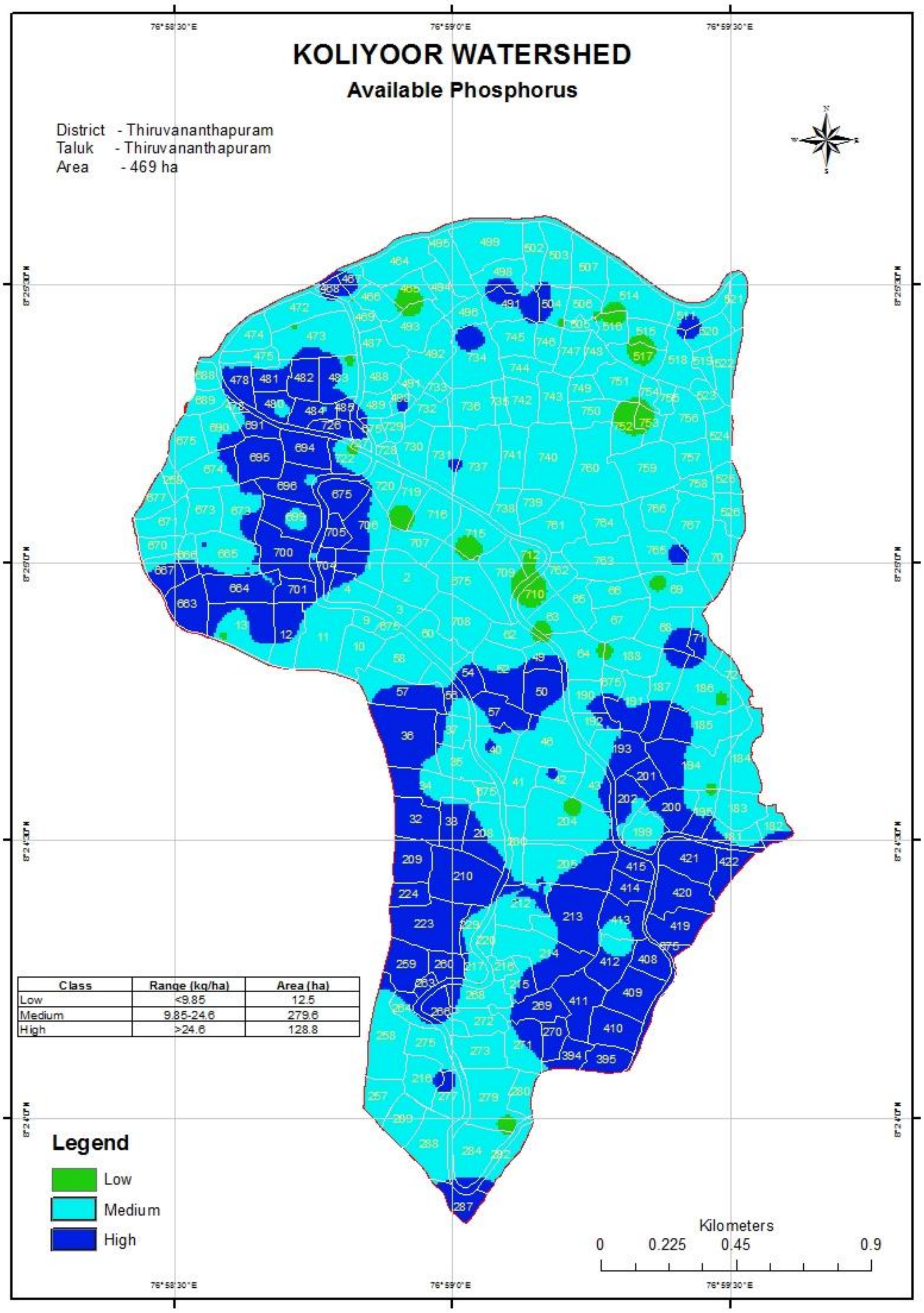
Majority of the watershed area belongs to the Medium class of available P. The values ranged from 3.1 to 59.1 kg/ha with a mean value of 22.1 kg/ha. The lowest status was shown by the sample 'S 5' taken from 504th survey plot. Highest status was found from the sample 'S 59' taken from 13th survey plot.

85 soils samples out of 174 (48.9%) showed low P status while 23 samples (13.2 %) fell in category of medium status. 66 samples (37.9 %) showed high status. When the samples were categorized based on land use, those from converted paddy fields showed highest mean value (25.5 kg/ha) of P status. Lowest mean value (20.1 kg/ha) was shown by the samples taken from non-agricultural area.

In the map produced after interpolation, 12.5 ha (3 %) of the total area is with low P status and 279.6 ha (66 %) showed medium status. High P status was shown by 128.9 (31 %) of the area. Fig.6 shows the distribution of fertility classes of available P over Koliyoor micro watershed.

Fig. 6. Distribution of fertility classes of available P over

Koliyoor micro watershed.



4.3.1.3 Available Potassium

In the case of K availability also, majority of the area shows medium status. It ranged from 20.16 to 481 kg/ha. The mean value was found as 196.55 kg/ha. Lowest available K content was shown by the sample 'S 154' taken from the boundary of the 473rd and 482nd survey plots. Maximum available K content was recorded from the sample 'S 92' taken from 57th survey plot.

Most of the samples fell in the medium class on fertility rating.ie, 96 samples (55.2 %). 30 samples (17.2 %) showed low status while 48 samples (27.6 %) showed high status for K. Mean value (250.5 kg/ha) regarding the available K content were highest in the samples taken from converted paddy fields. Soil samples from homestead area showed lowest mean value (101.4 kg/ha).

13.1 ha (3 %) of the area showed low K status while 89.01 ha (23 %) area showed high K status. 318.8 ha (75.7 %) showed medium status regarding K. Fig.7 shows the distribution of fertility classes of available K over Koliyoor micro watershed.

4.3.1.4 Overlaid fertility map for primary nutrients

Using the 'intersect' tool available with the ESRI software package, individual maps of available N, P and K were overlaid for identifying the areas having low status of these three nutrients (Fig. 8). A total of 24 fertility units were obtained by doing so. Only 0.1 ha area showed low status for all of the three nutrients. High status was shown for these nutrients by about 15.23 ha area. 200 ha area was medium in the case of combined NPK status.

Analysis of point data showed that three sampling locations showed high status for all of the primary nutrient availability. Low status was seen in only one location while 88 locations were medium.

Fig. 7.Map of distribution of fertility classes of available K over Koliyoor micro watershed

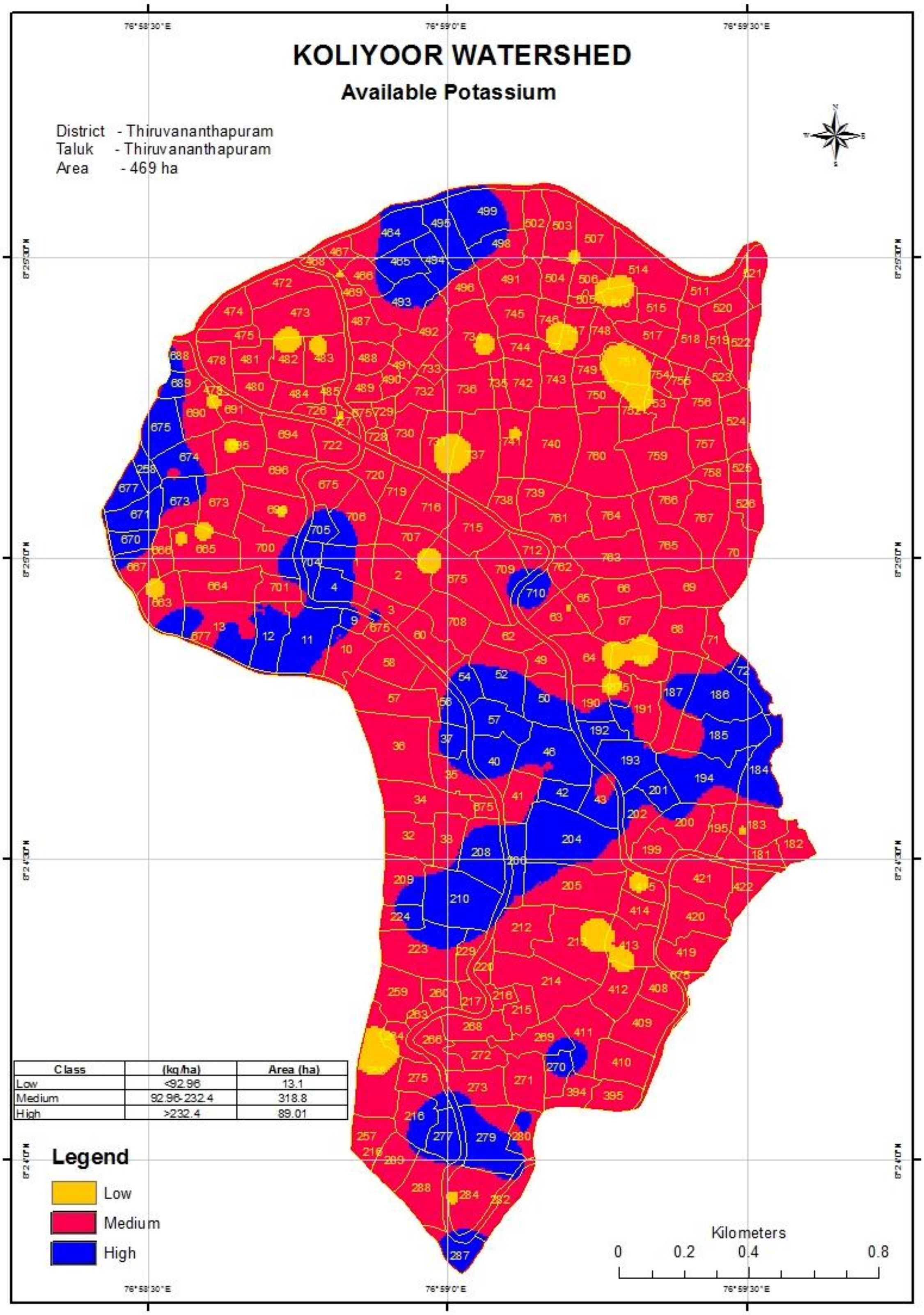
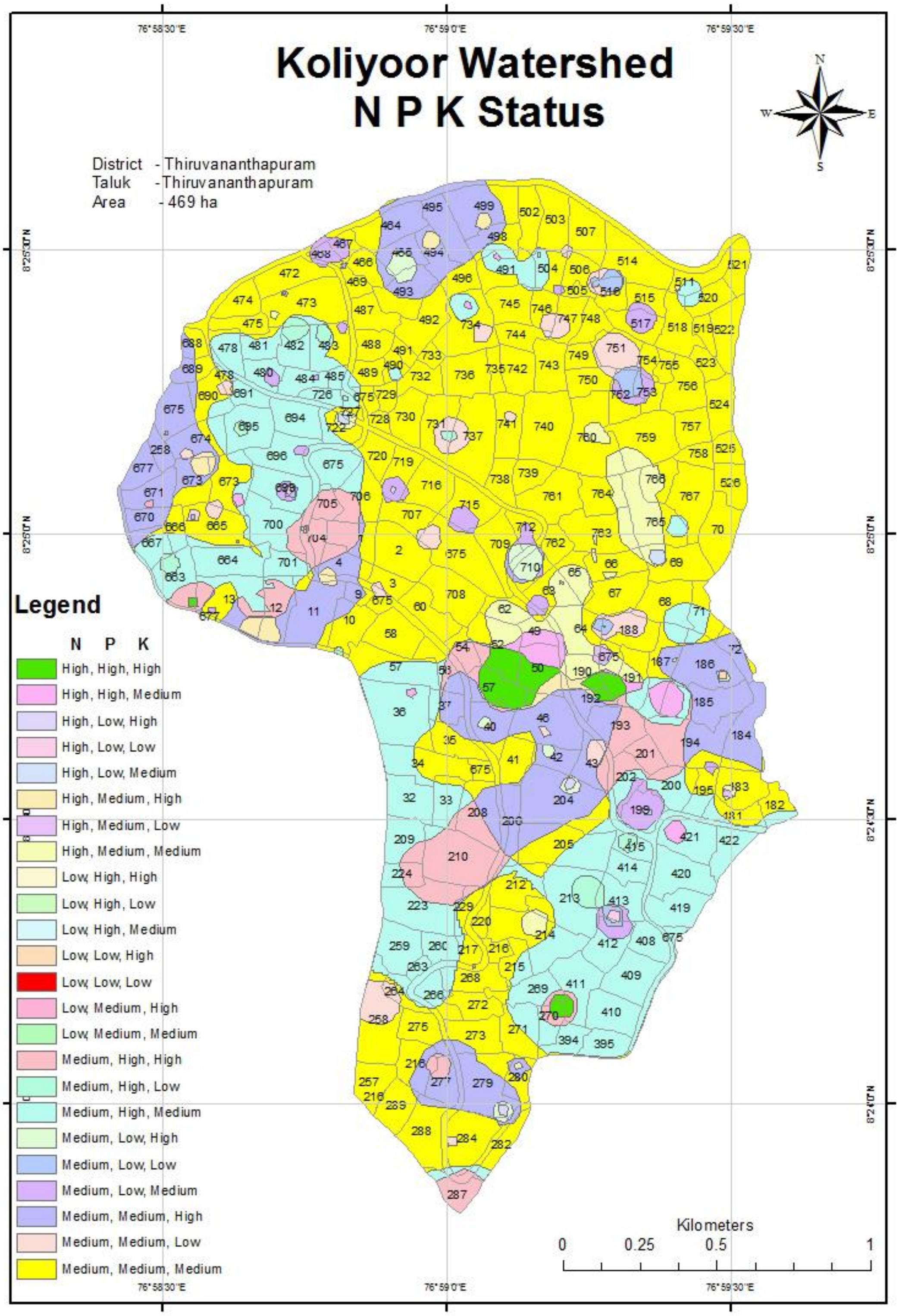


Fig. 8. Map of NPK status of Koliyoor micro watershed



4.3.2 Available Secondary Nutrients

4.3.2.1 Available Sulphur

Available S content of the samples ranged from 8.93 to 71.3 kg/ha. The mean value regarding total number of samples was 30 kg/ha and mode value was 37.5 kg/ha. Highest value was obtained from the sample ‘S 138’ which was taken from 696th survey plot. The sample ‘S 106’, ‘S 107’, and ‘S 146’ taken from showed lowest availability of S.

Among the samples, 50 samples (28.9 %) showed low available S. 116 samples (66.9 %) were medium in S availability while 8 samples (4.2 %) showed high status. When the samples were grouped according to land use of the plots, the highest average value (39.2 g/ha) was seen among the samples from homestead cultivation. Samples from non-agricultural area showed lowest mean availability (12.1 kg/ha) of S.

From interpolated map, it was found that 1.2 ha (0.3 %) of the watershed comes under low available S status. 29.8 ha (6.7 %) area showed medium S status while high S availability was seen over 370 ha (93 %) area. Fig.9 shows the distribution of fertility classes of available S over Koliyoor micro watershed.

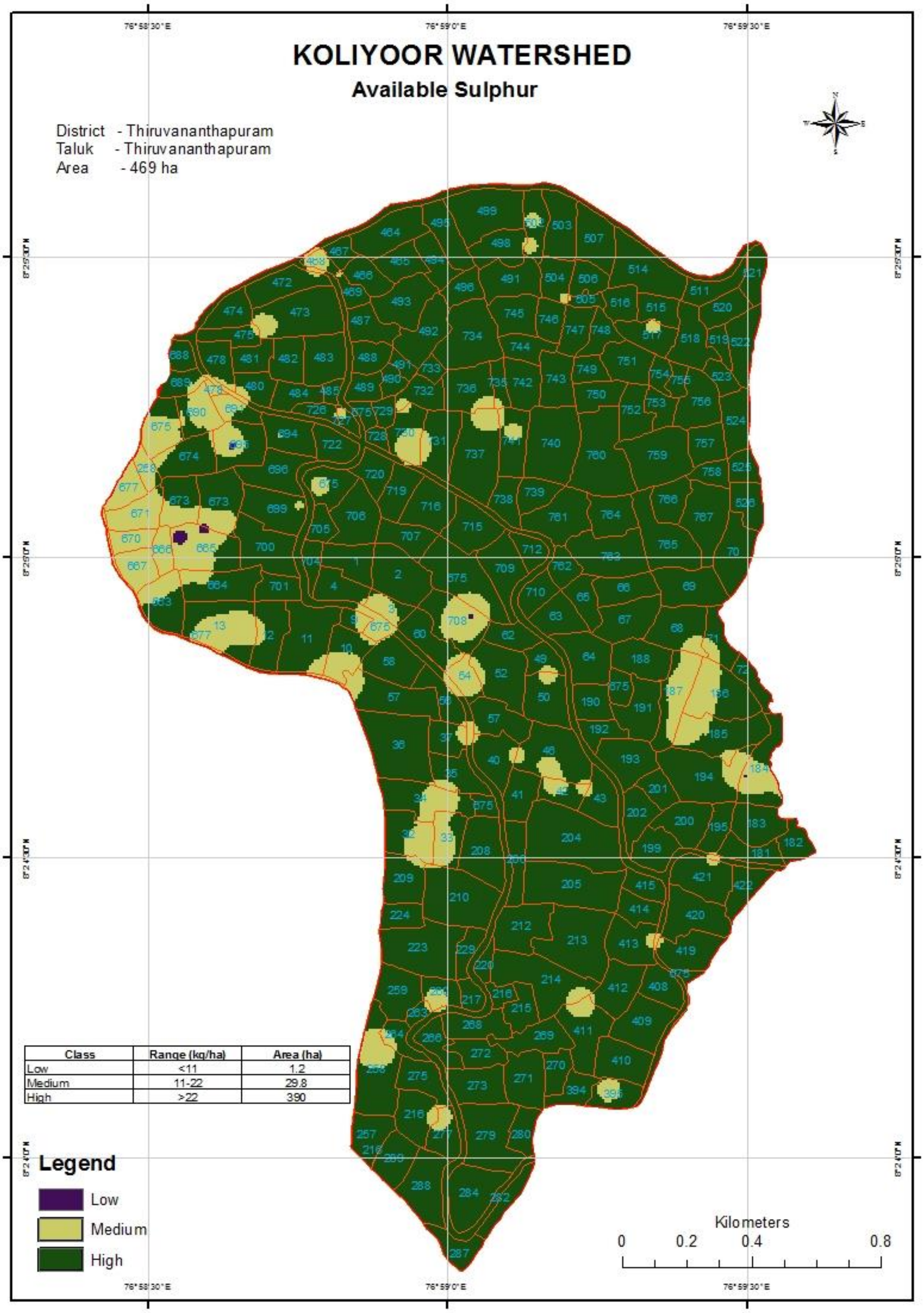
4.3.2.2 Available Calcium

Majority of the area of Koliyoor watershed showed relatively higher available Ca content. Samples ranged in their Ca availability status from 75 to 900 ppm with a mean value of 337.33 ppm and mode of 745 ppm. The sample which showed highest available Ca content was S 15 taken from 468th survey plot. The sample which showed the lowest Ca availability was ‘S 124’ taken from 743rd survey plot.

When the entire range was divided into two classes, 167samples (96 %) were included in ‘Sufficient’ category while only 7 samples (4 %) showed deficiency of available calcium. Land use wise analysis of samples showed that converted paddy filed samples were with the highest mean value (428.5 ppm) and

Fig. 9. Map of distribution of fertility classes of available S over

Koliyoor micro watershed



the lowest mean availability (301.1 ppm) was seen in the plots of coconut based cultivation.

Interpolated map showed that 311 ha (74 %) area sufficiency of available Ca while 110 ha (26 %) showed deficiency. Fig.10 shows the distribution of fertility classes of available Ca over Koliyoor micro watershed.

4.3.2.3 Available Magnesium

Mg deficiency was seen all over the area except in some pockets. It ranged from 12 to 167 ppm with a mean value of 49.47 ppm and mode value of 42 ppm. Highest available Mg content was found from sample 'S 2', taken from 514th survey plot. Lowest value of available Mg was obtained from three locations (S 109, S 31 and S 5) taken from 37th, 65th and 13th survey plots respectively.

Only seven samples (4 %) showed sufficient available Mg content. Rest of them (96 %) showed a range of 12 to 114 ppm. Converted paddy fields showed comparatively high status of available Mg with a mean value, 91 ppm while the lowest mean status (32.8 ppm) seen in the samples from coconut based cultivation plots.

Almost all the area, that is, 420.06 ha (99.9%) area showed deficiency status while only 0.4 ha (0.1 %) area was with sufficiency of available Mg. Fig.11 shows the distribution of fertility classes of available Mg over Koliyoor micro watershed.

4.3.3 Available Micro Nutrients

4.3.3.1 Available Iron

Koliyoor micro-watershed showed typical nature of Kerala soils regarding available Fe status in the soils. It ranged from 4.61 to 164 ppm with an average value of 49.62 ppm and mode of 67.72 ppm. Highest available Fe content was recorded from the sample 'S 125' taken from 737th survey plot and the lowest availability was from the sample 'S 157' of 722nd survey plot.

Fig. 10.Map of distribution of fertility classes of available Ca over

Koliyoor micro watershed.

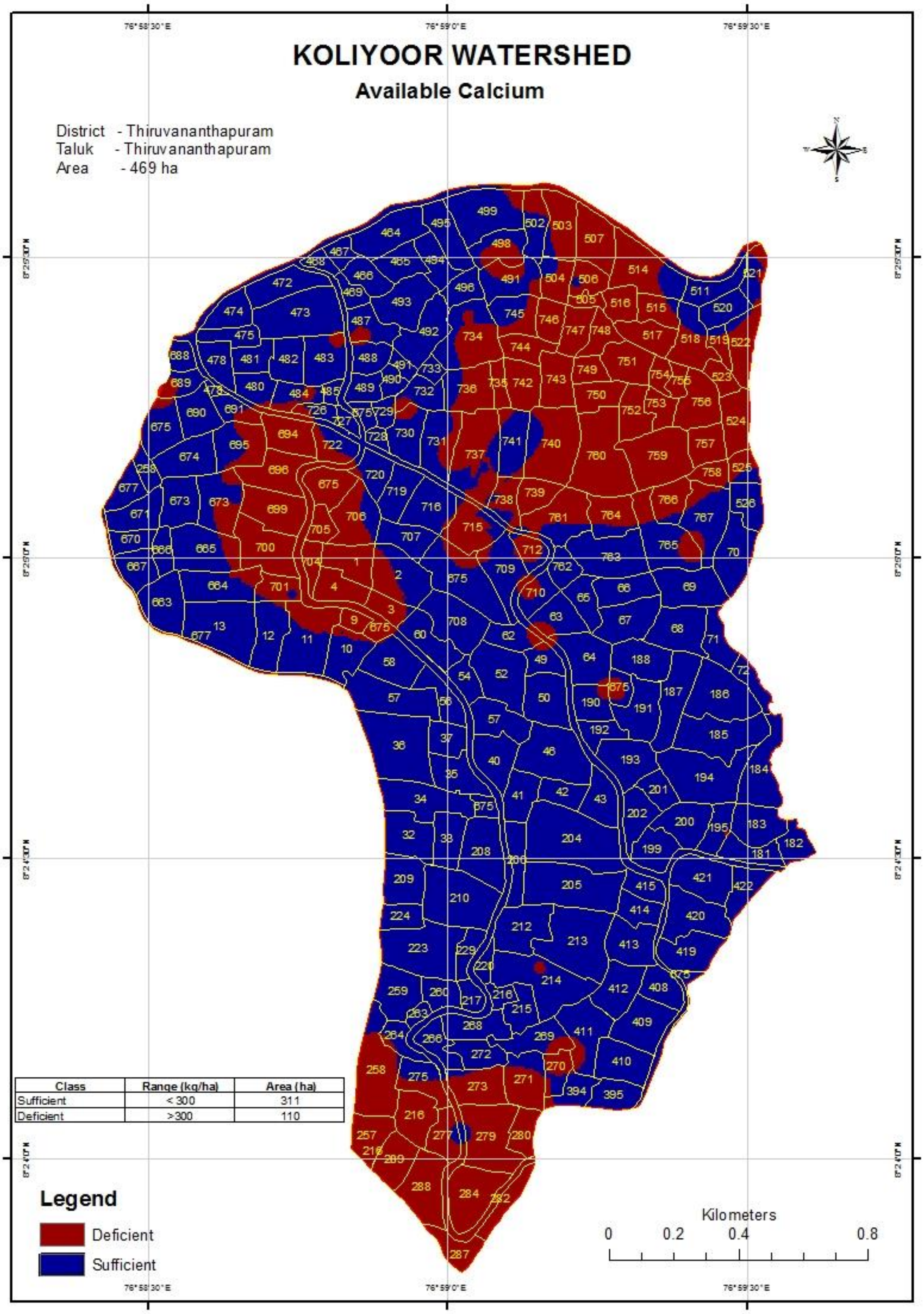
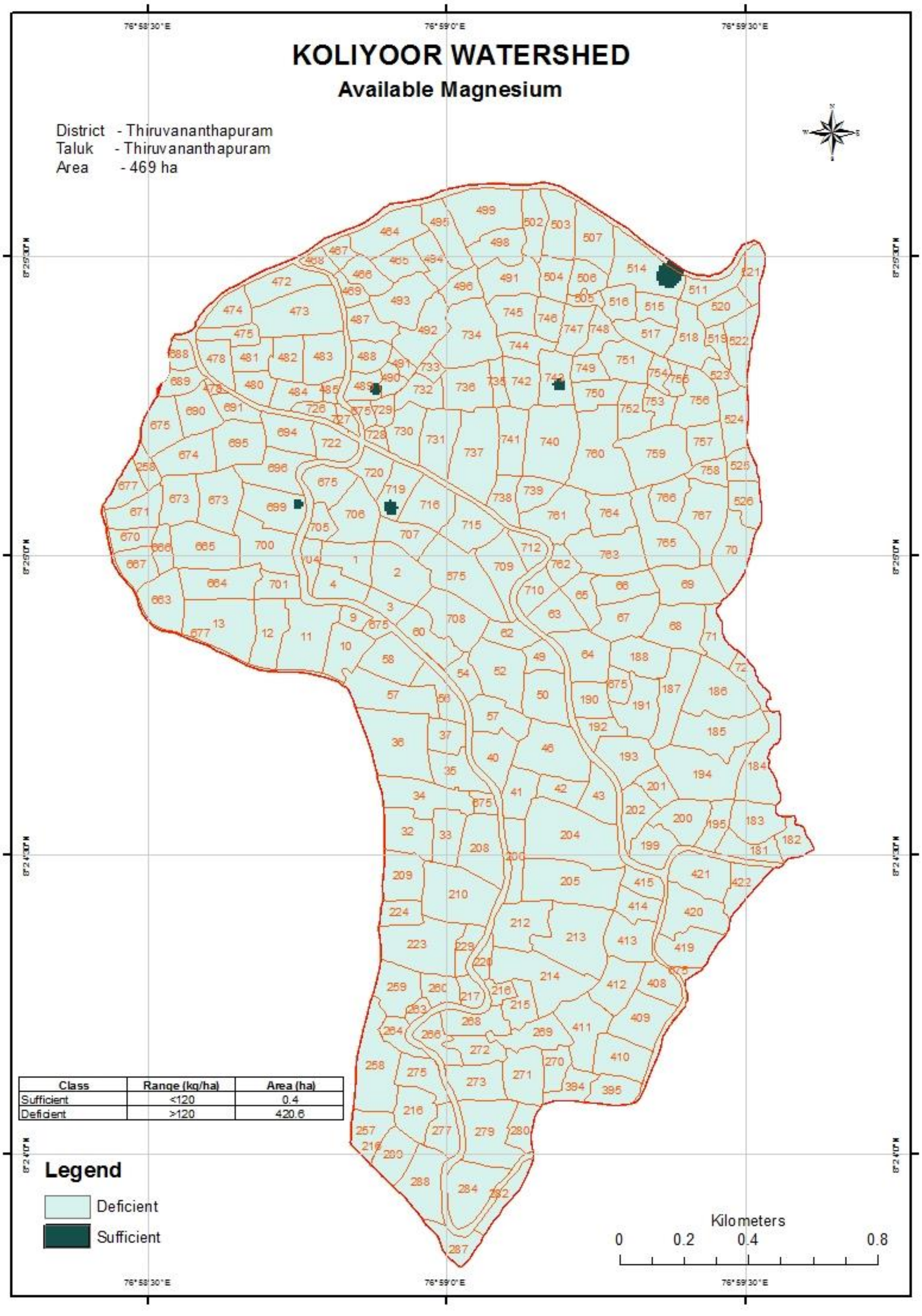


Fig. 11. Map of distribution of fertility classes of available Mg over Koliyoor micro watershed



Only 3 samples (2%) showed deficiency of available Fe while 171 samples (98 %) showed sufficiency. Highest mean value (69 ppm) was seen in the land use category of converted paddy fields. Samples from non-agricultural area showed lowest mean availability of Fe (41.03 ppm). Interpolation revealed that, about 420.6 ha (99.9 %) area came within sufficiency status of available Fe content while 0.4 ha (0.1%) area showed deficiency. Fig.12 shows the distribution of fertility classes of available Fe over Koliyoor micro watershed.

4.3.3.2 Available Copper

Soil samples from the study area ranged from 0.01 to 8.66 ppm in available Cu content. Mean value obtained was 3.47 ppm with a mode value of 0.8 ppm. Highest Cu availability was shown by the sample 'S 162' taken from 505th survey plot. The sample, 'S 8' from the 491st survey plot showed lowest Cu availability.

Among the total number, 152 samples (87.35 %) showed sufficient available Cu content while 22 samples (12.65 %) showed deficiency. When the samples were categorized based on land use, those from converted paddy fields showed highest mean value (4.1 ppm). The lowest mean value (1.1 ppm) was obtained from non-agricultural area.

Majority of the area, i.e., 419.9 ha (99.7 %) fell in sufficiency range of available Cu. Only 1.1 ha (0.3 %) showed deficiency. Fig.13 shows the distribution of fertility classes of available Cu over Koliyoor micro watershed.

4.3.3.3 Available Manganese

Koliyoor micro-watershed showed 100 % sufficiency of available Mn. Soil samples ranged from 5.5 to 95.3 ppm in Mn availability. The mean status obtained is 32 ppm and mode of 26.41 ppm. Within this range the highest value

Fig. 12. Map of distribution of fertility classes of available Fe over Koliyoor micro watershed.

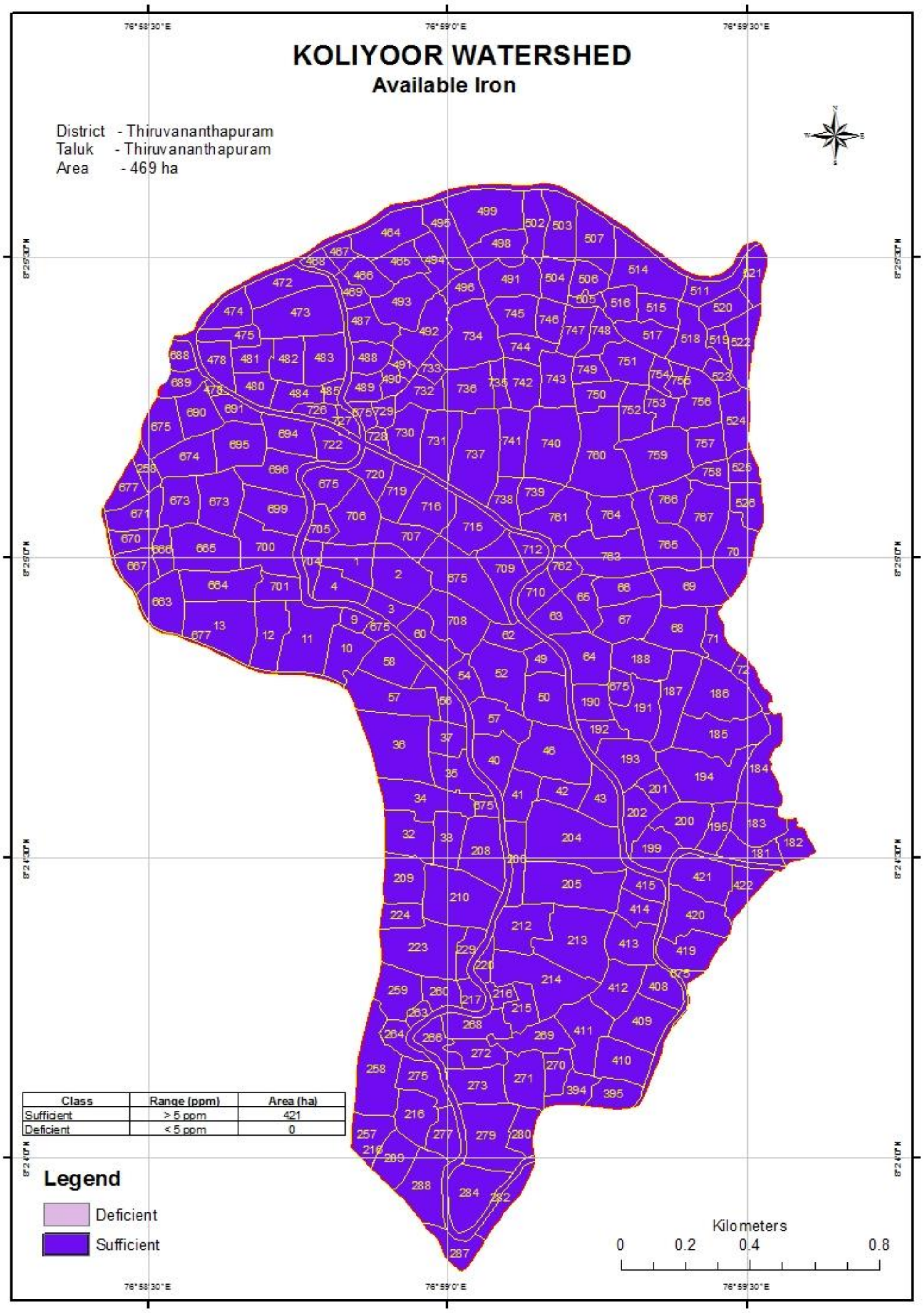
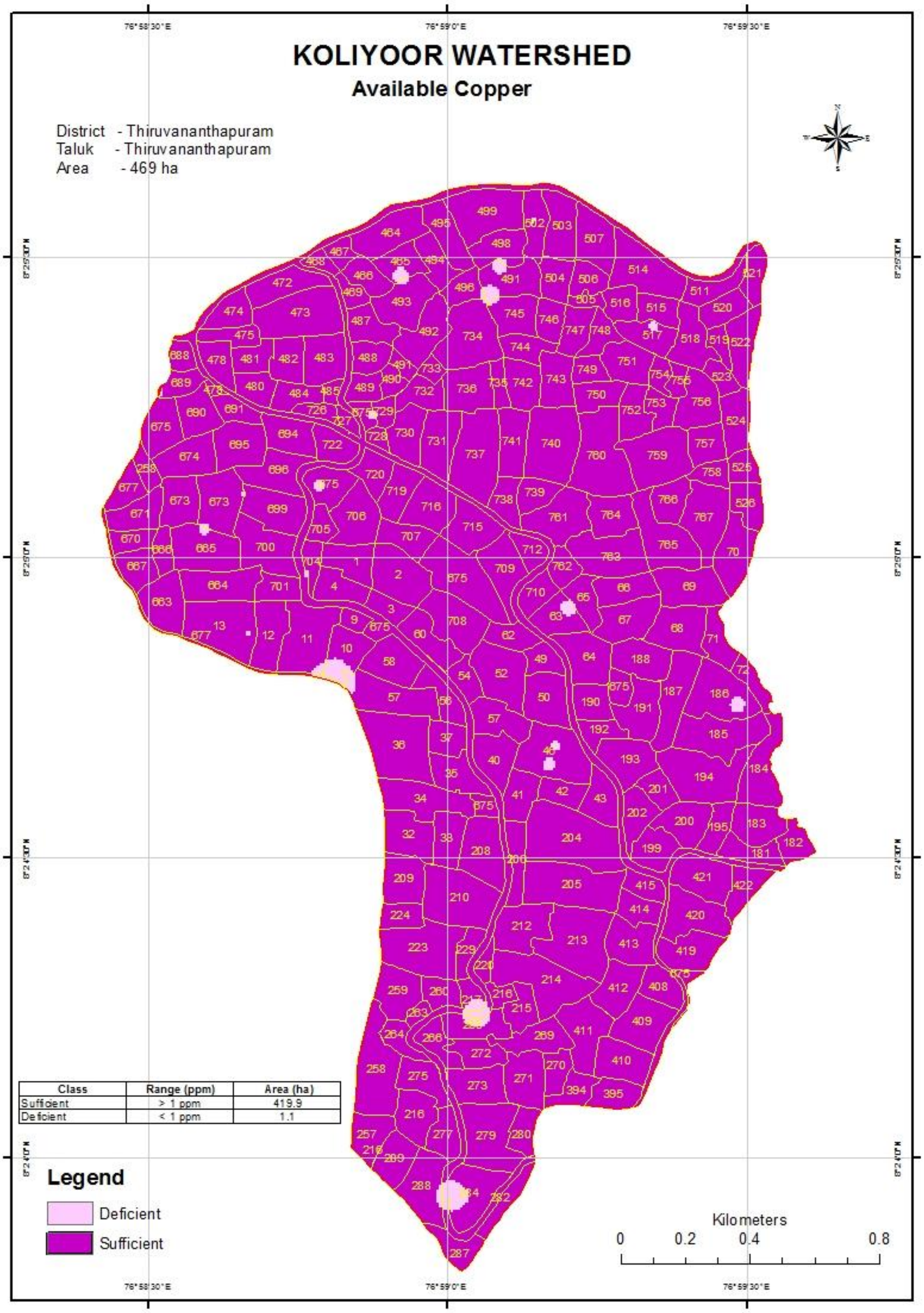


Fig. 13. Map of distribution of fertility classes of available Cu over Koliyoor micro watershed



was found in the sample, 'S 22' taken from 761st survey plot and the least available Cu content from the sample 'S 133' of 673rd survey plot.

As mentioned, none of the samples was deficient in available Mn status. Therefore, in interpolation also, the whole of the area came under sufficiency class.

When the samples were categorized based on type of land use, survey plots of homestead cultivation showed higher availability of Mn and highest mean value of 40.01 ppm. Lowest mean value (21.33 ppm) was seen sample category of non-agricultural area. Fig.14 shows the distribution of fertility classes of available Mn over Koliyoor micro watershed.

4.3.3.4 Available Zinc

Soil samples showed a range of 0.03 to 4.97 ppm regarding Zn availability. The average value obtained was 0.71 ppm while the mode value was 1.01 ppm. Highest available Zn was obtained from the sample 'S 12' taken from the 487th survey plot. Least availability of Zn was noticed at the Sample 'S 20' of 741st survey plot.

Only three samples (1.7 %) showed sufficiency of available Zn and 171 samples (98.3 %) showed deficiency in Zn availability. Among the land use types, plots of homestead cultivation showed higher Zn availability with a mean value of 1.01 ppm. The lowest mean value (0.53 ppm) was seen in the category of converted paddy fields.

After interpolation, it was found that 29.8 ha (7 %) area showed sufficiency of available Zn and 391 ha (93 %) area showed deficiency. Fig.15 shows the distribution of fertility classes of available Zn over Koliyoor micro watershed.

Fig. 14.Map of distribution of fertility classes of available Mn over Koliyoor micro watershed

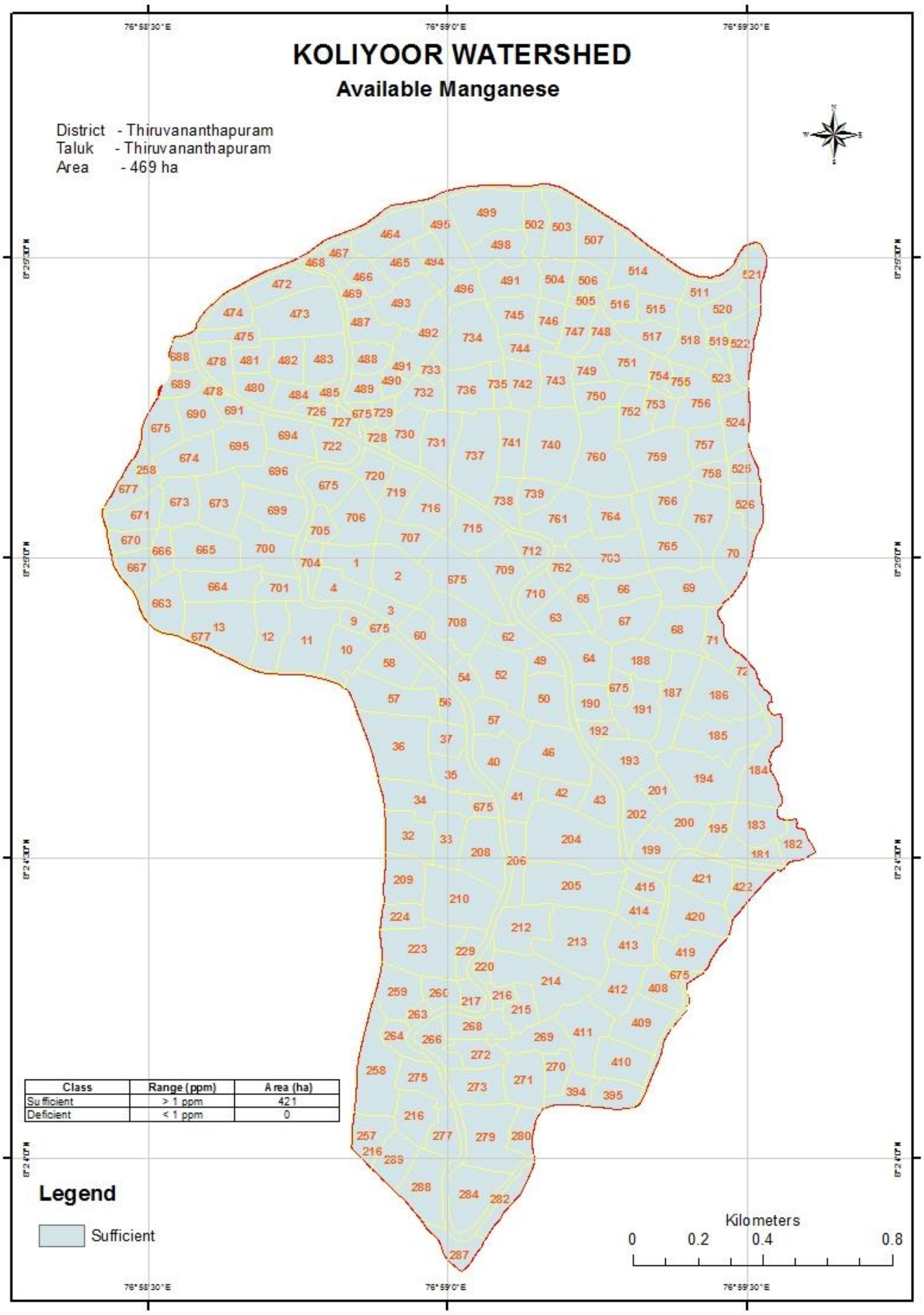
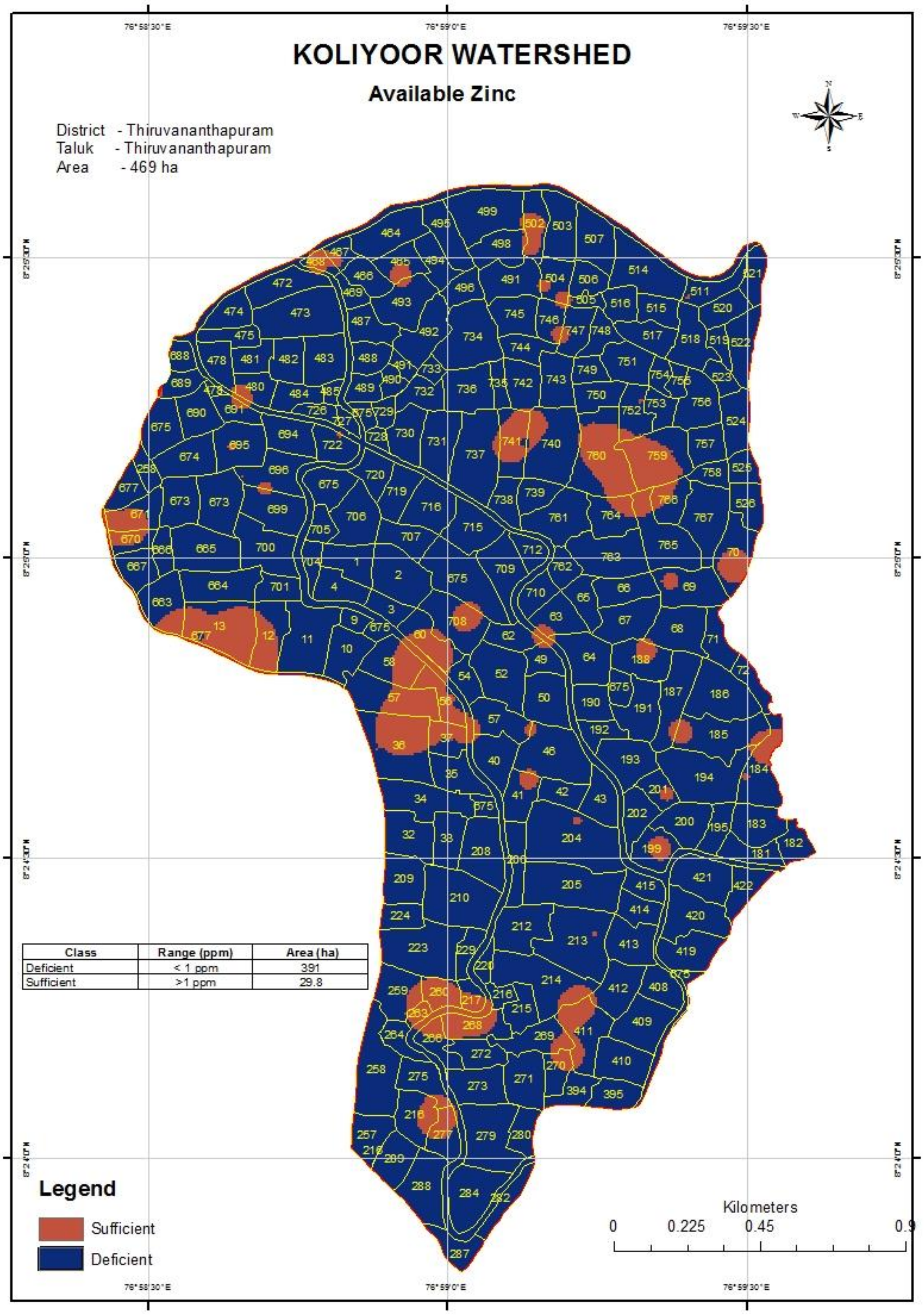


Fig. 15.Map of distribution of fertility classes of available Zn over

Koliyoor micro watershed



4.3.3.5 Available Boron

Soils of Koliyoor micro watershed showed an overall deficiency in B except one pocket. It ranged from 0.01 to 0.67 ppm with an average value of 0.27 ppm and mode of 0.35 ppm. Within this range the highest value was found from the sample, ‘S 14’ of 473rd survey plot and the least available B content from the Sample ‘S 151’ of 517th survey plot.

Among the sampling locations, B availability was sufficient in only one (0.6 %) sample. In land use wise analysis plots of coconut based cultivation showed lowest mean availability (0.22 ppm) of B while samples from non-agricultural area showed highest mean status of 0.43 ppm.

Interpolated map showed that, only 0.99 ha (0.2 %) area showed sufficiency of B availability while 420.01 ha (99.8) showed deficiency in this aspect. Fig.16 shows the distribution of fertility classes of available B over Koliyoor micro watershed.

4.4 PHYSICAL PROPERTIES

Apart from the analysis for texture, electro-chemical properties and fertility, two important physical properties (Water Holding Capacity and Bulk Density) were also determined for fifteen samples taken on grid basis. The results are presented in Table 10.

4.4.1 Bulk Density

Bulk density of the samples ranged from 1.2 to 1.7 gm/c.c with an average value of 1.4 gm/c.c. Samples from plots of relatively high content of organic carbon showed lower bulk density. Highest bulk density (1.7 gm/c.c) was shown by the sample ‘S 57’ which was taken from 671st survey plot and the least value (1.2 gm/c.c) was recorded from sample ‘S 8’ which was taken from 63rd survey plot. Fig.17 shows the spatial variation of soil bulk density over Koliyoor micro watershed.

Fig. 16.Map of distribution of fertility classes of available B over

Koliyoor micro watershed

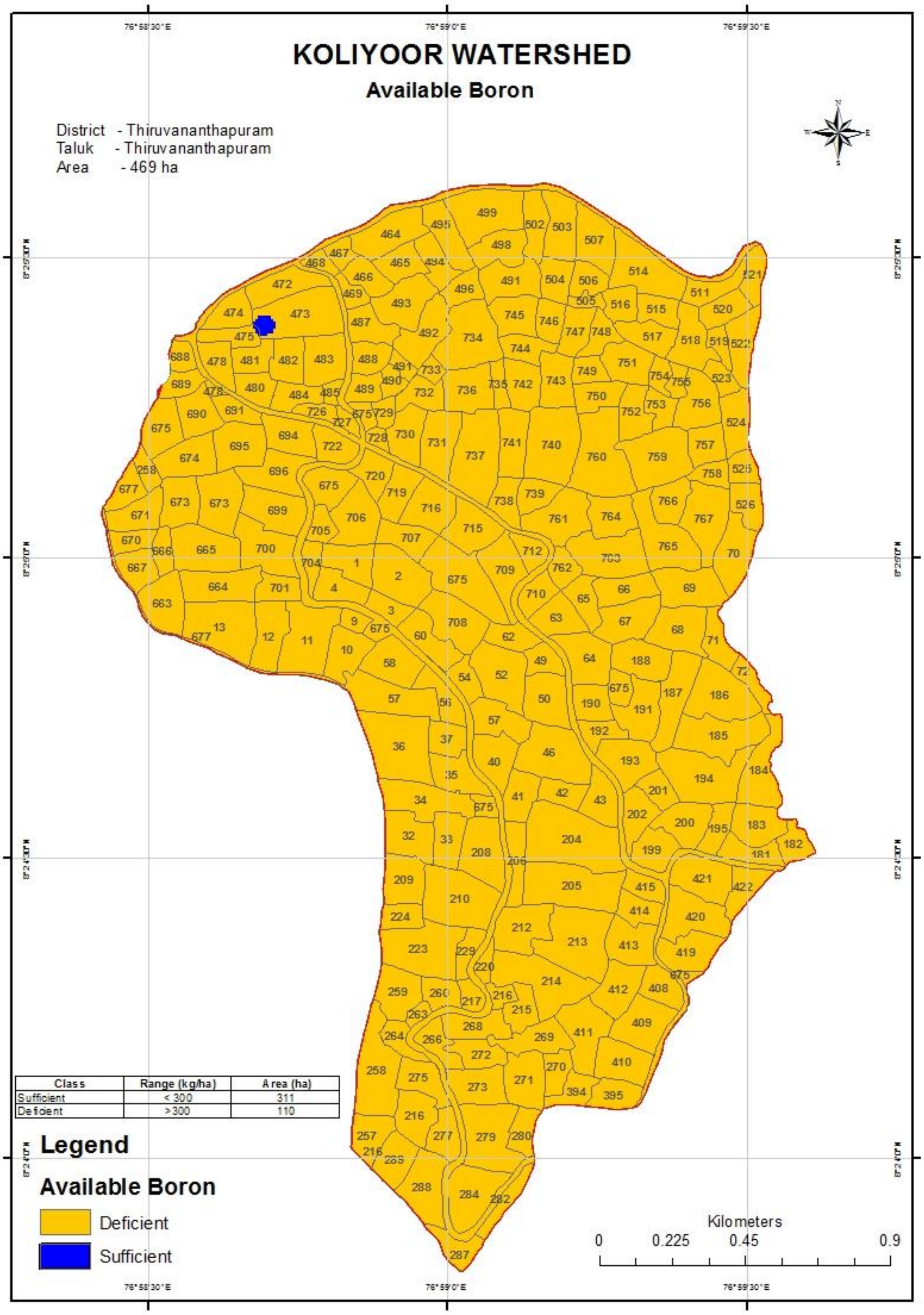


Fig. 17.Map of spatial variation of soil bulk density over Koliyoor micro watershed

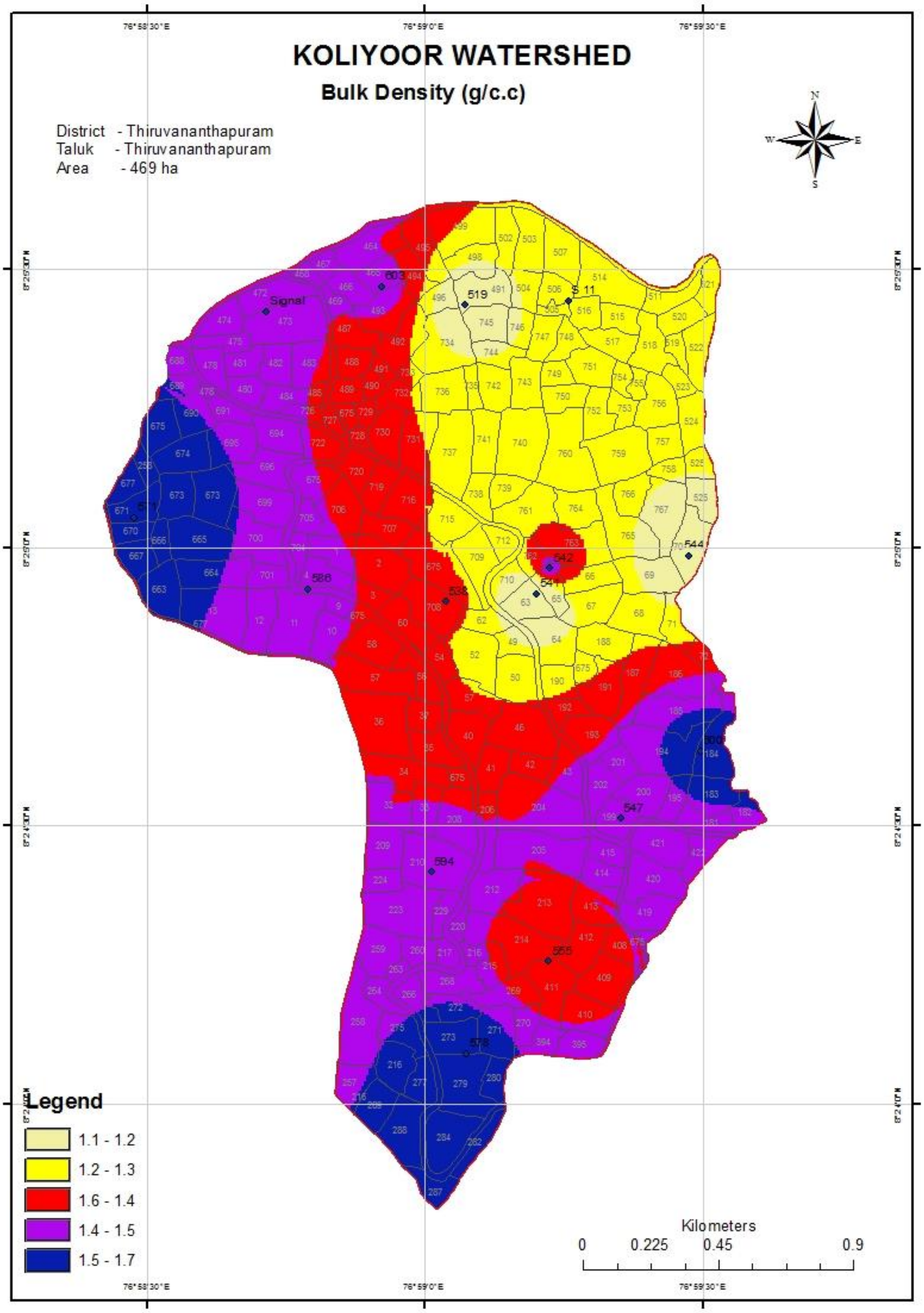


Fig. 18.Map of spatial variation of soil water holding capacity over

Koliyoor micro watershed

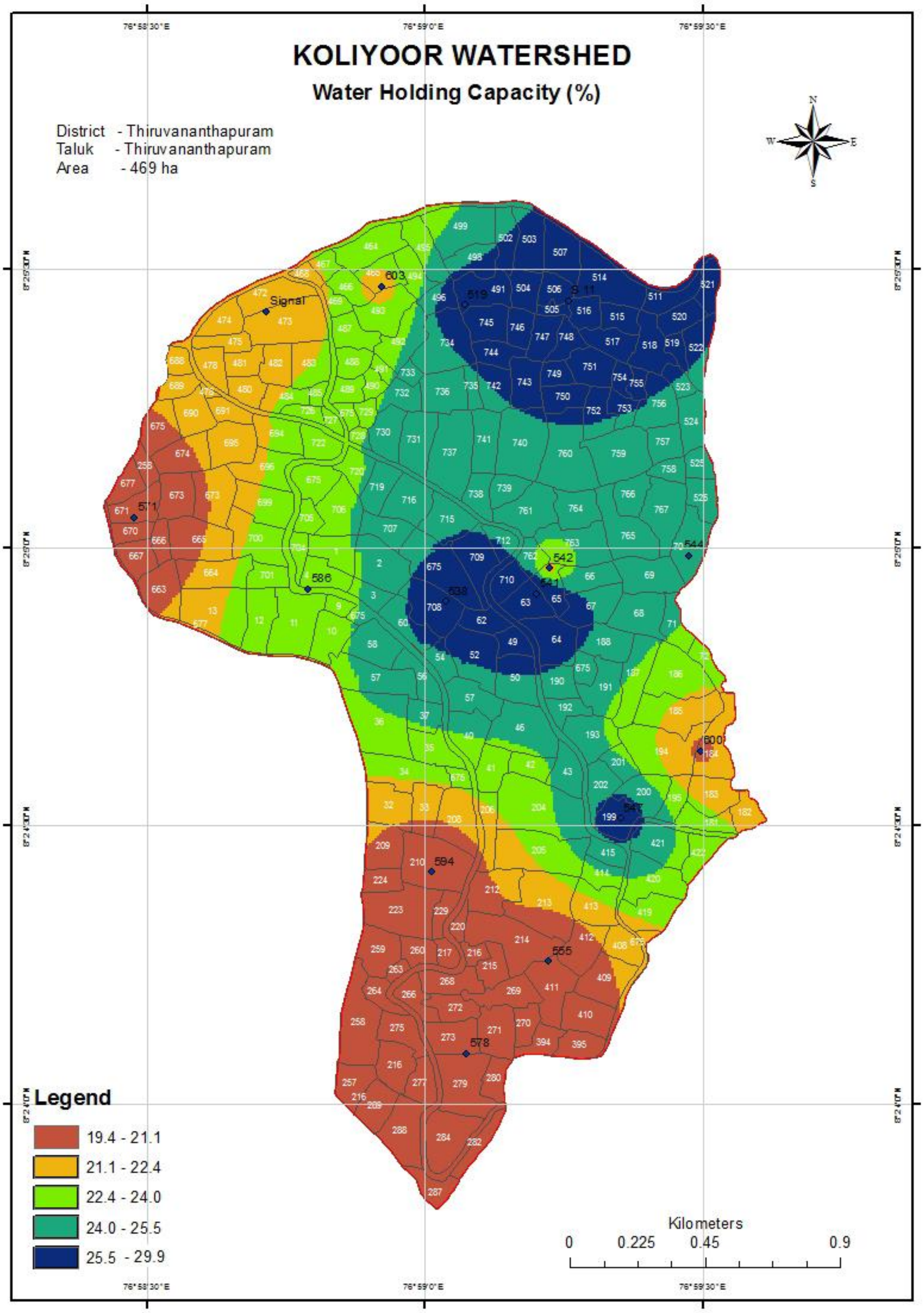


Table 10. Physical properties of soil samples from

Koliyoor micro watershed

Sl. No.	GPS Location	Water Holding Capacity (%)	Bulk Density (Mg/m3)
1	S 166	21.60	1.50
2	S 31	22.30	1.50
3	S 86	21.10	1.60
4	S 30	29.80	1.35
5	S 72	23.40	1.50
6	S 89	22.30	1.50
7	S 122	28.10	1.30
8	S 36	26.10	1.50
9	S 64	20.10	1.60
10	S 57	19.40	1.70
11	S 8	26.50	1.20
12	S 44	20.20	1.40
13	S 80	20.10	1.50
14	S 27	26.10	1.40
15	S 33	24.10	1.31

4.4.2 Water Holding Capacity

The samples showed a range of 19.4 to 29.8 % regarding water holding capacity. Average value obtained was 23.4 %. The highest value was shown by the sample ‘S 30’ which was taken from the 63rd survey plot. Lowest value was shown by the sample ‘S 57’ taken from 671st survey plot. Fig.18 shows the spatial variation of soil water holding capacity over Koliyoor micro watershed.

4.5 TOPOLOGICAL FEATURES

Topological and land feature data can be utilized for identifying the priority areas for implementing conservation practices. Using these data, Land Capability Classification can be done very easily.

4.5.1 Slope Gradient

The slope gradient classes present in the Koliyoor micro watershed were determined using the DEM and GPS elevation data. Range of the slope varied from 0 to 15 %. When this range was categorized according to the field manual of soil survey staff, five classes were obtained ranging from 'Nearly Level' to 'Strongly Sloping'. Table 11 shows the slope gradient classes identified using GIS and corrected subsequently by field checks.

Table 11. Slope gradient classes in Koliyoor micro watershed

Sl. No.	Slope Gradient Class	Range (%)	Area (ha)
1	Nearly Level	0 to 1	187.6
2	Very Gently Sloping	1 to 3	154.8
3	Gently Sloping	3 to 5	18.8
4	Moderately Sloping	5 to 10	79.7
5	Strongly Sloping	10 to 15	28.0

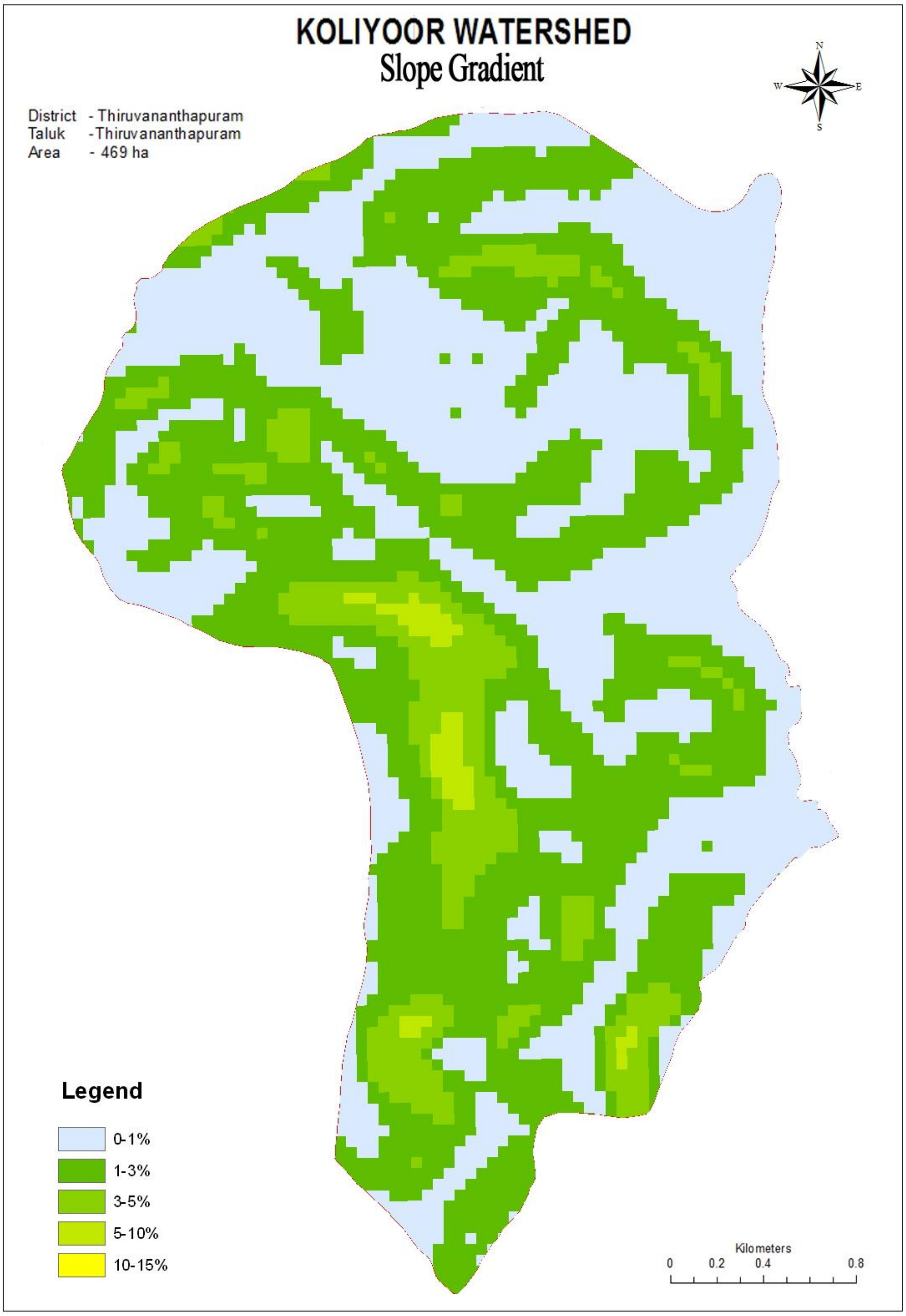
Within the obtained range of slope gradient, three topographical classes were identified, ranging from 'Flat' to 'Rolling' type. Table 12 shows the topographical classes and area covered within each class.

Table 12. Topographical classes in Koliyoor micro watershed

Sl. No.	Class	Range (%)	Area (ha)
1	Flat	Less than 2	200
2	Undulating	2 to 8	160
3	Rolling	8 to 16	109

Fig. 19.Map of spatial distribution of different slope gradient classes over Koliyoor micro watershed

Fig.19 shows the spatial distribution of different slope gradient classes over Koliyoor micro watershed.



4.5.2 Slope Aspect

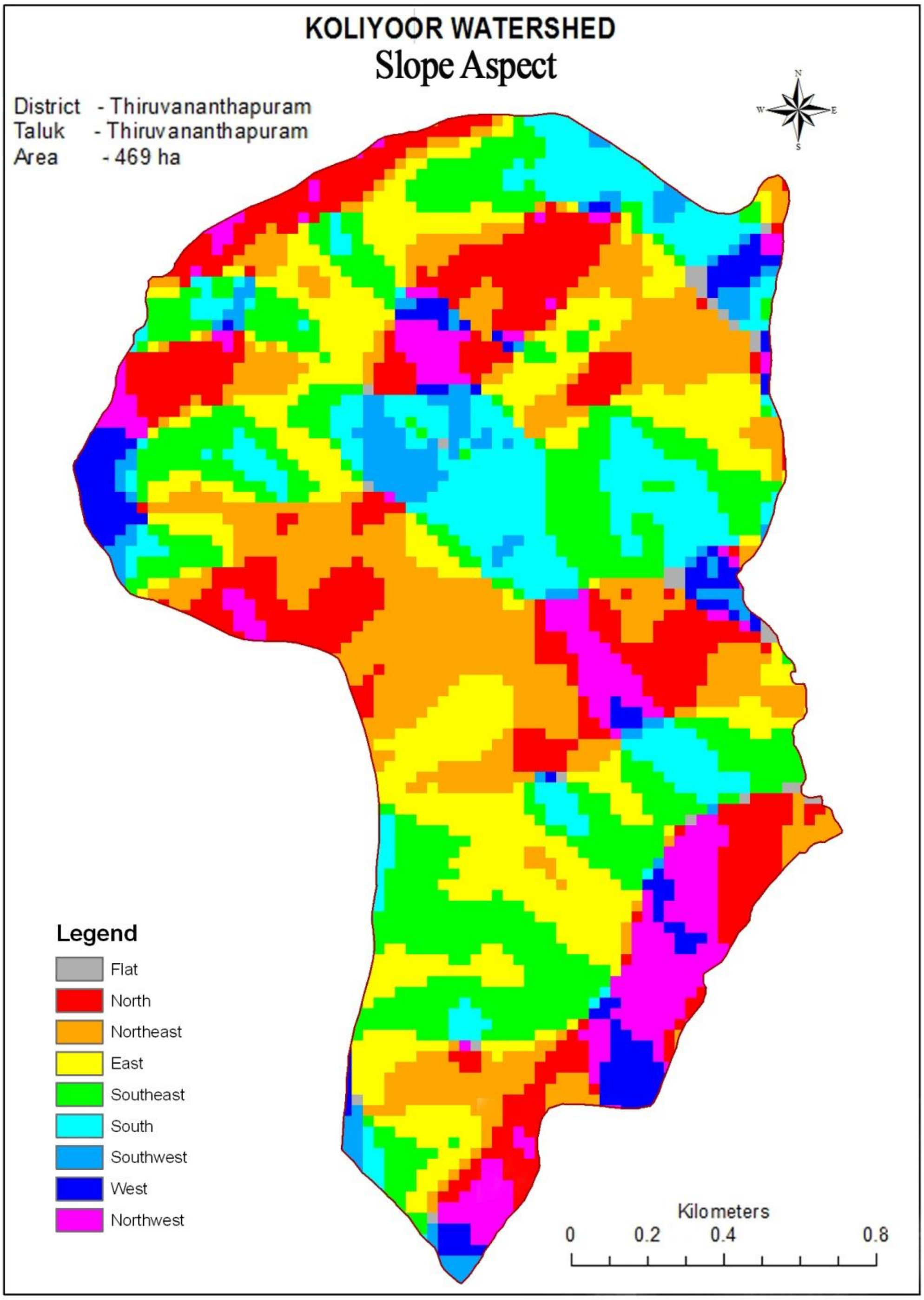
A map showing the direction of slopes within the entire area of Koliyoor micro watershed was generated. Nine slope direction classes were obtained. Table 13 shows the slope direction classes present in Koliyoor micro watershed and the area under each class.

Table 13. Slope aspect classes in Koliyoor micro watershed

Sl. No.	Slope Direction	Area (ha)
1	Flat	2
2	North	75
3	North-East	66
4	East	90
5	South-East	82
6	South	57
7	South-West	25
8	West	40
9	North-West	32

Fig.20 shows the spatial distribution of different slope aspect classes over Koliyoor micro watershed.

Fig. 20.Map of spatial distribution of different slope aspect classes over Koliyoor micro watershed



Discussion

5. DISCUSSION

The results of the investigation regarding various soil parameters of Koliyoor micro watershed were integrated in a GIS environment for effective interpretation. The soil samples taken were from the surface layers of plots having different types of land uses. The samples were analyzed for the status of available nutrients, electrochemical properties and important physical properties. Various topological features of the area and important taxonomic aspects were also noted. Using these data, thematic maps for different parameters were generated using GIS software. The GIS software as well as thematic maps can be used for interpretation and for making an optimum soil conservation and nutrient management plan effectively in terms of time and cost.

5.1 TEXTURAL VARIATIONS

Soil texture is considered as a basic physical property which cannot be altered easily. It influences the properties of soil like transmission of water, water holding capacity, soil air dynamics, fertility, etc.

The samples which showed sandy loam texture on analysis were taken from the plots having considerable slopes. When the map of slope gradient was generated (Fig 19) all of these plots were included in the slope classes starting from Gently Sloping to Strongly Sloping (3 to 15 %). The natural vulnerability of these plots to soil erosion might have caused leaching of clay particles resulting in lower mean clay content (17.33 %) compared to the samples taken from plots which are included in Nearly Level to Very Gently Sloping classes (0 to 3 %). The samples taken from Nearly Level to Very Gently Sloping plots (0 to 5 %) showed Sandy Clay Loam texture and comparatively higher mean clay content of 27.13 %. Most of them are situated in converted paddy fields and near to the paddy fields. Being lower topography and low sloping nature, there may be sedimentation of clay particles by the eroding water flow during the rainy season.

Maximum clay content (29.41 %) was found from the 70th survey plot. The same plot recorded minimum sand content (51.86 %). This survey plot is located just near to the VellayaniLake by the side of outlet of Koliyoor stream. Being lighter particles, high clay accumulation may be occurring there due to the flood water from upper plots during rainy periods. Various agricultural practices are other means of increment in clay content. Tiwari (2002) stated that clay content and silt content were comparatively higher in the soils of agricultural plots than those of other land use types.

Maximum sand content (64.84 %) was shown by 708th survey plot which comes under the Moderately Sloping class (5 to 10 %) which may have resulted in higher degree of removal of relatively erodible clay and silt particles. Lowest clay content (23.76 %) was shown by 671st survey plot which is being bordered by the ridge line in the western side. Comparatively higher elevation and erosion susceptibility may be the reasons for relatively low status of clay content. Thangasamy*et al.* (2005) identified topography and the parent material as the prime reasons behind the textural changes in the soils of Sivagiri micro watershed of Chittoor district in Andhra Pradesh.

Even though texture is considered as a basic property of soil, in long term perceptive, changes can be expected. Raju *et al.* (2005) found that textural variations can be expected as a result of differences in physiography which in turn affects the *in situ* weathering and translocation of clay.

5.2 ELECTROCHEMICAL PROPERTIES

5.2.1 Soil Reaction

Climatic parameters like humidity, rainfall, organic matter, parent material, application of fertilizers, etc influence the soil pH. Soils of Koliyoor micro watershed showed Strongly Acidic to Neutral soil reaction. Medium acidity was shown by majority (56 %) of the samples. This variation may be the result of typical rainfall pattern and high atmospheric humidity prevailing in the area.

However other factors also may have an effect. Thangasamy*et al*. (2005) observed the variation in soil reaction was related to parent material, rainfall and topography in the soils of Sivagiri micro-watershed, Andhra Pradesh.

When the samples were categorized according to land use, lowest mean value (5.1) of soil reaction was shown by the homestead area. This may be due to the excessive litter accumulation because of perennial foliar coverage of trees and its decay resulting in release of organic acids.

Highest mean value (6.1) of soil reaction was recorded from the samples taken from plots of coconut based cultivation. Most of the coconut cultivated plots are without any other sources of organic matter addition. And some plots which are under careless management have considerable grass coverage. These two factors may contribute relatively low presence of organic acids and higher recycling of bases resulting in this pH status.

Highest acidity was shown by the 498^{th} survey plot which is situated near the northern boundary of watershed. The low soil pH may be attributed to the presence of biodegradable wastes and effluents from a hotel working adjacent. The highest value of pH (6.6) was recorded from 675^{th} survey plot. As mentioned earlier, this plot comes under coconut based cultivation having significant amount of grassy weeds which may be the reason of low acidity due to the enhanced recycling of base forming cations.

Apart from all of these possibilities, seasonal effects can exert influences on soil reaction. In order to ascertain the seasonal effect on soil reaction, detailed temporal variation study of soil reaction is needed.

5.2.2 Electrical Conductivity

Electrical Conductivity soils of Koliyoor micro watershed ranged from 0.01 to 0.26 dS/m which means that only non-saline soils are there in this area. This is typical all over the soils of Kerala. It may be attributed to humid climate because of which the soluble salts originally present in soil materials and those formed by weathering of minerals generally are carried downward into the ground water and are transported ultimately by streams or rivers. Non-saline ground water, non-proximity of saline water bodies, etc may be the other possibilities for lower EC. In Koliyoor micro watershed, EC values were seen extremely dependent on the elevation as well as slope of the survey plots.

Within this non-saline range, majority of survey plots near to the western ridge line are with below average values of EC. This area is with highest elevation and relatively high slopes. So naturally these survey plots may be experiencing high intensity removal of soluble salts into lower topographical regions as well as the pockets having flat terrain. GIS analysis of data of slope gradient and EC shows that lower topographical regions and plots without considerable slopes are with above average values for EC. These conditions may favor relatively low movement of soluble salts by water.

When the land use based categories of soil samples were compared, highest mean EC (0.11 dS/m) was shown by those from plots of homestead cultivation possibly because of supply of soluble salts by decay of organic matter. Most of these survey plots are with dense vegetation, which might slowed down the erosion. However, some of the homestead survey plots showed below average EC values. High organic matter may have resulted in comparatively low EC possibly due to the alterations in mineralization-immobilization dynamics. The survey plots from non-agricultural area showed lowest mean EC (0.06 dS/m). Absence of conservation attitude in the land use of these regions may result higher rate of transportation of soluble salts by water.

The lowest value was obtained from the 210th survey plot. It may be because of the fact that it is located in a steep slope from the ridge line which may have increased the removal of soluble salts by runoff water. Highest EC value was shown by the sample from 737th survey plot where the slope gradient was 0 to 1 %. So naturally, absence of erosion or runoff removal of soluble salts by the water may have caused the occurrence of comparatively higher EC.

5.3 AVAILABLE NUTRIENTS

Plants absorb nutrients as single nutrient element which is uncombined with other nutrients and essential nutrient element combined with other elements to form nitrate, phosphate, sulfate, etc. Thus mineral nutrients are available to the plant both in ionic and molecular forms, the proportions depending on the nature of soil solutions and the conditions. In this view, information on available nutrients is valuable for formulating a nutrient management plan according to the existing land use.

5.3.1 Available Major Nutrients

5.3.1.1 Organic Carbon

Interpolation of point data showed that organic carbon status was fairly good all over the area except some pockets showing low availability. Among the five pockets of low organic carbon content, three are located in the survey plots nearer to the western ridgeline. From transect walk, it could be identified that majority of area near western ridgeline is dominated by non-agricultural uses like stone quarrying, construction works like resorts, etc. Even though, plots of coconut cultivation were there, good cultivation practices were absent with the existence of rocky nature of land, steep slopes, etc. Even if grassy vegetation was prominent in some of the plots, organic carbon content was comparatively less because the grass originated organic matter and its mode of decomposition encourages a reduced rate of decay. Cassava cultivation was seen at elevated coconut plots. All of these conditions may have resulted in formation of those pockets of low organic carbon content. Evidence of laterization could be seen sporadically along the ridgeline suggesting increased exposure of land and rapid oxidizing conditions of organic matter.

Land use wise analysis of samples had proved that plots of homestead cultivation were having the highest mean value of organic carbon content (0.82 %). Few plots showed organic carbon content near up to 2 %. This may be due to the continuous addition of organic matter by the perennial trees which are an important aspect of homestead cultivation and relatively undisturbed soil surface in these areas. Locations of the samples ‘S 90’ and ‘S 92’ are typical examples for this condition. Nine survey plots of converted paddy fields also showed high status of organic carbon content. It may be attributed to poorly drained condition of soil. Unscientific land use changes in the paddy fields result in impeded drainage. Koliyoor micro watershed is witnessing large scale land use changes and land modification and the paddy fields are no exception.

Lowest mean value of organic carbon content (0.21 %) was obtained from samples of non-agricultural area. Absence of vegetation cover and large scale soil surface changes might cause rapid depletion of soil organic matter due to oxidation which is a common phenomenon in populated places.

5.3.1.2 Available Phosphorus

On analysis, samples showed a range 3.1 to 59.1 kg/ha with a mean value of 22.1 kg/ha regarding available P content. Within a North-South distance of 3.3 km and East-West distance of 2.1 km, Koliyoor micro watershed shows high diversity regarding vegetation, land use, topography, soil series, slope and other land features. Even within the survey plots, different slope gradient classes as well as topographical classes occur. These high degree variations may be the reasons for wide range of available P.

Interpolation revealed that majority of the area (66 %) showed medium status of P. Land use wise analysis of samples had showed that highest mean available P status (25.5 kg/ha) was found from converted paddy fields. Majority of plots of converted paddy fields in Koliyoor micro watershed are being intensively cultivated. So the application of phosphatic fertilizers may have increased available P in those samples. Application of fertilizers like ammonium phosphate also causes the same effect. Some of the paddy fields had showed higher organic carbon content. So the presence of organically bound soluble complex is another possible reason of higher status of available P.

Lowest mean P status was shown by samples from non-agricultural area. The lowest mean organic carbon content of non-agriculture plots may be the reason for this low available P status. However, interpolation revealed that, about 43 ha area comprising non-agricultural plots was with high available P status. The reason may be three fold. Even though these plots are non-cultivated and showed lowest mean organic carbon status, they showed medium status of organic carbon content on fertility rating. Secondly, those plots experience comparatively less crop removal of available P because of absence of intensive cultivation. Quarrying is the prominent type of land use in these areas which can cause spread of rock dust into adjacent plots by several means and thus may have increased P content in the soil. Rose (2008) observed that, rock dust application resulted in percentage increment of 34.5 to 43.2 P with some other nutrients in the soil when compared with inorganic fertilizer application. Silicate minerals and rocks contain most of the nutrients required by the crops.

Among the survey plots, highest available P status was shown by sample from 13th plot. It can be reasoned as the result of good soil management prevailing there. Because interpolation showed that, this plot was showing high status regarding other parameters like available potassium, organic carbon and available S. Selvi*et al.* (2003) stated that continuous application of P fertilizers in combination with N and K significantly increased available P_2O_5 content of the soil.

The 504th survey plot showed lowest status of available P. This plot is a converted paddy field having cassava and banana cultivation. So, intensive cultivation without a balanced nutrient input may be the reason for this lowest status of available P. Further, Banana has been identified as a high water and nutrient exhaustive crop (Rao, 1998).

5.3.1.3 Available Potassium

Extent of the area of Koliyoor micro watershed within the fertility classes followed the order, Medium (75.7 %), High (23 %) and Low (3 %) just like all other major nutrients. Similar to available P, huge variation was seen in the case of available K also. Similar conclusion was obtained by Priya (2011) during a study conducted in the farmers' fields coming under KalliyoorPachayath. The low status was shown by discreet patches especially by the northern half of the watershed. Land use wise percentage analysis done only on these patches proves that, most of them lies on upland plots where the lower percentage clay particles occur which can be a possible reason for low potassium status.

When the land use wise point data analysis was done for the whole area of watershed, highest mean value (210 kg/ha) was seen over converted paddy fields. Lower topography and comparatively higher clay content of those soils might cause high retention of potassium ions. Lowest mean value (101.4 kg/ha) was obtained from the plots having homestead cultivation. It may be an indication of unbalanced nutrient management in these areas. Application of non-potassic chemical amendments like FACT fertilizers alone may be prevailing here. However one of the samples from homestead cultivation area showed highest available potassium content.

Interpolation showed that, plots showing high available potassium status were either having lower topography or more or less flat terrain which eliminates the chances of loss of potassium ions by erosion. This fact emphasizes the role of proper soil erosion controlling factors for maintaining chemical fertility. The plot which showed highest available potassium status (418 kg/ha) is 57th which was under homestead cultivation. It may be due to the organic sources with the over application of potassium containing fertilizers. Otherwise, there may be a potassium transformation process prevailing there which can convert unavailable forms into plant available forms of this nutrient.

Lowest available potassium (20.16 kg/ha) was shown by the sample from 473rd survey plot which is under coconut cultivation. Increased crop removal without proper supply of fertilizer potassium may be the reason.

5.3.1.4 Overlaid fertility map for primary nutrients

Over laying and analysis showed that majority of the area of Koliyoor micro watershed was under medium class regarding availability of N, P and K. This may be due to the fairly good use of high analysis fertilizers and organic matter content of the soils. By the combination of three fertility classes of three nutrients, a total of 27 fertility units should be obtained. But only 24 fertility units were seen on analysis due to the absence of three units.

5.3.2 Available Secondary Nutrients

5.3.2.1 Available Sulphur

May be due to the status of organic matter, 99.7 % of the area of Koliyoor micro watershed was under medium to high status of available S. The topographical diversity of the watershed seemed comparatively insignificant regarding status of available S. It may be due to perennial vegetation present all over the area which is an outstanding source of organic matter, application of fertilizers containing S as impurities or as a nutrient itself.

Sample from homestead area showed highest mean status of available S (39.2 kg/ha). Being under foliage of trees like jack which is very common in the homestead area, plots may be receiving sufficient S input from litter accumulation and decay. This is further substantiated by the fact that non-agricultural plots lacking this situation showed minimum mean availability of S (12.1 kg/ha).

The 696th survey plot showed highest availability of S (71.4 kg/ha). It must be because of comparatively higher organic matter content. After interpolation, high status of organic carbon was shown by three adjacent survey plots (722, 699 and 673). Lowest S status was shown by 184th survey plot located by the side of converted paddy fields and it was seemed surrounded by area of medium S availability. Those areas were with intensive cultivation of Banana and Cassava. So frequent soil disturbances and intensive cultivation might have caused lower organic matter content as well as available S. The adjacent survey plots (186, 185 and 194) showed organic carbon deficiency as patches which may be another evidence for organic matter deficiency.

5.3.2.2 Available Calcium

Being one of the secondary nutrients essential for plant growth, importance of Ca is much more evident in acid and alkali soils compared to neutral or alkaline soils. Relatively larger area (74 %) of Koliyoor micro watershed came under sufficiency status of available Ca. It may be due to the fact that, majority of plots is under homestead cultivation and fairly good vegetation preventing leaching losses, laterisation, etc.

526th survey plot which is situated near the outlet showed highest available Ca status (900ppm) located at the southern side. Eastern boundary of the Koliyoor micro watershed is having the lowest mean elevation of 8 m from mean sea level compared to other portions. Usually lower topographical regions show more level of accumulated Ca, brought down from areas of higher elevation. Not only in southern side but also many pockets of lower topographical regions within the whole area of watershed showed the same trend. Those regions also experience the same condition of southern side in which large level accumulation of nutrients occurs due to leaching from adjacent elevated area. The sample, which showed the lowest Ca availability (75ppm), was from the 743rd survey plot. Possibilities of leaching of Ca ions could be found because of its comparatively elevated position by the side of the converted paddy fields.

Land use wise analysis of samples revealed that the highest mean Ca availability (428.5ppm) was found among the converted paddy fields which may be attributed to the lower topography. Samples from non-agricultural area especially from Kovalam-Azhakulam side, showed lowest mean content of available Ca possibly because of higher elevated survey plots and chances of increased leaching.

5.3.2.3 Available Magnesium

Contradictory to the Ca availability, Mg deficiency was seen over majority of the area (99.9 %). Regardless the topographical position, land use type, Koliyoor micro watershed showed Mg availability which is less than the critical level of 120ppm in 97 % of samples. Several reasons may be there for this condition. For reaching into a precise conclusion, mineralogical properties of soil, percentage of sand, types and nature of dominant clay particles, etc should be taken into account. Presence of exchangeable aluminium, potassium ion, ammonium ion, etc also exerts an adverse effect on Mg availability.

Regarding the land use availability, mean Mg status (91ppm) was higher among the samples from converted paddy fields. As in the case of Ca, it may be due to the accumulation of Mg in lower topographical regions. Lowest mean Mg availability was shown by plots of coconut based cultivation. Low presence of Mg minerals with high rate of crop removal may be the reason for this. It is further substantiated by the fact that, no NPK fertilizer usually contains Mg in a significant proportion enough to replete the soil Mg content.

Highest available Mg content was found at the 514th survey plot. It is under homestead cultivation with comparatively higher presence of human settlement. Four other plots (489, 742, 719 and 699) show the sufficiency of available Mg. It may be due to the fact that they are belonging to some of the pockets of depressed locations within the watershed. Lowest value of available Mg was obtained from 65th and 13th survey plots. Among these, 13th survey plot is located near to the western ridgeline and 65th survey plot is by the side of the canal. Therefore, relatively higher elevation of these sites may cause leaching out of Mg ions trough the rain water.

5.3.3 Available Micro Nutrients

Micro nutrient management in the soil has gained wide spread attraction by recent times only. Each of them is influenced in a characteristic way by the soil environment. Organic matter content, presence of mineralogical sources, complimentary-antagonistic interactions among nutrients, redox conditions, moisture regime, texture, etc are the important factors. Improved crop varieties and macro-nutrient fertilizer applications have greatly increased crop yield and thereby the micro-nutrient removal. The trend towards high-analysis fertilizers has reduced the use of impure salts, which formerly contained some micro-nutrients. Because of these facts, our soils are suffering problems related to status of some of the micro-nutrient.

5.3.3.1 Available Iron

Iron is the fourth most abundant element in earth's lithosphere. Kerala soil generally shows high content of available Fe because of its specific environmental factors. Koliyoor micro watershed is no exception. 99.9 % of area showed Fe sufficiency. It may be attributed by intensive rainfall, acidity, etc.

Iron availability ranged from 4.6 to 164ppm. This wide range may be the result of existence of high diversity of land due to topography, relief, type of soils, land use, type of parent material, etc. Samples from converted paddy fields showed highest mean availability (69ppm) of Fe. It may be because of comparatively higher moisture content of those plots. Non-agricultural area was with lowest mean status of Fe availability. Absence of organic-Fe complexes may have caused this situation. Highest available Fe content was recorded from the 737th survey plot and the lowest availability was from 722nd survey plot.

5.3.3.2 Available Manganese

Similar to Fe, Mn deficiency was noted nowhere in Koliyoor micro watershed. Even none of the samples showed its deficiency unlike the case of Fe. However the range (5.5 to 95.3ppm) was less than that of available Fe content (4.6 to 164ppm) of samples. Rainfall pattern, soil moisture status, organic matter status, etc should be considered as general reasons for this condition. Within this range it seemed availability was increasing in accordance with pH value.

Plots of homestead cultivation showed highest mean status (40.01ppm) of available Mn possibly due to comparatively high organic matter reserve of the soil. Non-agricultural area showed lowest mean availability (21.33ppm) which can be attributed to the lower organic matter content of those plots. The 761st survey plot which showed highest availability is near the market working at Koliyoor. So the input of biodegradable wastes may be sited as the reason. The 673rd survey plot which showed lowest available Mn was showing a pH near to neutral class. So this comparatively high pH may have a hindrance effect on Mn availability.

5.3.3.3 Available Copper

Soils of Koliyoor micro watershed exhibited a mean available Cu content of 3.47ppm. Presence of organic matter may have resulted that 99.7 % of the area showed sufficiency.

Relatively higher mean availability from converted paddy fields (4.1ppm) can be an indication of leaching and accumulation of this nutrient from elevated areas. The 505th survey plot which is in converted paddy field showed highest status (8.66ppm) of available Cu. However, a comprehensive study is needed regarding Cu status in these plots. Because, the uses of anti-fungal chemicals like Bordeaux mixture, Copper oxy chloride, etc also results in higher Cu content in the soils. Cultivation of vegetables was prominent in these survey plots. The 491st survey plot showed lowest available Cu (0.01ppm). This sample location also is in converted paddy fields but with high intensity cultivation of annual crops. Crop removal without proper replenishment may have led to this highly deficient condition. Unbalanced application of nitrogen fertilizers also can be considered as a reason for this condition.

5.3.3.4 Available Zinc

Zn deficiency was seen over 93 % of the watershed area. This is typical to majority of Kerala soils. Unscientific use of high analysis fertilizers, acidic range of pH, leaching, etc can be the reasons for this wide spread deficiency of available Zn. Wide spread deficiency of Zn and B in Indian soils have started with the fast pace of cultivation. (Singh, 2008)

The plots of homestead cultivation showed higher Zn availability with a mean value of 1.01ppm. It can be attributed to the fact that homestead plots are relatively rich in organic matter than other land use categories. 487^{th} survey plot which showed highest Zn availability (4.01ppm) is under homestead cultivation. Lowest mean value (0.53ppm) obtained from the converted paddy fields may be the result of extensive crop removal without any compensatory supply through organic matter, micro-nutrient fertilizers, etc. Among the samples, one which showed lowest Zn availability was from a coconut cultivated field. Long term cultivation of this perennial crop may have resulted in low availability.

Wide spread Zn deficiencies were reported under acidic lateritic environment due to the presence of excess of Mn and Fe (Sureshkumar, 1999). Application of Zn might not solve the problem, since it is not the total content but the availability that matters. Formation of insoluble Zn phosphate also could be expected.

A holistic approach is needed for managing this problem. Application of fortified fertilizers like Zincated urea along with optimum quantity of FYM, poultry manure, etc should be used. This combination not only supplies but also improves the conversion of unavailable form of Zn to available forms. Zinc sulphateheptahydrate ($ZnSO_4$) also has been proposed as a viable option under Indian conditions (Singh, 2008).

5.3.3.5 Available Boron

Overall deficiency of B also was found in Koliyoor micro watershed. It was even prominent than Zn deficiency. Crop removal of this nutrient without any supply, decline in organic matter content, etc should be considered as major reasons. Singh (2008) stated that deficiency of B and Zn is a major impediment in acid soils. The soils of Meghalaya, Assam and West Bengal which show several similarities in agro-ecological aspects with that of Kerala suffer the same in a severe degree.

A highest mean availability of 0.22ppm was shown by the samples from non-agricultural area. The absence of cultivation may have resulted in comparatively low removal of natural pool of B. The 473rd survey plot which showed highest status of B (0.66ppm) was under homestead cultivation. Yearlong presence of organic matter source can be pointed as the reason. Coconut cultivated plots showed the lowest mean availability (0.22ppm) possibly because of crop removal problem. Application of NPK fertilizers also can reduce the micro nutrient availability. In order to manage this problem, fertilizers like Borax may be applied in the case of soil or the application of 0.2 to 0.4 % solution of boric acid as foliar spray should be done (Singh, 2008). As in the case of Zn, incorporation of organic matter also is beneficial for enhancing B availability.

By combining all of these data, it can be concluded that Koliyoor micro watershed followed more or less typical condition of Kerala soils especially in Fe, Zn and B status. Maintenance of a proper level of soil moisture, a good range of soil pH, application of micro-nutrient fertilizers, preservation of good organic matter reserve, etc are some of the common immediate micro nutrient management practices. In a long term perspective, care should be taken for the establishment of a proper research backup on micro nutrients, formulation of a more accurate database regarding status of micro nutrients in soils and a joint effort by the researchers from the soil science, agronomy and plant breeding. So all of these factors should be considered with emphasize on soil conservation practices like erosion control for a good micro nutrient status in soil.

5.4 PHYSICAL PROPERTIES

Physical fertility of the soil is essential for good growth of crops. Properties and processes like moisture retention, mobility of nutrients, water transmission, soil air dynamics, etcare highly dependent on physical aspects of the soil. In this study, two important physical properties of the soil (Bulk density and Water Holding Capacity) were analyzed on grid basis.

5.4.1 Bulk Density

Bulk Density is the ratio between weight per unit volume of soil mass including pore space. It is of greater importance than particle density in understanding the physical behavior of soils. Generally soils having low and high bulk densities exhibit favorable and poor physical conditions respectively.

The difference between lowest value of bulk density (1.2 gm/c.c) and highest value (1.7 gm/c.c) was just 0.5 units. Samples showed a relative homogeneity regarding bulk density unlike the variation seen in several chemical properties. Das (2004) stated that normally, soil bulk density varies from 1 to 1.6 gm/ c.c. The range of bulk density (1.2 to 1.7 gm/c.c) obtained from Koliyoor micro watershed was not different from the above mentioned normal range significantly.

The organic matter content and textural status of soils are the most important factors influencing the physical properties of soil. It could be rendered from the interpretation of map, that organic carbon variation was more or less uniform over the whole area. Similarly in textural analysis also, samples showed minor variation. The above mentioned aspects may be the possible reasons of this homogeneity in bulk density. Swarnam*et al.* (2004) found that the bulk density in the Entisols and Inceptisols of Shaibi basin in Hariyana and Delhi varied from 1.48 to 1.87 gm/c.c and 1.5 to 1.69 gm/c.c, respectively. They suggested that higher bulk density values could be due to their coarse texture and low organic matter content. According to Balpande*et al.* (2007) soil having higher percentage of sand or gravel has more bulk density than those having high clay content.

As per the results, 671st survey plot showed highest bulk density of 1.7 g/c.c. On interpolation of the point data of organic carbon status, one of the pockets of low organic carbon status was found at the same plot. This may be the primary reason for this highest bulk density. Thangasamy*et al*. (2005) observed similar increment in bulk density in accordance with the low organic matter status of soils of Sivagiri micro watershed of Chittor district, Andhra Pradesh.

Lowest bulk density (1.2 gm/c.c) was shown by the 63rd survey plot. In this case also, role of organic matter content of the plot mattered. Because, interpolation showed that about half of the area of 63rd plot is having high status of organic carbon. Vara Prasad Rao*et al.* (2008) reviewed that, the decrease in bulk density is due to higher organic matter in the surface soils of RamachandrapuramMandal in Chittoor district.

5.4.2 Water Holding Capacity

Among the three important factors of water availability to the plants like plant factors, climatic factors and soil factors, the latter is considered most important. So the measurement of water holding capacity works as the best index of water availability to the plant from soil.

Range of water holding capacity (18 to 29.8 %) was comparatively wider than that of bulk density. There may be much more diversity in controlling factors like texture, organic matter, type and percentage of clay, porosity, soil management practices, etc. of the sampling locations. The highest and lowest values of water holding capacity were obtained from 63rd and 671st survey plots respectively. These results may be due to the organic matter status of respective plots as mentioned in the case of bulk density. The clay content of the soils also may result in conspicuous water retention capacity in the soil. Shilpa*et al.* (2010) found that water holding capacity of the clayey soils increases under homogenous status of other parameters like organic matter content.

The comparative analysis of physical properties showed the paramount importance of organic matter status in maintaining a well suited soil physical environment for optimum crop growth.

5.5 TOPOLOGICAL FEATURES

Topological attributes of the land is another important factor influencing the cultivation in that area. In addition to drainage, profile depth, texture, gravellines, structure, local depth and slope also affects the agricultural production (Khatter*et al.*, 1998). Further, a management plan will be accurate and effective as far as we bring maximum factors into the analysis field. Saroinsong*et al.* (2007) stated that a multi-criteria analysis is needed for precise evaluation and planning regarding natural resource management.

5.5.1 Slope Gradient

Slope gradient or steepness is one of the factors affecting soil erosion according to the Universal Soil Loss Equation. Existence of five slope gradient classes shows the differential susceptibilities of various plots for varying degrees of soil erosion. Significance of topography, as a genetic factor, is more noticeable locally through its effect on the micro-climate and vegetation of an area. It also affects the soil evolution in many ways. Sarkar*et al*. (2001) stated that the soils of upper slopes in the toposequence of Chhotanagpur plateau were yellowish red (5YR 4/6) in colour in the surface layer and dark red (2.5 YR 4/6) in the lower layers while the lower slopes of the toposequence were light brownish gray to light gray in surface horizon and gray in the lower layers. In context of crop productivity, their effect is significant on soil erosion, leaching of nutrients, etc.

Nearly level (0-1 %) plots are generally devoid of hazards like soil erosion. Almost the entire water received as rainfall percolates through the soil. Under such conditions, the soils formed may be considered as representative of the regional climate. But these points are not applicable in areas of high rainfall. When the slope factor is taken alone, these plots can be included in the 1st land capability class. These plots may be requiring only prudent crop management to maintain their productivity.

Very gently sloping (1-3 %) plots have some limitations in comparison with the plots of nearly level slope class. The soils of these plots require some moderate conservation practices. During the months of heavy rainfall, soil conservation practices like terracing, strip cropping, etc are to be followed. These recommendations are to be considered for the Gently sloping class having a slope of 3-5 %. In addition to these, it is desirable to practice contour tillage, crop rotations including grasses, etc.

The plots having moderate range of slope (5-10 %) have somewhat severe limitations that reduce the choice of plants or require special conservation practices or both. The crops that provide soil cover, such as grasses and legumes, must be more prominent in the rotations used. Problems like high erosion hazards, slow water permeability, restricted root zone, low water holding capacity, etc can be expected. Tile or other drainage systems also may be needed in poorly drained plots of this class.

Strongly sloping plots having a slope range of 10-15 % may require a careful choice of crops. Close growing crops must be used extensively, and row crops cannot be grown safely in most cases. These plots can be with more serious scenario of mentioned limitations for moderately sloping plots.

5.5.2 Slope Aspect

Slope aspect or exposure is another way through which the topography affects soil properties and thus the crop growth. In Koliyoor micro watershed the land showed 9 slope aspect classes facing the directions ranging from Flat to North-West.

The exposure towards each direction has its own effects. The southern exposures are comparatively warmer than others. Chances are there that those plots may be subjected to marked fluctuations in temperature and moisture. The northern exposures, on the other hand, are comparatively cooler and humid. The eastern and western exposures occupy intermediate positions in this respect. In long term perspective these factors affects soil evolution and influences on basic soil properties. Najar*et al*. (2009) observed the distribution of soil textures that varied from silty loam in Northern aspect to clayey in Southern aspect in some apple growing soils of Kashmir. Taking account of these facts, proper management practices should be adopted in these plots.

Summary

6. SUMMARY

A research work has been done to assess the resource potential of soils of Koliyoor micro watershed using GIS technology. In order to generate various thematic layers, cadastral map of whole area (1:5000), toposheets produced by survey of India (1:50000), DEM (ASTER-30m) and satellite imageries available with Google earth were used. The total area of watershed was transected and soil samples were collected. The attribute data base, formulated using the analysis results of 174 soil samples were integrated to the GIS and various thematic maps were produced. The salient features in the results are summarized below.

1. All the samples fell into two textural classes, Sandy Clay Loam and Sandy Loam. 87 % samples were Sandy Clay Loam in texture while, 13 % of the samples showed Sandy Loam textural status. The samples, which showed Sandy Clay Loam textural class, showed a mean sand content of 56.01 % and a mean silt content of 15.6 %. The mean clay content of the samples of ‘Sandy Clay Loam’ category was 27.13 %. The samples, which showed ‘Sandy Loam’ textural status, showed a mean sand content of 59.3 %. They showed average silt content of 13.14 %. The mean clay content of these samples was 17.33 %.

2. In general, soils were acidic and all the samples showed an average soil reaction of 6.02. Most of the samples were in Medium Acid class and the least in Neutral class. When the samples were categorized according to land use, lowest mean value (5.1) of soil reaction was shown by the samples taken from homestead area. Highest mean value (6.1) of soil reaction was recorded from the samples taken from plots of coconut based cultivation.

3. The EC of soils of Koliyoor micro watershed ranged from 0.01 to 0.26 dS/m, which means that only non-saline soils are there in this area. The mean value obtained was 0.08 dS/m. The highest mean electrical conductivity (0.11 dS/m) was shown by the samples from plots of homestead cultivation while samples from non-agricultural area showed lowest mean electrical conductivity (0.06 dS/m).

4. Organic carbon content of the samples ranged from 0.1 to 1.9 % with a mean value of 0.72 %. Plots of homestead cultivation showed maximum mean status (0.82 %) of organic carbon in samples. Least mean organic carbon content (0.21 %) was recorded from the plots of non-agricultural area especially which were dominated by stone quarries.

5. Majority of the watershed area belongs to the medium class of available phosphorus. Among the samples, it ranged from 3.1 to 59.1 kg/ha with a mean value of 22.1 kg/ha. The samples from converted paddy fields showed highest mean value (25.5 kg/ha) of P status. Lowest mean value (20.1 kg/ha) was shown by the samples taken from non-agricultural area.

6. In the case of potassium also, majority of the area shows medium status. It ranged from 20.16 to 481 kg/ha. The mean value was found as 196.55 kg/ha. Samples taken from converted paddy fields showed highest mean availability of potassium (210 kg/ha). Soil samples from homestead area showed lowest mean value (101.4 kg/ha).

7. NPK status analysis revealed that, only 0.1 ha area showed low status for all of the three nutrients. High status was shown for these nutrients by about 15.23 ha area and 200 ha area was medium in the case of NPK status.

8. Sulfur content of the samples ranged from 8.93 to 71.4 kg/ha. The mean value regarding total number of samples was 30 kg/ha. The highest average value (39.2 g/ha) was seen among the samples from homestead cultivation. Samples from non-agricultural area showed lowest mean availability (12.1 kg/ha) of sulfur.

9. Majority of the area of Koliyoor watershed showed relatively higher Ca content. Samples ranged in their Ca status from 75 to 900 ppm with a mean value of 337.33 ppm. Land use wise analysis of samples showed that converted paddy field samples were with the highest mean value (428.5 ppm) and the lowest mean availability (301.1 ppm) was seen in the plots of coconut based cultivation.

10. Magnesium deficiency was seen all over the area except in some pockets. It ranged from 12 to 167 ppm with a mean value of 49.47 ppm and mode value of 42 ppm. Converted paddy fields showed comparatively high status of available magnesium with a mean value of 91 ppm while the lowest mean status (32.8 ppm) was seen in the samples from coconut based cultivation plots.

11. Koliyoor micro-watershed showed typical nature of Kerala soils regarding available iron status in the soils. It ranged from 4.6 to 164 ppm with an average value of 49.62 ppm. Highest mean value (69 ppm) was seen in the land use category of converted paddy fields. Samples from non-agricultural area showed lowest mean availability of iron (41.03 ppm).

12. Soil samples from the study area ranged from 0.01 to 8.66 ppm in available copper content. Mean value obtained was 3.47 ppm. Samples from converted paddy fields showed highest mean value (4.1 ppm). The lowest mean value (1.1 ppm) was obtained from non-agricultural area.

13. Koliyoor micro-watershed showed 100 % sufficiency of available manganese. Soil samples ranged from 5.5 to 95.3 ppm in manganese availability. The mean status obtained is 32 ppm. When the samples were categorized based on type of land use, survey plots of homestead cultivation showed higher availability of manganese and highest mean value of 40.01 ppm. Lowest mean value (21.33 ppm) was seen in sample category of non-agricultural area.

14. Soil samples showed a range of 0.03 to 4.01 ppm regarding zinc availability. The average value obtained was 0.71 ppm. Among the land use types, plots of homestead cultivation showed higher zinc availability with a mean value of 1.01 ppm. The lowest mean value (0.53 ppm) was seen in the category of converted paddy fields.

15. Soils of Koliyoor micro watershed showed an overall deficiency in Boron availability except one pocket. It ranged from 0.01 to 0.66 ppm with an average value of 0.27 ppm. In land use wise analysis plots of coconut based cultivation

showed lowest mean availability (0.22 ppm) of boron while samples from non-agricultural area showed highest mean status of 0.43 ppm.

16. Bulk density of the samples ranged from 1.3 to 1.7 mega gram per cubic meter with an average value of 1.4 mega gram per cubic meter. Organic matter status and texture of the soils were important in influencing the bulk density of soils.

17. The samples showed a range of 18 to 29.8 % on water holding capacity. Average value obtained was 23.4 %.

18. The slope of different plots in Koliyoor micro watershed ranged from zero to 15 %. When this range was categorized according to the field manual of soil survey staff, five classes were obtained ranging from 'Nearly Level' to 'Strongly Sloping'. Within the obtained range of slope gradient, three topographical classes were identified, ranging from 'Flat' to 'Rolling' type.

19. In Koliyoor micro watershed the land showed 9 slope aspect classes facing the directions ranging from Flat to North-West.

From the above findings and the formulated data base of GIS, the present scope and limitations of soils can be assessed by using the capacity of soil to the maximum extend and the agricultural production can be restructured for optimum crop production. The knowledge regarding the properties of soils of the Koliyoor micro watershed will play an important role in preparing a new resource management plan for this area for maximum returns for the local population while keeping the ecological sustainability. Soil information systems, which work in GIS platform has tremendous potential in aiding the farmers for optimum utilization of the resources of their land.

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Appendices

Appendix-I

Weather data from the observatory of College of Agriculture, Vellayani for the study period

(September 2011 to March 2012)

Standard week	Temperature (^{0}C) (maximum)	Rainfall (mm)	Relative Humidity (%)	Evaporation (mm/day)
29	30.17	14.07	84.14	3.4
30	30.34	4.73	85.07	3.42
31	30.34	2.6	86.29	3.46
32	30.46	3.8	85.86	3.51
33	30.2	6.69	84.36	3.29
34	30.37	0	83.79	3.51
35	30.46	0	84.5	3.51
36	30.6	3.83	83.49	3.49
37	30.43	3.03	82.86	3.4
38	30.8	3.37	82.43	3.51
39	30.66	8.97	82.36	3.11
40	29.63	53.03	84.43	2.6
41	29.69	17.74	84.79	2.8
42	30.8	0.46	82.29	3.6

Appendix II

Raw data generated by the analytical work on the soil samples from Koliyoor micro watershed

Sample ID	Org.	Av.	Av.	Av.	Av.	Av.	Av.	Av.	Av.	Av.	Av.
S 1	0.98	7.75	210.6	55.36	450	72	3.94	27.34	75.12	0.85	0.39
S 2	0.45	12.58	134.4	33.57	325	162	2.36	21.69	59.93	1.6	0.32
S 3	0.94	15.51	217.3	35.71	430	42	2.14	35.58	44.11	0.9	0.22
S 4	0.24	17.23	206.1	12.5	360	42	5.4	107.08	24.5	0.95	0.31
S 5	0.35	3.1	210.6	12.5	340	12	1.1	64.18	43.67	1.04	0.24
S 6	0.22	28.09	109.8	46.43	440	24	3.34	24.77	46.94	1.57	0.35
S 7	0.36	18.78	221.8	30.36	330	48	5.37	17.96	21.34	1.8	0.38
S 8	0.66	13.96	208.3	37.5	835	96	0.01	30.35	27.15	2.16	0.23
S 9	0.98	30.5	168	44.64	290	54	1.92	45.98	48.44	2.5	0.17
S 10	0.79	27.57	203.8	33.93	680	66	3.95	21.41	39.01	2.09	0.3
S 11	0.68	16.89	219.5	69.64	711	144	1.46	10.98	9.48	1.47	0.23
S 12	0.72	24.3	147.8	42.86	245	18	4.35	57.32	69.69	4.97	0.16
S 13	0.87	5.34	215	33.93	265	78	2.57	38.05	27.34	4.04	0.21
S 14	1.14	9.99	118.7	16.07	575	24	3.54	26.24	58.35	1.54	0.67
S 15	0.8	28.26	208.3	17.86	900	84	2.64	28.16	34.11	0.69	0.28
S 16	0.67	16.54	98.56	12.5	365	24	4.62	35.74	46.42	1.49	0.32
S 17	0.95	4.48	217.3	33.93	535	126	1.7	10.62	35.82	1.06	0.36
S 18	0.69	25.67	49.28	25	260	36	6.6	42.33	12.12	1.1	0.34
S 19	0.81	7.41	107.5	35.71	245	66	1.43	15.7	73.64	1.87	0.24
S 20	0.45	23.26	47.04	12.5	510	18	5.56	56.44	22.27	0.03	0.33
S 21	0.32	11.03	219.5	37.5	375	84	3.84	38.08	45.76	1.2	0.22
S 22	0.47	15.16	154.6	48.21	255	72	8.46	91.4	106.6	1.11	0.36
S 23	1.18	24.47	210.6	37.5	240	30	7.46	18.09	70.23	0.63	0.32
S 24	0.58	29.46	217.3	26.79	225	66	6.4	33.76	59.41	1.45	0.26
S 25	0.6	9.48	206.1	33.93	285	30	3.33	18.17	34.6	1.85	0.27
S 26	0.57	5.34	98.56	37.5	205	102	4.21	36.85	9.61	0.66	0.29
S 27	0.64	16.2	107.5	10.71	315	42	2.46	59.41	43.01	0.8	0.35
S 28	0.62	21.02	62.72	37.5	340	24	1.14	94.45	21.4	1.37	0.33
S 29	1.16	14.82	197.1	33.93	370	42	5.11	70.84	20.3	1.87	0.35
S 30	1.07	10.34	89.6	35.71	575	42	0.2	113	18.78	1.75	0.22
S 31	0.9	20.68	217.3	37.5	540	12	3.98	109.4	36.3	2.1	0.33
S 32	1.43	12.23	192.6	33.93	465	66	1.21	81.4	61.45	1.94	0.38
S 33	0.29	17.58	199.4	33.93	415	72	2.9	116.48	27.02	0.8	0.31
S 34	0.24	7.41	69.44	23.21	425	30	2.98	101.55	16	1.7	0.32
S 35	0.22	26.19	62.72	62.5	390	54	3.6	125	11.43	3.66	0.35
S 36	0.99	12.75	201.6	46.43	320	48	4.61	92.74	38.83	0.47	0.32
S 37	0.94	23.43	163.5	32.14	385	36	5.72	49.68	8.93	1.18	0.3
S 38	0.61	7.06	179.2	25	310	72	8.06	100.3	30.96	3.77	0.31
S 39	0.74	25.16	192.6	30.36	290	36	4.13	31.37	14.29	1.6	0.28
S 40	0.85	33.43	112	19.64	400	54	8.62	67.72	58.13	2.04	0.24
S 41	1.14	18.09	78.4	41.07	525	42	4.75	10.48	21.12	1.42	0.22
S 42	0.82	36.18	53.76	48.67	380	42	6.9	22.59	54.83	0.98	0.5
S 43	1.04	15.51	76.16	26.79	360	114	4.22	31.52	41.67	3.21	0.36
S 44	0.51	42.39	134.4	14.29	335	102	1.26	134.1	29.03	0.16	0.33
S 45	1.29	17.58	190.4	32.14	295	42	8.37	28.53	42.27	1.8	0.28
S 46	0.32	21.88	159	23.52	245	42	5.18	60.1	18.2	1.73	0.02
S 47	0.8	14.47	199.4	19.64	355	72	0.8	47.74	23.16	0.36	0.22

Appendix II
Raw data generated by the analytical work on the soil samples from Koliyoor micro watershed (Continued...)

Sample ID	Org.	Av.	Av.	Av.	Av.	Av.	Av.	Av.	Av.	Av.	Av. B
S 48	0.36	18.61	183.7	16.07	320	30	4.36	29.18	29.4	0.65	0.28
S 49	0.55	36.36	188.2	25	285	48	8.11	50.46	56.8	0.84	0.32
S 50	1.03	33.43	221.8	33.93	90	48	0.21	83.95	39.75	2.04	0.35
S 51	1.21	16.54	380	37.5	360	42	4.53	46.27	28.15	1.99	0.11
S 52	0.6	4.65	367	25	270	42	7.91	36.47	14.26	2.1	0.2
S 53	0.98	12.23	31.36	39.29	240	42	3.52	48.04	35.89	1.07	0.3
S 54	1.32	31.7	341	51.79	310	36	8.13	65.21	40.59	2.11	0.28
S 55	0.57	11.89	386	25	245	48	0.8	32.69	21.94	0.96	0.37
S 56	0.51	16.2	355	16.07	325	42	3.52	37.42	17.08	1.49	0.33
S 57	0.12	20.85	381	14.51	440	18	1.41	54.4	23.53	0.53	0.28
S 58	0.88	34.98	53.76	19.64	365	48	2.3	70.24	16.92	1.79	0.25
S 59	1.18	59.1	343	53.57	320	66	1.15	67.05	22.74	0.49	0.3
S 60	1.63	11.54	404	32.14	430	96	1.2	11.46	10.53	0.73	0.31
S 61	0.45	21.37	31.36	19.64	290	42	4.13	35.87	23.74	1.15	0.38
S 62	0.52	13.96	388	35.71	315	30	1.77	46.65	13.05	1.08	0.38
S 63	0.33	27.57	240	16.07	295	30	2.6	124.31	22.3	0.68	0.36
S 64	0.79	18.78	190.4	33.93	235	24	4.43	81.52	40.11	1.52	0.33
S 65	0.96	21.02	235	48.21	270	48	1.16	105.28	39.01	2.3	0.27
S 66	1.03	7.24	237	25	165	84	3.2	36.02	28.34	1.37	0.31
S 67	0.65	13.44	82.88	33.93	140	18	0.46	49.93	8.45	1.57	0.34
S 68	0.45	32.74	261.5	37.5	210	42	1.85	74.81	24.63	1.81	0.41
S 69	1.22	48.42	279	50	255	54	1.26	20.06	20.89	0.75	0.33
S 70	0.82	33.08	264	32.14	225	48	0.8	15.97	17.91	2.2	0.29
S 71	0.65	25.33	194.9	39.29	305	42	2.96	63.84	31.77	1.7	0.35
S 72	1.14	16.2	255	26.79	285	36	1.7	117.74	29.06	1.54	0.39
S 73	0.33	14.3	234	16.07	255	48	2.69	74.28	14.63	1.4	0.26
S 74	0.79	17.4	145.6	23.21	330	30	2.1	43.01	35.5	0.49	0.38
S 75	0.22	26.02	246	12.5	320	36	1.79	50.71	30.96	1.09	0.36
S 76	0.27	13.61	257	17.86	375	42	5.2	36.38	27.53	0.74	0.3
S 77	0.7	25.16	264	25	350	42	5.42	15.24	10.69	1.89	0.34
S 78	0.45	22.74	129.9	33.93	370	36	4.53	27.13	14.83	2.01	0.33
S 79	0.57	24.12	338	23.21	345	36	1.9	101.15	35.22	3.17	0.43
S 80	0.84	35.84	346	42.86	365	54	1.77	85.32	46.15	4.11	0.2
S 81	0.69	38.08	401	34.61	385	72	2.96	50.97	32.97	0.88	0.24
S 82	1.47	33.94	105.3	17.9	425	30	2.1	107.09	41.35	0.61	0.16
S 83	0.94	20.68	365	12.5	390	36	3	66.92	20.67	2.3	0.38
S 84	0.1	8.44	392	25	400	48	0.7	34.76	36.85	3.55	0.3
S 85	0.57	11.37	371	28.57	365	42	2.57	38.45	50.14	0.47	0.25
S 86	0.31	24.3	334	10.71	340	36	3.1	112.3	24.63	0.95	0.29
S 87	0.69	34.46	112	17.86	350	42	2.92	53.13	19.52	2.4	0.4
S 88	1.07	14.99	320	30.36	375	36	3.46	34.52	26.41	1.08	0.35
S 89	0.75	3.62	365	46.43	390	42	0.61	19.8	21.98	0.7	0.2
S 90	2	42.04	203.8	17.86	400	18	2.8	120.63	35.57	1.12	0.16
S 91	1.13	26.88	337	55.36	370	36	2.63	42.94	41.58	0.87	0.12
S 92	1.95	48.94	481	44.64	430	30	5.87	31.86	28.03	1.12	0.23
S 93	0.7	18.26	224	12.5	415	36	0.31	46.2	25.11	2.11	0.19
S 94	0.45	26.54	388	18.36	440	42	1.94	51	37.29	3.31	0.28
S 95	0.59	15.34	346	16.07	395	42	2.72	43.4	23.57	1.95	0.3

Appendix II

Raw data generated by the analytical work on the soil samples from Koliyoor micro watershed (Continued...)

Sample ID	Org. C.	Av. P	Av. K	Av. S	Av. Ca	Av. Mg	Av. Cu	Av. Fe	Av. Mn	Av. Zn	Av. B
S 96	0.28	12.58	112	33.93	450	30	6.3	23.41	19.24	1.08	0.37
S 97	1.19	5	356	39.29	420	42	4.19	39.8	28.36	0.92	0.23
S 98	0.52	50.66	344	33.93	400	36	4.44	54.6	39.05	3.1	0.33
S 99	0.45	15.34	100.8	25	380	36	3.6	35.5	22.06	0.16	0.3
S 100	0.58	10.51	302	39.29	440	42	0.73	36.4	15.34	1.28	0.28
S 101	0.88	21.02	256	17.86	405	30	1.82	41.1	36.81	1.51	0.31
S 102	0.8	16.2	47.04	26.79	425	36	2.91	97.45	47.24	0.68	0.22
S 103	0.22	19.3	333	12.54	450	42	4.73	13.69	6.98	2.2	0.36
S 104	1.49	17.92	421	35.71	445	24	4.84	28.51	20.11	1.94	0.32
S 105	0.68	19.99	210.6	28.57	455	36	5.61	52.64	24.73	1.2	0.28
S 106	0.68	10.51	56	8.93	470	42	0.2	67.07	22.69	2.2	0.37
S 107	0.68	24.81	76.16	8.93	480	48	4.39	22.5	15.81	1.55	0.34
S 108	0.83	33.94	221.8	14.29	450	36	0.97	70.15	46.93	0.1	0.3
S 109	0.97	38.08	194.9	48.21	465	12	1.48	46.34	34.45	0.48	0.4
S 110	0.81	17.06	143.4	17.86	430	30	3.3	42.12	19.37	1.39	0.36
S 111	0.45	42.73	199.4	16.07	420	36	2.54	99.39	24.86	1.04	0.33
S 112	0.59	46.7	219.5	19.64	405	42	2.51	108.47	35.12	0.5	0.36
S 113	0.33	9.65	145.6	33.93	425	48	0.11	51.11	27.61	0.74	0.27
S 114	0.47	15.16	212.8	37.5	445	36	3.53	43.2	19.05	1.64	0.35
S 115	1.19	48.25	203.8	37.5	390	36	2.55	34.68	28.83	1.1	0.33
S 116	0.4	34.63	136.6	19.64	410	42	3.8	69.8	36.74	2.4	0.29
S 117	0.57	25.33	197.1	30.36	435	36	3.57	18.42	14.98	2.6	0.25
S 118	0.4	27.57	136.6	19.64	450	48	4.66	26.59	11.42	1.41	0.18
S 119	0.91	34.63	194.9	42.86	370	96	4.17	8.49	54.11	2.13	0.37
S 120	0.12	22.92	201.6	14.29	375	48	0.12	30.51	9.68	1.99	0.36
S 121	0.57	17.58	64.96	39.29	110	30	3.56	58.42	14.56	1.54	0.11
S 122	0.74	9.32	56	35.71	150	42	3.2	26.4	9	2.87	0.18
S 123	0.68	5	85.12	32.14	270	60	2.76	31.75	26.41	0.99	0.04
S 124	0.67	16.54	199.4	53.57	75	126	3.3	43.08	38.3	1.1	0.06
S 125	0.47	18.61	96.32	14.29	100	66	4.9	164	23.74	1.63	0.12
S 126	0.84	15.34	125.4	53.57	110	18	2.8	22.08	28.79	1.55	0.16
S 127	1.26	16.2	156.8	39.29	85	42	2.9	20.11	31.47	0.36	0.14
S 128	0.84	18.95	215	16.07	130	54	3.2	10.94	43.16	1.04	0.21
S 129	0.8	25.85	138.9	43.75	125	30	1.3	59.54	27.19	0.98	0.18
S 130	0.88	32.91	177	28.57	145	60	0.1	14.95	21.56	1.71	0.24
S 131	0.57	16.71	177	37.5	570	102	3.24	28.91	31.64	2.84	0.19
S 132	0.91	25.5	127.7	35.71	145	54	8.21	14.61	33.16	2.8	0.28
S 133	1.04	28.09	145.6	14.29	105	24	5.25	18.4	5.53	1.37	0.23
S 134	0.77	31.7	138.9	30.36	230	24	4.7	111.23	65.08	1.89	0.14
S 135	0.92	24.12	401	42.86	155	72	5.14	33.4	42.24	1.72	0.31
S 136	0.75	34.46	371	28.58	150	100	1.28	8.41	11.7	1.21	0.16
S 137	0.4	33.43	116.5	17.86	200	138	4.1	18.14	39.47	1.69	0.27
S 138	1.07	14.82	64.96	71.43	245	60	3.46	20.01	11.79	1.48	0.19
S 139	0.91	28.6	168	39.29	190	24	2.99	19.4	76.4	0.55	0.32
S 140	0.88	18.95	192.6	42.86	125	78	4.6	98.4	48.1	1.7	0.31
S 141	0.59	36.18	215	32.14	115	84	4.7	97.7	35.7	1.39	0.26

Appendix II
Raw data generated by the analytical work on the soil samples from Koliyoor micro watershed (Continued...)

Sample ID	Org. C.	Av. P	Av. K	Av. S	Av. Ca	Av. Mg	Av. Cu	Av. Fe	Av. Mn	Av. Zn	Av. B
S 142	0.69	46.52	136.6	12.5	120	48	0.12	65.61	45.34	1.5	0.16
S 143	0.89	32.74	221.8	37.5	180	24	7.57	40.31	28.92	1.73	0.26
S 144	0.8	46.52	174.7	21.43	95	54	4	17.01	19	2.04	0.36
S 145	0.89	41.35	168	23.21	155	30	7.81	21.68	26.16	1.85	0.27
S 146	0.69	29.29	53.76	8.93	505	54	2.62	22.82	20.34	0.93	0.21
S 147	0.87	18.78	64.96	16.07	380	36	1.1	11.34	36.54	1.63	0.15
S 148	0.62	44.8	219.5	16.07	350	66	3.61	36.4	64.29	0.37	0.23
S 149	0.62	36.18	221.8	44.64	400	54	4.3	36.71	51.63	1.57	0.34
S 150	0.5	16.54	201.6	39.29	300	54	2.64	21.44	47.49	1.29	0.31
S 151	0.37	5.34	156.8	19.64	170	66	0.8	116.4	9.25	1.3	0.01
S 152	0.35	24.47	194.9	25	290	36	3.31	18.01	52.89	4.71	0.26
S 153	0.43	33.43	44.8	35.71	325	54	7.54	24.3	25.02	1.19	0.08
S 154	0.5	34.63	20.16	26.79	385	48	3.27	7.48	15.7	1.19	0.11
S 155	0.54	44.8	89.6	17.86	395	24	5.7	15.52	61.97	1.5	0.18
S 156	0.62	13.96	141.1	37.5	425	60	0.6	6.82	13.05	1.29	0.12
S 157	1.37	4.65	96.32	44.64	360	114	4.8	4.61	19.94	0.96	0.22
S 158	0.53	13.44	219.5	30.36	515	18	2.55	14.15	22.3	2.49	0.23
S 159	0.37	8.27	73.92	21.43	475	54	4.1	48.35	40.99	1.69	0.33
S 160	0.8	33.6	217.3	25	340	18	2.7	16.9	55.64	0.73	0.34
S 161	0.6	7.06	67.2	32.14	135	36	4.47	61.27	16.53	2.95	0.05
S 162	0.37	7.58	199.4	19.64	105	30	8.66	37.44	23.59	0.71	0.02
S 163	0.75	14.82	67.2	46.43	105	90	2.22	76.42	51.1	1.39	0.07
S 164	0.6	12.41	24.64	28.57	210	60	3.8	123.4	63.21	2.1	0.1
S 165	0.67	16.2	42.56	53.57	125	78	8	34.58	39.53	0.86	0.13
S 166	0.23	9.3	208.3	30.36	465	84	2.58	23.41	69.96	1.58	0.29
S 167	0.32	21.88	159	23.52	245	42	5.18	60.1	18.2	1.73	0.02
S 168	0.57	11.37	371	28.57	365	42	2.57	38.45	50.14	0.47	0.25
S 169	0.31	24.3	334	10.71	340	36	3.1	112.3	24.63	0.95	0.29
S 170	1.14	18.09	78.4	41.07	525	42	4.75	10.48	21.12	1.42	0.22
S 171	0.85	33.43	112	19.64	400	54	8.62	67.72	58.13	2.04	0.24
S 172	0.45	32.74	261.5	37.5	210	42	1.85	74.81	24.63	1.81	0.41
S 173	0.51	16.2	355	16.07	325	42	3.52	37.42	17.08	1.49	0.33
S 174	0.12	20.85	381	14.51	440	18	1.41	54.4	23.53	0.53	0.28

Appendix III

Fertility rating of the soil samples from Koliyoor micro watershed

Sample ID	Org. C.	Av. P	Av. K	Av. S	Av. Ca	Av. Mg	Av. Cu	Av. Fe	Av. Mn	Av. Zn	Av. B
S 1	High	Low	Med.	Suff.	Suff.	Med.	Def.	Suff.	Suff.	Suff.	Def.
S 2	Low	Med.	Med.	Suff.	Suff.	High	Suff.	Suff.	Suff.	Suff.	Def.
S 3	High	Med.	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 4	Low	Med.	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 5	Low	Low	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 6	Low	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 7	Low	Med.	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 8	Med.	Med.	Med.	Suff.	Suff.	High	Suff.	Def.	Suff.	Suff.	Def.
S 9	High	High	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 10	High	High	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 11	Med.	Med.	Med.	Suff.	Suff.	High	Suff.	Suff.	Suff.	Suff.	Def.
S 12	Med.	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 13	High	Low	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 14	High	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Suff.
S 15	High	High	Med.	Suff.	Suff.	Med.	Def.	Suff.	Suff.	Suff.	Def.
S 16	Med.	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 17	High	Low	Med.	Suff.	Suff.	High	Suff.	Suff.	Suff.	Suff.	Def.
S 18	Med.	High	Low	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 19	High	Low	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 20	Low	Med.	Low	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 21	Low	Med.	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 22	Low	Med.	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 23	High	Med.	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 24	Med.	High	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 25	Med.	Low	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 26	Med.	Low	Med.	Suff.	Suff.	High	Def.	Suff.	Suff.	Suff.	Def.
S 27	Med.	Med.	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 28	Med.	Med.	Low	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 29	High	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 30	High	Med.	Med.	Suff.	Suff.	Low	Suff.	Def.	Suff.	Suff.	Def.
S 31	High	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 32	High	Med.	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 33	Low	Med.	Med.	Suff.	Suff.	Med.	Def.	Suff.	Suff.	Suff.	Def.
S 34	Low	Low	Low	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 35	Low	High	Low	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 36	High	Med.	Med.	Suff.	Suff.	Med.	Def.	Suff.	Suff.	Suff.	Def.
S 37	High	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 38	Med.	Low	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 39	Med.	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 40	High	High	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 41	High	Med.	Low	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 42	High	High	Low	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 43	High	Med.	Low	Suff.	Suff.	High	Suff.	Suff.	Suff.	Suff.	Def.
S 44	Med.	High	Med.	Suff.	Suff.	High	Def.	Suff.	Suff.	Suff.	Def.
S 45	High	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 46	Low	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 47	High	Med.	Med.	Suff.	Suff.	Med.	Def.	Def.	Suff.	Suff.	Def.

Appendix III

Fertility rating of the soil samples from Koliyoor micro watershed (Continued...)

Sample ID	Org. C.	Av. P	Av. K	Av. S	Av. Ca	Av. Mg	Av. Cu	Av. Fe	Av. Mn	Av. Zn	Av. B
S 48	Low	Med.	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 49	Med.	High	Med.	Suff.	Suff.	Med.	Def.	Suff.	Suff.	Suff.	Def.
S 50	High	High	Med.	Suff.	Def.	Med.	Suff.	Def.	Suff.	Suff.	Def.
S 51	High	Med.	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 52	Med.	Low	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 53	High	Med.	Low	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 54	High	High	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 55	Med.	Med.	High	Suff.	Suff.	Med.	Def.	Def.	Suff.	Suff.	Def.
S 56	Med.	Med.	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 57	Low	Med.	High	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 58	High	High	Low	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 59	High	High	High	Suff.	Suff.	Med.	Def.	Suff.	Suff.	Suff.	Def.
S 60	High	Med.	High	Suff.	Suff.	High	Def.	Suff.	Suff.	Suff.	Def.
S 61	Low	Med.	Low	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 62	Med.	Med.	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 63	Low	High	High	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 64	High	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 65	High	Med.	High	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 66	High	Low	High	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 67	Med.	Med.	Low	Suff.	Suff.	Low	Suff.	Def.	Suff.	Suff.	Def.
S 68	Low	High	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 69	High	High	High	Suff.	Suff.	Med.	Def.	Suff.	Suff.	Suff.	Def.
S 70	High	High	High	Suff.	Suff.	Med.	Suff.	Def.	Suff.	Suff.	Def.
S 71	Med.	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 72	High	Med.	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 73	Low	Med.	High	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 74	High	Med.	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 75	Low	High	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 76	Low	Med.	High	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 77	Med.	High	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 78	Low	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 79	Med.	Med.	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 80	High	High	High	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 81	Med.	High	High	Suff.	Suff.	Med.	Def.	Suff.	Suff.	Suff.	Def.
S 82	High	High	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 83	High	Med.	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 84	Low	Low	High	Suff.	Suff.	Med.	Suff.	Def.	Suff.	Suff.	Def.
S 85	Med.	Med.	High	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 86	Low	Med.	High	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 87	Med.	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 88	High	Med.	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 89	High	Low	High	Suff.	Suff.	Low	Def.	Def.	Suff.	Suff.	Def.
S 90	High	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 91	High	High	High	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 92	High	High	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 93	Med.	Med.	Med.	Suff.	Suff.	Low	Suff.	Def.	Suff.	Suff.	Def.
S 94	Low	High	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 95	Med.	Med.	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.

Appendix III

Fertility rating of the soil samples from Koliyoor micro watershed (Continued...)

Sample ID	Org. C.	Av. P	Av. K	Av. S	Av. Ca	Av. Mg	Av. Cu	Av. Fe	Av. Mn	Av. Zn	Av. B
S 96	Low	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 97	High	Low	High	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 98	Med.	High	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 99	Low	Med.	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 100	Med.	Med.	High	Suff.	Suff.	Low	Suff.	Def.	Suff.	Suff.	Def.
S 101	High	Med.	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 102	High	Med.	Low	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 103	Low	Med.	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 104	High	Med.	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 105	Med.	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 106	Med.	Med.	Low	Def.	Suff.	Low	Suff.	Def.	Suff.	Suff.	Def.
S 107	Med.	High	Low	Def.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 108	High	High	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 109	High	High	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 110	High	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 111	Low	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 112	Med.	High	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 113	Low	Med.	Med.	Suff.	Suff.	Med.	Def.	Def.	Suff.	Suff.	Def.
S 114	Low	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 115	High	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 116	Low	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 117	Med.	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 118	Low	High	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 119	High	High	Med.	Suff.	Suff.	High	Suff.	Suff.	Suff.	Suff.	Def.
S 120	Low	Med.	Med.	Suff.	Suff.	Med.	Suff.	Def.	Suff.	Suff.	Def.
S 121	Med.	Med.	Low	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 122	Med.	Low	Low	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 123	Med.	Low	Low	Suff.	Suff.	Med.	Def.	Suff.	Suff.	Suff.	Def.
S 124	Med.	Med.	Med.	Suff.	Def.	High	Suff.	Suff.	Suff.	Suff.	Def.
S 125	Low	Med.	Med.	Suff.	Def.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 126	High	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 127	High	Med.	Med.	Suff.	Def.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 128	High	Med.	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 129	High	High	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 130	High	High	Med.	Suff.	Suff.	Med.	Suff.	Def.	Suff.	Suff.	Def.
S 131	Med.	Med.	Med.	Suff.	Suff.	High	Suff.	Suff.	Suff.	Suff.	Def.
S 132	High	High	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 133	High	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 134	High	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 135	High	Med.	High	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 136	High	High	High	Suff.	Suff.	High	Suff.	Suff.	Suff.	Suff.	Def.
S 137	Low	High	Med.	Suff.	Suff.	High	Suff.	Suff.	Suff.	Suff.	Def.
S 138	High	Med.	Low	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 139	High	High	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 140	High	Med.	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 141	Med.	High	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.

Appendix III

Fertility rating of the soil samples from Koliyoor micro watershed (Continued...)

Sample ID	Org. C.	Av. P	Av. K	Av. S	Av. Ca	Av. Mg	Av. Cu	Av. Fe	Av. Mn	Av. Zn	Av. B
S 142	Med.	High	Med.	Suff.	Suff.	Med.	Suff.	Def.	Suff.	Suff.	Def.
S 143	High	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 144	High	High	Med.	Suff.	Def.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 145	High	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 146	Med.	High	Low	Def.	Suff.	Med.	Def.	Suff.	Suff.	Suff.	Def.
S 147	High	Med.	Low	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 148	Med.	High	Med.	Suff.	Suff.	Med.	Def.	Suff.	Suff.	Suff.	Def.
S 149	Med.	High	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 150	Low	Med.	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 151	Low	Low	Med.	Suff.	Suff.	Med.	Suff.	Def.	Suff.	Suff.	Def.
S 152	Low	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 153	Low	High	Low	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 154	Low	High	Low	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 155	Med.	High	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 156	Med.	Med.	Med.	Suff.	Suff.	Med.	Suff.	Def.	Suff.	Suff.	Def.
S 157	High	Low	Med.	Suff.	Suff.	High	Def.	Suff.	Suff.	Def.	Def.
S 158	Med.	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 159	Low	Low	Low	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 160	High	High	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 161	Med.	Low	Low	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 162	Low	Low	Med.	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 163	High	Med.	Low	Suff.	Suff.	High	Suff.	Suff.	Suff.	Suff.	Def.
S 164	Med.	Med.	Low	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 165	Med.	Med.	Low	Suff.	Suff.	Med.	Def.	Suff.	Suff.	Suff.	Def.
S 166	Low	Low	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 167	Low	Med.	Med.	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 168	Med.	Med.	High	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 169	Low	Med.	High	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.
S 170	High	Med.	Low	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 171	High	High	Med.	Suff.	Suff.	Med.	Suff.	Suff.	Suff.	Suff.	Def.
S 172	Low	High	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 173	Med.	Med.	High	Suff.	Suff.	Low	Suff.	Suff.	Suff.	Suff.	Def.
S 174	Low	Med.	High	Suff.	Suff.	Low	Def.	Suff.	Suff.	Suff.	Def.

CHARACTERISATION OF THE SOILS OF KOLIYOOR MICRO WATERSHED USING GEOGRAPHIC INFORMATION SYSTEM.

APPU M. G

ABSTRACT

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ABSTRACT

A research work has been done to characterise the soils of Koliyoor watershed using Geographic Information System (GIS) tools. In order to generate various thematic layers, cadastral maps (1:5000), toposheets (1:50000), DEM (ASTER-30m) and satellite imageries of Google earth were used. The watershed was transected and soil sample were collected. The attribute data base, formulated using the results of chemical analysis of 174 soil samples was integrated into the GIS and various thematic maps were produced.

The major outputs generated on the Koliyoor micro watershed were the rated fertility maps of Organic Carbon, Available Phosphorus, Available Potassium, Available Sulfur, Available Calcium, Available Magnesium, Available Iron, Available Manganese, Available Copper, Available Zinc, and Available Boron. Maps showing the spatial variation of Soil Reaction, Electrical Conductivity, Bulk Density, Water Holding Capacity, Slope Aspect and Slope Classes were also generated. Data of Organic Carbon content was used for rating of Available Nitrogen. Using the thematic layers of Available Nitrogen, Available Phosphorus and Available Potassium, map showing NPK status also was generated.

The samples fell into two textural classes namely, Sandy Clay Loam and Sandy Loam. Soils were acidic with an average soil reaction of 6.02. Most of the samples were in Medium Acid class and the least in Neutral class. Highest mean value (6.1) of soil reaction was recorded from the samples taken from plots of coconut based cultivation. Electrical conductivity of the soils of Koliyoor micro watershed ranged from 0.01 to 0.26 dS/m which means that only non-saline soils are there in this area.

Organic carbon content of the samples ranged from 0.1 to 1.9 % with a mean value of 0.72 %. Plots of homestead cultivation showed maximum mean status (0.82 %) of organic carbon in samples. Majority of the watershed area belongs to the Medium class of available phosphorus with a range of 3.1 to 59.1

kg/ha and mean value of 22.1 kg/ha. The samples from converted paddy fields showed highest mean value (25.5 kg/ha) of P status. In the case of potassium also, majority of the area shows medium status. It ranged from 20.16 to 481 kg/ha. The mean value was found as 196.55 kg/ha. Samples taken from converted paddy fields showed highest mean availability of potassium (210 kg/ha). Soil samples from homestead area showed lowest mean value (101.4 kg/ha).

NPK status analysis revealed that, only 0.1 ha area showed low status for all of the three nutrients. High status was shown for these nutrients by about 15.23 ha area. 200 ha area was medium in the case of combined in NPK status.

Sulfur content of the samples ranged from 8.93 to 71.4 kg/ha with a mean of 30 kg/ha. The highest average value (39.2 g/ha) was seen among the samples from homestead cultivation and lowest mean (12.1 kg/ha) was from non-agricultural area. Koliyoor watershed showed relatively higher Ca content that ranged from 75 to 900 ppm with a mean value of 337.33 ppm. Converted paddy field samples were with the highest mean value (428.5 ppm) and the lowest mean availability (301.1 ppm) was seen in the plots of coconut based cultivation. Magnesium deficiency was seen all over the area, which ranged from 12 to 167 ppm with a mean value of 49.47 ppm and mode value of 42 ppm. Converted paddy fields showed comparatively high status of available magnesium with a mean value of 91 ppm while the lowest mean status (32.8 ppm) was seen in the samples from coconut based cultivation.

Iron status in the soils ranged from 4.6 to 164 ppm with an average value of 49.62 ppm. Highest mean value (69 ppm) was seen in converted paddy fields and the lowest (41.03 ppm) from non-agricultural area. Soil samples from the study area ranged from 0.01 to 8.66 ppm in available copper content. Mean value obtained was 3.47 ppm. Samples from converted paddy fields showed highest mean value (4.1 ppm). The lowest mean value (1.1 ppm) was obtained from non-agricultural area. Koliyoor micro-watershed showed 100 % sufficiency of available manganese. Soil samples ranged from 5.5 to 95.3 ppm in manganese availability. The mean status obtained is 32 ppm. Plots of homestead cultivation showed higher availability of manganese and highest mean value of 40.01 ppm. Lowest mean value (21.33 ppm) was seen in non-agricultural area. Soil samples showed a range of 0.03 to 4.01 ppm regarding zinc availability. The average value obtained was 0.71 ppm. Among the land use types, plots of homestead cultivation showed higher zinc availability with a mean value of 1.01 ppm. The lowest mean value (0.53 ppm) was seen in the category of converted paddy fields. Soils of Koliyoor micro watershed showed an overall deficiency in Boron availability. It ranged from 0.01 to 0.66 ppm with an average value of 0.27 ppm. Coconut based cultivation showed lowest mean availability (0.22 ppm) of boron while samples from non-agricultural area showed highest mean status of 0.43 ppm.

Bulk density of the samples ranged from 1.3 to 1.7 mega gram per cubic meter with an average value of 1.4 mega gram per cubic meter. Organic matter status and texture of the soils were important in influencing the bulk density of soils. The samples showed a range of 18 to 29.8 per cent regarding water holding capacity. Average value obtained was 23.4 per cent.

The slope of Koliyoor micro watershed ranged from zero to 15 percentage forming five classes, ranging from 'Nearly Level' to 'Strongly Sloping'. Within the obtained range of slope gradient, three topographical classes were identified, ranging from 'Flat' to 'Rolling' type. In Koliyoor micro watershed, the land showed 9 slope aspect classes facing the directions ranging from Flat to North-West.

The data on soil resources of Koliyoor micro watershed were integrated in a GIS environment and thematic maps on all the parameters were generated. Spatial distribution of different classes of nutrients was used for fertility characterisation of the watershed.