

**CHARACTERIZATION OF WATER, SOIL,
CROPS AND LAND USE/LAND COVER
MAPPING IN MUSI COMMAND AREA
USING REMOTE SENSING AND GIS**

BY

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B. Sc. (Ag.)

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July, 2012

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Mr. **PAVAN KUMAR REDDY YERASI** has satisfactorily prosecuted the course of research and that the thesis entitled “**CHARACTERIZATION OF WATER, SOIL, CROPS AND LANDUSE/LAND COVER MAPPING IN MUSI COMMAND AREA USING REMOTE SENSING AND GIS**” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University

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This is to certify that the thesis entitled “**CHARACTERIZATION OF WATER, SOIL, CROPS AND LANDUSE/LAND COVER MAPPING IN MUSI COMMAND AREA USING REMOTE SENSING AND GIS**” submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the Acharya N.G. Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mr.PAVAN KUMAR REDDY YERASI** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been duly acknowledged by the author of the thesis.

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Chairperson of the Advisory Committee

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	per cent
<	:	less than
>	:	greater than
BOD	:	biochemical oxygen demand
Ca ⁺²	:	calcium ion
CF	:	crude fiber
Cd	:	cadmium
CO ₃ ⁻²	:	carbonates
cm	:	centimeter
COD	:	chemical oxygen demand
Cd	:	Cadmium
Co	:	cobalt
Cr	:	chromium
Cu	:	copper
d S m ⁻¹	:	deci Siemen per meter
EC	:	electrical conductivity
<i>et al</i>	:	and others
Fig.	:	figure
Fe	:	iron
ha	:	hectare
HCO ₃ ⁻	:	bicarbonates
i.e.,	:	that is
K	:	potassium in percent
K ₂ O	:	potassium
Kg ha ⁻¹	:	kilogram per hectare
Kg	:	kilogram (s)
l	:	litre (s)
mg kg ⁻¹	:	milli gram per kilogram
mg l ⁻¹	:	milli gram per litre
µg l ⁻¹	:	micro gram per litre
mg	:	milli gram
Mn	:	manganese
N	:	nitrogen in percent
Ni	:	nickel
OC	:	organic carbon
P	:	phosphorous in percent
P ₂ O ₅	:	phosporous
Pb	:	plumbum
pH	:	soil reaction
ppm	:	parts per million
RSC	:	residual sodium bicarbonate
SAR	:	sodium abortion ratio
t ha ⁻¹	:	tonnes per hectare
viz,	:	namely
WHO	:	world health organisation
Zn	:	zinc

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ABSTRACT

An investigation entitled '**Characterization of water, soil, crops and land use/land cover mapping in Musi command area using remote sensing and GIS**' was carried out during 2011-12. The Musi project is located at village Solipet near Suryapet (17⁰15'E and 79⁰33'N). The project is intended to irrigate cultivable command area of 13,360 ha in Nalgonda district. Soil samples (95), water samples (open well-28, bore well-23 and canal water samples 6) were collected during pre monsoon period (June, 2011). During post monsoon period (January, 2012) water (canal water -49, open well-23, bore well-13) samples and rice plant samples (51) (April, 2012) were collected from the farmers fields along with GPS readings. Collected samples were analysed for different constituents. Data on *rabi* rice grain and straw yields from selected farmer's fields were collected by crop cut experiments. For preparation of land use / land cover map, satellite data from LISS III sensor of IRS P6 satellite, dated 6th February, 2012 was used. The Survey of India (SOI) topographical maps of 57O₇, 57O₈, 57O₁₁, 57O₁₂ of 1:50,000 scale covering Musi project command area were used as reference maps for geo-referencing of the remote sensing data in Erdas imagine 9.3 software and demarcated the study area. The thematic maps on spatial variability of water quality and soil fertility were generated by ordinary krigging method, using Arc GIS 9.3 GIS software.

As per USDA Hand Book on Agriculture No. 60, based on **pH**, all the **canal water** samples were alkaline. **Bore well** water samples during both the periods and open well samples during pre monsoon were neutral to alkaline. During post monsoon season all the

open well samples were alkaline. In general pH increased from pre-monsoon to post monsoon period. Based on **EC and SAR**, among **canals**, all water samples collected during both the seasons were found to be under the class II (C_3S_1). Among **bore wells**, during pre monsoon, majority of samples (92%) were under class II (C_3S_1) and remaining 8 % were under class III (C_4S_1). But during post monsoon, only 31% were under class II (C_3S_1) and 69% were under class III (C_4S_1). Among **open wells**, during both the seasons, majority of samples (81 to 83 %) were under class II (C_3S_1) and remaining 17 to 19 % were under class III (C_4S_1). The chlorides of water samples were moderate to unsafe (6 to 25 mg l^{-1}). The fluorides (0.026-1 mg l^{-1}) were in safe limits. The Nitrates were safe to unsafe (3-100 mg l^{-1}) and ammonia was within safe limits. Among the trace elements, the heavy metals Ni and Cd were found to be above the phytotoxic threshold levels.

Majority of the **soils** are sandy clay loam (70 %) in texture, followed by sandy loam (14%), sandy clay (7%), loamy (4%), clayey (3%) and clay loam (2%). They were moderately alkaline (55%) in soil pH, followed by slightly alkaline (29%), strongly alkaline (12%) and very less percentage of samples are in neutral range (4%). All soils are non saline, high in organic carbon, low in available N, high in available P and potassium. There is a need to reduce the P and K doses due to their high levels in soils. Among the micronutrients, about 22 to 25 % of samples were found to be deficit in available Cu and Zn and in these deficit soils, there is a need to include these elements in fertilizer schedules. However there is a threat from pollution point of view with regard to the heavy metals, especially Cd and Pb.

Thematic maps on spatial variability of water quality (pH, EC, SAR, RSC, EC-SAR, Cl, NO_3^- , F) and soil fertility (pH, EC, available N and K) have been generated.

The **rice** (variety-MTU 1010) yields in Musi command area during *rabi* 2011-12 varied from 1050 to 8000 kg ha^{-1} with the mean yield of 5120 kg ha^{-1} . The rice yields were high in the head region of Musi command area due to more availability of Musi project canal water, whereas in middle and tail end regions, the crop was suffered due to water stress. In rice grain and straw samples, the N, P, K, Fe, Mn, Cu and Zn contents were in deficit to normal range but except Cr, other heavy metals (Co, Ni, Cd and Pb) were found to be beyond the threshold levels. The total uptake by rice for N ranged from 5.30 to 92.11 kg ha^{-1} with mean of 34.46 kg ha^{-1} . The total P uptake ranged from 1.22 to 42.5 kg ha^{-1} with mean of 10.38 kg ha^{-1} . The total K uptake ranged from 8.72 to 149 kg ha^{-1} with mean of 60.10 kg ha^{-1} .

From the **land use land cover map of Musi command area** developed, it could be inferred that among the eight classes, the rice crop occupied the highest area among all crops, covering 20.1 per cent (5043 ha) of the gross command area (24, 906 ha), followed by other crops 19.7 per cent (4925 ha) and plantations 7.5 per cent (1875 ha). The overall accuracy obtained was 94.2 % with kappa's co-efficient of 0.91.

Chapter I

INTRODUCTION

Land and water are natural finite resources but due to indiscriminate and unscrupulous utilization, these resources are diminishing at an alarming rate. Water is becoming the most important limiting natural resources now days. The Food and Agriculture Organization (FAO) forecasted 14 per cent growth in irrigation withdrawals from 1995 to 2025. While, the International Water Management Institute (IWMI) states 17 per cent growth in withdrawals for irrigation. But food production from irrigated land during the same period must increase by at least 40 per cent to meet the food grain requirements of a 33 per cent increase in population and to satisfy trends for improved nutrition (Bos *et al.*, 2005). More food has to be produced per unit of water available for agriculture and to meet the increased demand of agricultural production. Hence, it's multiple uses and re-use is becoming more and more important. However use of waste water as a supplemental source of irrigation is inevitable for increased agricultural production in many arid and semi-arid regions where irrigation supplies are insufficient to meet crop water needs.

Use of wastewater in agriculture undoubtedly leads to soil contamination and groundwater pollution is the major environmental concern and also helps to recycle useful nutrients through the food chain. But it also poses risks simultaneously for the profitability of the cultivated crop and human health because of the possible presence of toxic elements in the irrigation water. Paddy yields have decreased by 40-50% over the years by continuous wastewater irrigation (Buechler and Gayathri Devi, 2005), because sewage water have a high nutrient load, suspended solids, dissolved nitrates. However in addition to that the waste water also contains residues of pesticides, heavy metals and many other toxic materials / chemicals which may be hazardous and it may affect the soil micro-flora, soil texture and quality and also the plant growth and development.

The Musi River is a tributary of the Krishna River in Andhra Pradesh, originates in Anantagiri hills, about 90 km to the west of fast growing city of Hyderabad and flows through Vikarabad, Pargi, Chevella, Kalvakul, Palankal and Golkonda mandals and reaches Osmansagar reservoir at Gandipet having its catchment of 11,000 km² .

The Musi river receives fresh water from rains during June, July and August and would have remained dry, but the population of Hyderabad has increased by 19.3% (JNNURM, 2005) the 700 million liters of untreated wastewater released into it every day from the city drains which is flowing, as a river or joined with streams, towards the village resulting in increased wastewater flows into the Musi river leading to further deterioration. For more than 30 years now, wastewater from the Hyderabad city has been flowing into Musi River untreated and in the last ten years (1991-2001), where most of the farmers, who have fields near the banks of these sewage canals are using this as a source of irrigation and pumping/flooding water directly to their field extensively used for irrigation, first by peri-urban farmers, to produce about 2100 ha of para grass and 10,000 ha of paddy is cultivated with un-treated wastewater (Gayathri devi, 2006).

The Musi river flows through the city of Hyderabad carrying heavy load of pollutants. Earlier reports indicated that the Musi (sewage) water contains elements at toxic levels within the city limits. Along the Musi river in peri urban and rural Hyderabad is irrigated with domestic sewage and industrial effluent water and then by other farmers in the wastewater zone to produce rice. Up to 40 kilometers downstream the region earning their lively hood through agriculture. A clear improvement in river water quality, both in appearance and smell, was observed with increased distance from the city. The effluent water is expected to contain abnormally high amounts of some micronutrients and heavy metals *viz.*, Zn, Cu, Fe, Mn, Pb, Ni, Cd and Cr which may readily be absorbed by grasses grown on these soils. (Chary *et al*, 2008) .In the long run such biomagnifications could prove harmful to life and ultimately affect the human health. There were complaints of poor quality of soil and crop due to irrigation from Musi water.

Musi project was constructed across Musi river at Solipeta village near Suryapet, in Nalgonda district of Andhra Pradesh. The Musi Medium Irrigation project covers an area of 12,500 ha. Wastewater of mixed domestic and industrial origin. It is utilized to irrigate approximately >10,000 ha of rice. The major crop in the sub-basin is rice, followed by vegetables, groundnuts, cotton, chilies, sugar cane, maize and pulses. Work on quality of water at downstream of Musi river, off Hyderabad, under Musi Project command is meager.

This project has been planned to study the quality of water at different locations and seasons in Musi project command area for identification of changing trends in nutrient and pollutant loads due to spatial and temporal variations. Further, GIS technology also allows the integration of the datasets for deriving meaningful information and outputting these information derivatives in the map format and tabular format. The integration of information derived from the remote sensing techniques with other data at different scales enables to study the potentials and limitations of natural resources and generate action plans for optimal utilization of the resources. These techniques have potential to predict and zonate different levels of crop response in a spatial and temporal dimension, when coupled with relevant information. Suitable blend of these technologies will aid in efficient management of resources to enhance the crop productivity in a sustainable basis. So, simultaneously it is also planned to prepare a soil and water quality maps, land use land cover map for estimating the crop acreage cultivated by Musi water along its course as well as for developing the relationship between the water quality and rice yields in command area.

The objectives of the study are given below:

1. To study the quality of surface and ground water in the command area of Musi project.
2. To study the physical and chemical properties of the soils in Musi command area.
3. To develop a land use land cover map of Musi project command area using remote sensing and GIS
4. To study the rice yield variations in farmers fields irrigated by Musi project water and ground water.

Chapter II

REVIEW OF LITERATURE

The literature related to water and soil quality and mapping of canal command using remote sensing and GIS is presented in this chapter under the following heads

- 2.1. Soil properties under canal commands.
- 2.2. Water quality under canal commands.
- 2.3. Effect of sewage water irrigation on crop and soil.
- 2.4. Assessment of yield using crop cutting experiments and yield data.
- 2.5. Land use land cover map preparation using remote sensing.
- 2.6. Preparation of map using krigging functions in Arc GIS.
- 2.7. Correlation between water quality, soil properties and crop yield.

2.1. Soil properties under canal commands

2.1.1. Bulk density and texture

Rattan *et al.* (2005) indicated that fields irrigated with sewage irrigation water around the peri urban areas of Keshopur Sewage Treatment Plant had sand and silt contents ranged from 56 to 86 and 8 to 28%, respectively, while maximum (18%) clay was recorded. Out of 30 samples analyzed, 7 samples belong to loamy sand and 23 samples were classified as sandy loam.

2.1.2. Soil reaction & EC

Soils irrigated continuous by with sewage water recorded higher pH and EC as compared to soils irrigated with normal water (Ramesh,2003).

Yaseen and Ishtiaque (2002) concluded from soil salinity data of soils under canal water that there was no remarkable change in EC, pH, SAR and ESP. Almost the same trend was found alternating with marginal water and canal water. However,

in marginal water a slight increase in E_{Ce}, pH, SAR and ESP have been noticed at all the sampling depths up to 120 cm from ground surface.

Kharche *et al.* (2011) reported that continuous use of sewage irrigation recorded improvement in soil physical properties like bulk density, water retention, hydraulic conductivity, organic carbon and build up of soil N, P, K, micronutrients, heavy metals and microbial count.

Bhise *et al.* (2007) concluded that waste water irrigation had adverse effect on some soil properties like EC, ESP and soluble cations(Na/K and Na/Mg) ratios and heavy metal content.

Keremane (2009) studied that the EC, values of Musi were higher than those recommended by FAO guidelines with urban, periurban and rural areas having 2.1, 2.6, and 2.6 d S m⁻¹, respectively.

Sewage including paper mill effluent of Jagiroad, Assam had a pH of 7.6 and conductivity of 7.12 dS m⁻¹ (Dutta and Boissya 1999). Similarly neutral reaction and 0.99 dS m⁻¹ EC was reported in water contaminated by sewage water at main research station, Hebbal, UAS, Bangalore (Nanjudappa *et al.*, 2002).

Tiwari *et al.* (1996) observed that soils irrigated with treated sewage water had relatively higher pH (8.0) and EC (0.2 d S m⁻¹) as compared to soils irrigated with tube well water (7.5) at Banaras Hindu University, Varanasi, U.P.

Rattan *et al.* (2005) concluded that the soil pH dropped on an average, by 0.4 units as a result of the long-term effect of sewage irrigation sewage irrigation.

2.1.3. Organic Carbon

Ramesh (2003) proved that the effect of continuous irrigation with sewage water on soil properties like organic carbon was high as compared to soils irrigated with normal water.

Rattan *et al.* (2005) indicated that there was an increase in organic carbon content ranging from 38 to 79 per cent in sewage-irrigated soils (content varied from 0.14 to 3.71% with average of 0.65%) as compared to tube well water-irrigated ones

(content varied from 0.14–0.76 with an average of 0.39 per cent) from a study on long term effect of sewage irrigation on heavy metal content in soils, plants and groundwater in peri-urban agricultural lands under Keshopur Effluent Irrigation Scheme (KEIS) of Delhi.

Sashikanth (2010) reported that the soil under Musi irrigation recorded high level of OC percentage i.e., > 1.0 per cent (ranging from 1.35 at Budwel to 1.84 at Afzalgunj).

2.1. 3.Chemical properties

2.1.3.1. Exchangeable cations

Ramesh (2003) found that the effect of continuous irrigation with sewage water increase exchangeable cations to a lot of extent. Similarly, Yadav *et al* (2003) expressed that the sewage water discharged through all the districts of Haryana contained micronutrients like Zn, Fe and Co to the extent of. 30.1,178.8 and 4.3 mg l⁻¹, respectively.

Ambika *et al.* (2010) suggested that waste water application increases the yield, macronutrients of cabbage, soil salinity, organic carbon, N, K, Ca, Mg cations to a lot. Soil is a bio filter that can reduce a large part of domestic waste water pollutants, but this filtering increased EC, SAR, Na, Ca and Mg of soil. (Darvishi *et al.*, 2010)

2.1.3.2. Available N, P, K

Priyanie amerasinghe *et.al.* (2008) observed that direct and lift irrigation with Musi sweage water plots showed that increased soil total N content, available phosphorus and exchangeable K content.

Kharche *et al.* (2011) concluded that the sewage irrigated soils recorded higher available N, P, K indicating their significant addition through sewage water as low grade cheap fertilizers.

Yadav *et al.* (2003) reported a nutrient potential of 8100, 1200 and 11000 tonnes of N, P and K through sewage discharges of 485 million litres/day that can be used for irrigation (supplemented) to an area of 16000-32000 ha/annum in peri-urban areas in Haryana.

Cao van Phung *et al.* (2009) proved that waste water was rich in nitrogen, phosphorus, and potassium and analysis of soil samples at harvest time showed that total nitrogen, phosphorus and potassium in rice irrigated with wastewater were significantly higher than plots without wastewater application,

Kiziloglu *et al.* (2007) reported that the waste water and preliminary treated waste water significantly affected the soil chemical properties up to 0-30 cm soil depth and plant nutrient contents of cabbage plants irrigated with waste water for one year.

2.1.3.3. Micronutrients and Heavy metals

Rattan *et al.* (2005) reported that 45 per cent of wastewater irrigated areas in China are contaminated with heavy metal at the most serious level. Cadmium and lead are the elements most seriously contaminating soils, not only in China, this has been a problem in several other countries like Germany, France and India as well (Ingwersen and Strect, 2006; Dere, *et al* , 2006 and Singh and Kumar (2006).

The excessive accumulation of heavy metals in agricultural soils through wastewater irrigation, may not only result in soil contamination, but also lead to elevated heavy metal uptake by crops and thus affect food quality and safety (Muchuweti *et al.*, 2006).

Kharche *et al.* (2011) concluded that the mean content of Fe, Mn, Zn, Cu, Cd, Cr and Ni in 0-30 cm layer of sewage irrigated soils was 1.05, 1.24, 3.98, 1.51, 2.10, 1.62, 1.24 more times than their content in normal soil.

Mathavan (2001) reported that among the 25 samples studied for toxic metal contents, lead was found to be at toxic levels where as Cd, Ni, Cr and Co were in higher range when compared to the contents encountered in normal soils. The Pb contents in sewage water were above the recommended level (0.05 mg l^{-1}) for use of sewage water for irrigation.

The dissolved salt content of the Musi river water indicated that it can be used for irrigation with restrictions. Nutrient concentration in most of the locations studied

was above the permissible limit which predisposes the sewage water and soil for biomagnifications in the cultivated paragrass samples (Urmila Devi, 2005).

Kuhad *et al.* (1989) reported that the DTPA extractable Zn content ranged from 0.28 to 89.3 mg kg⁻¹ in sewage irrigated soils in Haryana and observed that the contents of available micronutrients decreased with increase in depth through maximum accumulation of micronutrients was observed in the surface horizons of all soils.

Priyane amerasinghe *et al.* (2008) concluded that soil Pb, Zn and Cd concentrations in soils irrigated with Musi sewage water, were significantly lower than the EU (European Union) Maximum Permissible (MP) level in most of the samples except few samples those significantly higher.

Priyane amerasinghe *et al.* (2008) concluded that significantly higher concentrations of Cd and Pb levels for 'direct' and 'lift' irrigated rice plots (4.56 and 2.24 mg kg⁻¹ and 14.6 and 11.9 mg kg⁻¹) respectively and groundwater irrigated, plots were relatively lower having 1.41 and 9.78 mg kg⁻¹, Cd and Pb levels respectively.

Simmons *et al.* (2006) concluded that soils irrigated with Sewage water for 20 years resulted into significant build-up of DTPA extractable Zn (2.1 times), Cu (1.7 times), Fe (1.7 times), Ni (63.1%) and Pb (29%) in sewage-irrigated soils over adjacent tube well water irrigated soils.

Rattan *et al.* (2005) studied the long term (20 years) impact of irrigation with sewage effluents on heavy metal content in soil, crops and ground water and found that sewage water contain much higher amount of P, K, S, Zn, Cu, Fe, Mn and Ni compared to ground water. Similar results were reported by Malla *et al.* (2007).

Ambika *et al.* (2010) reported that Sewage water often have a high nutrient load, suspended solids, dissolved nitrates, pesticides, heavy metals and many other

toxic materials / chemicals which may be hazardous and it may affect the soil microflora, soil texture and quality and also the plant growth and development.

2.2. Water quality under canal commands

2.2. 1 pH and EC

Usha Rani (2007) reported that the pH of ground water samples in Musi basin varied from 6.6 to 7.4 with a mean value of 6.97 where as EC values varied from 1.37 to 4.97 with mean value of 2.94 dS m⁻¹.

Ghosh and George (1989) found that pH was found as alkaline during monsoon and gradually decreased on onset of summer and reached the minimum of seven in Hussain sagar lake of Hyderabad.

Priyane amerasinghe *et al.* (2008) indicated increased EC levels (1272.1 – 1672.4 $\mu\text{S cm}^{-1}$) along a 40 km stretch of the Musi River, due to evaporative water loss, and run-off from agricultural fields with high levels of chemical fertilizers in due course.

The mean pH of water samples collected from sewage discharges from Patancheru, Kattedan, Nacharam and Jeedimetla industrial areas of Hyderabad were 6.9, 7.1, 6.9 and 7.0, respectively, (Madhavi and Prasad Rao, 2003).

Sashikanth (2010) observed that the Electrical conductivity of Musi water was the highest in water samples collected from Nagole (2.07 dS m⁻¹), while EC lowest in water sample of Sagam (1.29 dS m⁻¹) with the mean value of 1.55 dS m⁻¹.

Rattan *et al.* (2005) indicated that sewage irrigation water fields irrigated around the peri urban areas of sewage effluents originating from Keshopur Sewage Treatment Plant have been used for irrigation purposes were acidic in reaction with pH values ranging from 5.8 to 6.5 and electrical conductivity of sewage effluents in all samples exceeded 1 d S m⁻¹ (1.36–2.88 d S m⁻¹) saline.

Ganesh and Keremane (2007) concluded that the EC values are 2.1, 2.6, 2.6 d S m⁻¹ in urban, semi urban, rural respectively and total dissolved solids (TDS)

values were also higher than those recommended by the FAO guidelines and so was the total nitrogen in Musi water.

Mc Cartney *et al.* (2008) reported that with distance away along the downstream TDS (Total Dissolved Solids) decreased slightly due to the water draining into the river have lower salt concentrations.

Buechler and Gayathri Devi (2005) concluded that is the EC and TDS values were higher than those recommended by the FAO guidelines in the pre-monsoon water quality samples from the Musi river were taken at five points in the urban, peri-urban and rural research sites.

Yadav *et al* (2003) too reported slightly alkaline (pH 7.1-8.3) reaction electrical conductivity of 0.9 to 3.2 dS m⁻¹ SAR 1.4-6.2 in sewage water discharged from various districts of Haryana during 2001-02 which was rated as suitable for irrigation.

2.2. 2. Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

Priyanie amerasinghe *et al.* (2008) reported that, total nitrogen (35.19-14.88 mg l⁻¹) and BOD (180.8-25.9 mg l⁻¹) decreased significantly, where as EC levels (1272.1-1672.4 µScm⁻¹) increased along 40 km stretch of Musi river. The BOD levels were relatively higher ranging from 90 –266 mg l⁻¹ at the first sampling point, than the rest of the sampling points.

Ensink *et al.* (2010) observed that BOD was found to be high at initial sample points and declined as the samples were move away from city and improved better water quality.

2.2.3. SAR & RSC

The potential problems associated with recycled sewage water irrigation mere salinity build up, relatively high Na and B accumulation in the soil and possibility of long term reductions in soil hydraulic conductivity and infiltration rate in soil with high clay content the salt leaching would become less effective. The values of

residual sodium carbonate (RSC) varied from traces to 1.2 which were below 1.25 me l⁻¹ i.e. safe limit for irrigation water (Darvishi *et al.* 2010)

2.2.4. Heavy metals & micronutrients

Dixit and Tiwari (2008) reported that Cu, Cr, Pb, Cd and Mn were present in relatively higher concentrations as compared to their permissible limits. The maximum concentration of Cu (1.4 mg l⁻¹) is reported in the month of May at stations 1 and 4, whereas the minimum concentration was 0.16 mg l⁻¹. High value in the month of May is due to high rates of evaporation, thereby increasing its concentration.

Ensink *et al.* (2010) reported that concentrations of heavy metals in Musi water were in general low (IWMI, unpublished data) with the exception of iron (Fe) and aluminium (Al) though even these did not exceed agricultural guideline concentrations (Pescod,1992), or guidelines set to protect public health (WHO 2006).

The results of study on long term effect of sewage irrigation in peri urban areas of New Delhi indicated that sewage effluents contained much higher amount of P, K, S, Zn, Cu, Fe, Mn and Ni compared to groundwater. There was no significant variation in Pb and Cd concentrations in these two sources (ground water and sewage water) of irrigation water and were the permissible limits for its use as irrigation water (Rattan *et al.*, 2005).

2.2.5. Nitrates, sulphates, chlorides and fluorides

Shanthi *et al.* (2002) reported that the nitrate concentration in Gulbarga city of Karnataka about 40 per cent of the study area has desired and 62 per cent of the area acceptable levels of nitrate according to WHO standards they also reported that the chloride concentration in 59 per cent of the study area having desired, and 41 per cent of the area acceptable levels of chloride according to WHO standards. The higher concentration of chloride is considered to be an indicator of pollution due to higher animal waste. This could be due to sewage mixing and increased temperature and evapo- transpiration of water.

2.3 Effect of sewage water irrigation on crop

2.3.1 Nitrogen, Phosphorous and Potassium

Dutta and Boissya (1999) revealed that nitrogen, phosphorous and potassium contents were high in plants grown in paper mill effluent affected areas of Nagaon Paper Mill area, Jagiroad, Assam than those grown in non- effluent affected areas.

Tiwari *et al* (1996) reported from Banara Hindu University, Uttar Pradesh that higher uptake of NPK by rice in treatments which received 50% of fertilizer dose and irrigated with treated sewage water indicating better utilization of applied fertilizers. The treatments which received 100 % fertilizer dose with sewage water lodged and recorded lower uptake of NPK.

Priyanie amerasinghe *et al.* (2008) concluded that rice straw N content (%) was very high under lift and direct irrigation conditions compared with the control value of 0.721 per cent and it was significantly lower in straw from 'lift' irrigated fields as compared with straw from 'direct' irrigated fields with mean values of 1.08 per cent and 1.38 per cent, respectively.

Ensink *et al.* (2010) reported that the nitrogen levels in Musi water exceeded marginally recommendations made by the FAO for unrestricted irrigation (Pescod 1992), though guideline values were only occasionally exceeded.

Patel *et al.* (2006) reported that with sewage water irrigation due to the high nutrient content, farmers are benefited with high yield with less fertilizer inputs.

Al- Nakshabandi *et al.* (1997) reported in their study with Dill seed plant (*Anethum graveolens*) and egg plant (*Solanum melongena*) which was irrigated with sewage and tube well water, a significantly higher yield for the treatment which received sewage irrigation.

Ali.A.Aljaloud (2010) showed that reuse of treated municipal waste water for irrigation provided plants with sufficient levels of nutrients, such as nitrogen (N), phosphorus (P) and potassium (K), and other micro-nutrients and saved 45 per cent

and 94 per cent in the cost of the fertilization programs for wheat and alfalfa, respectively by using treated municipal waste water in crop irrigation

2.3.2. Micronutrients and Heavy metals

The study on effect of long-term application of sewage effluents on contents of heavy metals in crops grown indicated that cadmium and cobalt contents in tissues of all plants were below the limits of analytical detection (Dutta and Biossya, 1999).

Analysis of the soils collected from fields of berseem, spinach and coriander irrigated with sewage water show that the soils contained higher amount of accumulation of heavy metals compared to ground water irrigated soils (Brar *et al.* 2002).

Priyane amerasinghe *et al.* (2008) concluded that all rice straw samples have Cd and Pb levels were below the EC (European commission) maximum permissible levels irrespective of irrigation method or duration of river water use. Over 95 per cent of the rice straw samples contained lower Zn concentrations which are considered as a reliable indicator of Zn deficiency.

Simmons *et al.* (2006) reported that Cd and Pb levels in rice straw, in soils irrigated with Musi waste water were significantly low (0.016, 0.026 and 0.31 mg kg⁻¹ of Cd) and (0.260, 0.246 and 0.369 mgkg⁻¹ Pb levels) in direct, lift and control irrigated rice plots due to high pH (> 8) and extremely higher levels wastewater induced of extremely P which effectively immobilized Cd and Pb in soil.

Mukherjee and Gautam Gupta (2011) opined that the results show that plots using wastewater containing organic nutrients earn higher profits than those using groundwater. However, plots using wastewater, negatively affected by the presence of heavy metals such as Chromium, Lead and Mercury that are found in the water and soil and need to regulate the discharge of heavy metals into the water from households and industries that are located upstream in the city of Kolkata.

A study by Nawaz *et al.* (2006) showed that contamination by Cu and Cd heavy metals was within safe limits in the soil irrigated with water from Nallah Daik in Pakistan and accumulation of these metals in the paddy plant parts, was within the permissible limit.

Fazeli *et al.* (1998) found remarkably low concentrations of heavy metals (Cu, Zn, Pb, Co, Cd, Cr and Ni) except Zn in the seeds of paddy, irrigated by paper mill effluents near Nanjangud, Mysore district, Karnataka. Although this was not the case for the roots and leaves, the crop was able to tolerate the presence of the heavy metals in the polluted water without suffering much damage.

Zeng *et al.* (2007) showed in green house experiment that when the Pb treatment was raised to the level of 500 mg kg^{-1} , there was an ecological risk both to soil microorganisms and plants. The results also revealed that there was a consistent increase in chlorophyll contents and rice biomass initially, peaking at a certain level of Pb treatment, and then a gradual decrease with a continued increase in Pb concentration. The study has shown that Pb was effective in inducing proline accumulation and that its toxicity causes oxidative stress in rice plants.

A study by Wang *et al.* (2003) indicated that Zn, Cu and Pb were the main pollutants in the experiment sites of paddy soil and the rapid development of village/township industries were to be the primary cause of severe environmental pollution in the Taihu Lake region in China, especially of irrigation river sediments.

Markandya and Murthy (2000), in their study of the Kanpur-Varanasi region in India, found that though the mean levels of Cd, Cr, Ni and Pb in the soils were above their respective tolerable limits for agricultural crops, since the pH of the receiving soil was alkaline, their effects were less harmful than expected.

Results showed the rice grain contained significantly lower amounts of five metals (Cd, As, Hg, Pb, Co) than straw and root in all sampling sites. Rice root accumulated Cd, As, and Hg from the paddy soil. Moreover, the rice plant

transported Arsenic (As) very weakly, whereas Hg was transported most easily into the straw and grain among studied heavy metals. (Liu *et.al*, 2008).

Cao van Phung.*et.al* (2009) reported that Cadmium released from the Jintustu river in Japan by mining activity used for irrigation to rice and a concentration of 15.5 microgram Cd g^{-1} extracted from the soil with 0.1 N HCl which was excessive levels of Cd in rice grain.

Rattan *et al.* (2005) observed that mean contents of metals in the dry matter of rice grain accumulated much higher amount of Zn and Cu grown on sewage irrigated soils compared to tube well water. While slight increase in Ni content was recorded. Manganese content in rice grain for sewage-irrigated soils was much lower than that for tube well water-irrigated soils. Although sewage effluent-irrigated soils exhibited much higher amount of DTPA-Fe, it was not reflected in Fe content of rice grain. Rice straw accumulated almost two times more Ni produced with sewage water over that of tube well water irrigation.

2.3.3 Crop Yields

Srinivasan and Ratna Reddy (2009) reported that nutrients present in wastewater resulted in higher crop yields and thereby considerably reduce the need to apply artificial fertilizers. A decline in plant height and grain yields of transplanted rice was observed when grown under paper mill effluent (Dutta and Boissya, 1999).

Cao van Phung.*et.al* (2009) reported that waste water irrigation reduced fertilizer inputs without affecting yield.

Priyanie amerasinghe *et al.* (2008) reported that rice directly irrigated from Musi river rewarded significantly higher straw and grain yields with rice variety MTU 1001 as compared to MTU 1010 and IR64.

Ensink *et al.* (2010) found that poor water quality, and in particular high salinity levels, was mentioned by farmers as an explanation for yield reductions in rice yields underground water compared to Musi water.

Chun G. Yoon and Soon K. Kwun (2001) reported that irrigation of treated sewage to paddy rice cultures did not adversely affect the growth or yield of rice at Konkuk University in Seoul, Korea and 10 per cent (with sewage dilution) or 50 per cent (without dilution) more yield on average than controls when the sewage was treated adequately and used properly.

Pandey et al. (2008) concluded that use of the distillery effluent even on 1:1 dilution with tap water inhibited germination of maize and rice.

Markandya and Murthy (2000), in their study of the Kanpur-Varanasi region in India, found that the positive effect on agricultural yield of nutrients present in partially treated wastewater when compared with crops grown using groundwater.

2.4 Assessment of yield using Crop Cutting Experiments and yield data derived from remote sensing

Estimation of crop yield in many countries is based on conventional techniques of data collection for crop and yield estimation based on ground-based field reports (*Reynolds et al.* 2000). These methods are costly, time consuming and are prone to large errors due to incomplete ground observations, leading to poor crop yield assessment and crop area estimations. Availability of data in most of the countries is too late for appropriate actions to be taken to avert food shortage. Remote sensing techniques are proved to be successful in providing the data timely and accurately.

The NDVI relationship derived between NDVI calculated from the satellite image and yield (collected as a ground truth) relationship has been used for estimating the yield at distributaries level during *rabi* 1992-93 (*Murthy et al.* 2003). The relationship is extended for *rabi* 1993-94 after taking into account the changes in crop calendar. The estimates were obtained for crop cut experiments (CCE) plots and were validated by comparing with actual yield as recorded in CCE. While the estimates are found to be promising in accuracy with less than 10 per cent deviation from actual, there is need to refine the yield and NDVI model by integrating the CCE

data of two to three seasons so as to get more dependable estimates in subsequent yield predications.

Saraf (1999) demonstrated the advantage of image fusion merging IRS-IC-PAN with IRS-IC-LISS-II data and showed that the merged image has the full length spatial quality of PAN data and spectral quality of LISS-II multi spectral data.

Manjunath and Potdar (2004) have developed wheat crop yield model at district level in Rajasthan using NOAA AVHRR NDVI data and found that among the seven yield models developed, the model based on fractional area approach with twenty days interval was the best.

2.5. Land use / land cover map preparation using remote sensing

Sreedhar *et al.* (2009) developed a total of eight LULC (land use land cover) classes and mapped for *kharif* (main monsoon rainy season; June-October) season particularly to identify the irrigated area of the Musi basin. The total areal extent being irrigated through the groundwater (supplemental), rain, canals and tanks is of the order of 5070.9 km².

2.6. Map preparation using Krigging function in Arc GIS

The geographical information system software Arc GIS was used to interpolate the results from the point data to the entire region. Kriging interpolation (Cressie, 1992) was used for the estimation of the spatial distribution of nutrients.

The results of interpolated maps developed for nitrogen, potassium, phosphorus, and organic carbon show a clear deficiency of nutrients across the district, as 96, 95, 76 and 95 per cent respectively and more than 50 per cent of the area has sandy loam to sandy clay loam soil texture in Hyderabad district of Pakistan. (Naheed Akhte *et al.* 2010).

Aishah *et.al* (2010) generated the krigged maps also showed that a large portion of the study area (66%) have high total N (0.30-0.40%), with low amount of

available P ($< 40 \text{ mg kg}^{-1}$) covering 70 per cent of the total study area (Sawah Sempadan is located in the Barat Laut Paddy Project within the north of Selangor State which is in the Southeast part of Malaysia), while most of the area have optimum content of exchangeable K ($> 0.10 \text{ c mol}^+ \text{ kg}^{-1}$). These results suggest the need for a site specific approach in managing paddy soils particularly with regard to nutrient management.

Balakrishnan *et al.* (2011) reported that the ground water quality information maps of the entire study area have been prepared using GIS spatial interpolation technique for the parameters like nitrates, chlorides, TDS and generated maps were coded as potable zones, non-potable zones in the study area, in terms of water quality.

A study was conducted by Minakshi *et al.* 2005 in Patiala district of Punjab to assess the micronutrient status of soil using Arc info GIS. About 11 per cent of total area of district was deficient in Zn. Only 4 and 5 per cent of the area was deficient in Mn and Fe, respectively. They prepared soil available micronutrient status maps for Patiala district of Punjab under Arc-info GIS environment.

2.7. Correlation between water quality, soil properties and crop yield

A few numbers of researches however are available regarding the analysis of groundwater quality data using regression techniques for prediction purposes in different parts of India and Bangladesh (Gabriel *et al.*, 2010).

Prasad and Prasad (2001) reported that correlation studies of coastal soils of Guntur district showed that EC and pH of water are highly significantly correlated with EC of soil. Similarly, it also correlated positively and significantly with SAR of soil.

Highly significant correlations were found between the chemical composition of irrigation water used and soil chemical properties (whole profile), which predict the soil contamination due to irrigation with low quality water (Kandil *et al.*, 2003).

The correlation matrix for different ground water quality variables of Sunamganj district calculated. It is evident that distribution of alkalinity, hardness, calcium, magnesium, sodium, chloride, bicarbonate, nitrate, and sulphate were significantly correlated with electrical conductivity in most of the study areas.

Highly positive correlation coefficient is observed between Na and K, Ca and Cl, Ca and EC, HCO_3 and EC, Na and TDS, TDS and K. While highly negative correlation coefficient is seen among NO_3 and TDS Ca and Mg. (Joarder *et al.*, 2008).

The fluoride content ground water positively correlated with SAR and RSC indicating that groundwater with higher pH, SAR and RSC values are likely to have a higher F content in irrigation water while higher calcium in groundwater may negatively correlate with the F content (Manjunatha Hebbara *et al.*, 2010).

Chapter III

MATERIAL AND METHODS

The details of the site, characteristics of the study area, materials used and methods adopted, to characterize the Musi command area is presented in this chapter.

3.1 The study area

The study area selected was command area of Musi project. The Musi project was across the river Musi, near solipet village in Nalgonda district in Telangana region of Andhra Pradesh falling in the Deccan Plateau Agro-climatic region of India. It lies between $17^{\circ}15'$ North latitude and $79^{\circ}33'$ East Longitudes. The Nalgonda district is located in the central part of Peninsular India and Northern part of Southern Deccan region. The district is bounded by Medak district and Warangal district in the North, Khammam and Krishna districts in the East, Guntur and Mahabubnagar districts in the South and Rangareddy and Mahabubnagar district in the Western side. The district is located within the geographical co-ordinates of $16^{\circ}25'$ and $17^{\circ}60'$ Northern latitudes and $78^{\circ}40'$ and $80^{\circ}05'$ Eastern longitudes, with a total geographical area of 14322 Km². (Hand book of Statistics, 2006-07, Chief planning officer, Nalgonda). The location map of study area is indicated in Fig.3.1

3.1.1 Geographical area and Extent

Musi project located at solipet near suryapet ($17^{\circ}15'E$ and $79^{\circ}33'N$) with 11,300 km² catchment area with a designed discharge of 9.34 cusecs. The project is intended to irrigate an ayacut (cultivable command area) of 7217 ha for right flank canal and 6143 ha for left flank canal in forty villages of seven mandals in Nalgonda district. Presently the water from Musi project was released during *rabi* season every year for supplying water for cultivation of irrigated dry crops. But majority of the farmers cultivated paddy crop only in head and middle region of project. The command area is comes under Agro-Eco

region 7-Hot Semi-arid eco region with red and black soils (K₆ D₂) (NBSS&LUP, 1992). The salient features of the Musi project are presented in Appendix

3.1.2 Physiography

The annual rainfall of the district is 530 mm. In Nalgonda district, Agriculture is the main occupation for 70 per cent of the population of the district. The land under cultivation forms 46.7 per cent of the geographical area.

3.1.3 Soils

The soils of the district are mostly consisting of red soil. The fertile black cotton soil forms only 9 per cent and occurs on the banks of Krishna and isolated patches here and there. Among the red soils 47 per cent is dubba soil (loamy sands), which has a very low moisture retaining capacity, and the rest is chalka soil, 44 per cent.

3.1.4 Crops and cropping pattern

The major crops cultivated in this district are paddy, maize, pulses, chilies, sesamum, cotton and castor. *kharif* season crops are paddy, groundnut, cotton, castor, red gram, jowar, greengram, horsegram, maize, sesamum, chilies and during *rabi* paddy, jowar, maize, greengram, horsegram, blackgram, groundnut, chilies and coriander are grown. It is supported by a well planned irrigation system which includes 26 lift irrigation and 1, 16,007 irrigation wells. (Hand book of Statistics, 2006-07, Chief planning officer, Nalgonda). Also there are six rivers flowing through the district. These are Krishna, Pedavagu, Kanagal *vagu*, Musi, Dindi, Alair *vagu* and Halia *vagu*.

The main crop of the study area in head and middle reach during *kharif* and *rabi* seasons is rice. (Variety -BPT-5204). During *kharif* rice crop is sown in the nursery during the last week of June and four weeks old seedlings are transplanted in the main fields during last week of July and first week of August depending on the release of canal water. Greengram and blackgram are also grown in uplands of the command area as a rain fed crops. During *rabi* season (October-February), the variety commonly grown is

MTU-1010. In some parts of head and middle reach and majority of tail end region, irrigated dry crop like cotton, red gram, bengal gram etc are grown.

3.2 Weather conditions during Crop growth period

Climate of the study area is semi-arid with distinct summer, winter and rainy seasons. More than 75 per cent of rainfall is received through South-West monsoon in this area. The selected areas are located in six mandals (Left flank canal- Kethepalle, Vemulapalle, Thipparthi and Right flank canal- Chivvemla, Suryapet and Penpahad). The total rainfall received during 2011 May to 2012 April was 788, 794, 1099, 704, 692 and 545 mm in Chivvemla, Kethepalle, Suryapet, Penpahad, Vemulapalle and Thipparthi mandals, respectively with a mean of 770mm. The mean minimum relative humidity (RH) ranged from 47 to 49 per cent in the command area during both the seasons, while, mean maximum RH was around 77 to 79 per cent in *kharif* 2011 and 66 to 68 per cent in *rabi* 2011-2012. The mean maximum and minimum temperature were 32⁰C 21⁰C, respectively.

3.3 Crop management practices followed by farmers in Musi command area

The primary data on land and land use and information on crop management for irrigated rice for the season (July to December during 2011) was collected from the farmers through personal interviews in prescribed Performa (Appendix). Farmers undertake different management practices to get reasonable yields from their plots and operate at different technological levels. Data on operation sequence that was followed by individual farmers was collected and analyzed and is represented in Annexure 2.

3.3.1 Varieties grown

The most common variety of paddy in *kharif* and *rabi* seasons was BPT 5204 and MTU-1010 respectively

3.3.2 Ploughing

Ploughing starts by June second fortnight in the head reach distributaries, by first fortnight of July in middle reach distributaries and by second fortnight in tail reach distributaries under both the right and left flank canal of Musi irrigation project. Farmers perform puddling just before transplanting with the help of tractors.

3.3.3 Transplanting

Paddy is mainly transplanted with the seedlings of 27 to 30 days old, sowing was mostly done from July first to second fortnight during *kharif 2011*. Farmers in the head reach started transplanting during July 1st week.

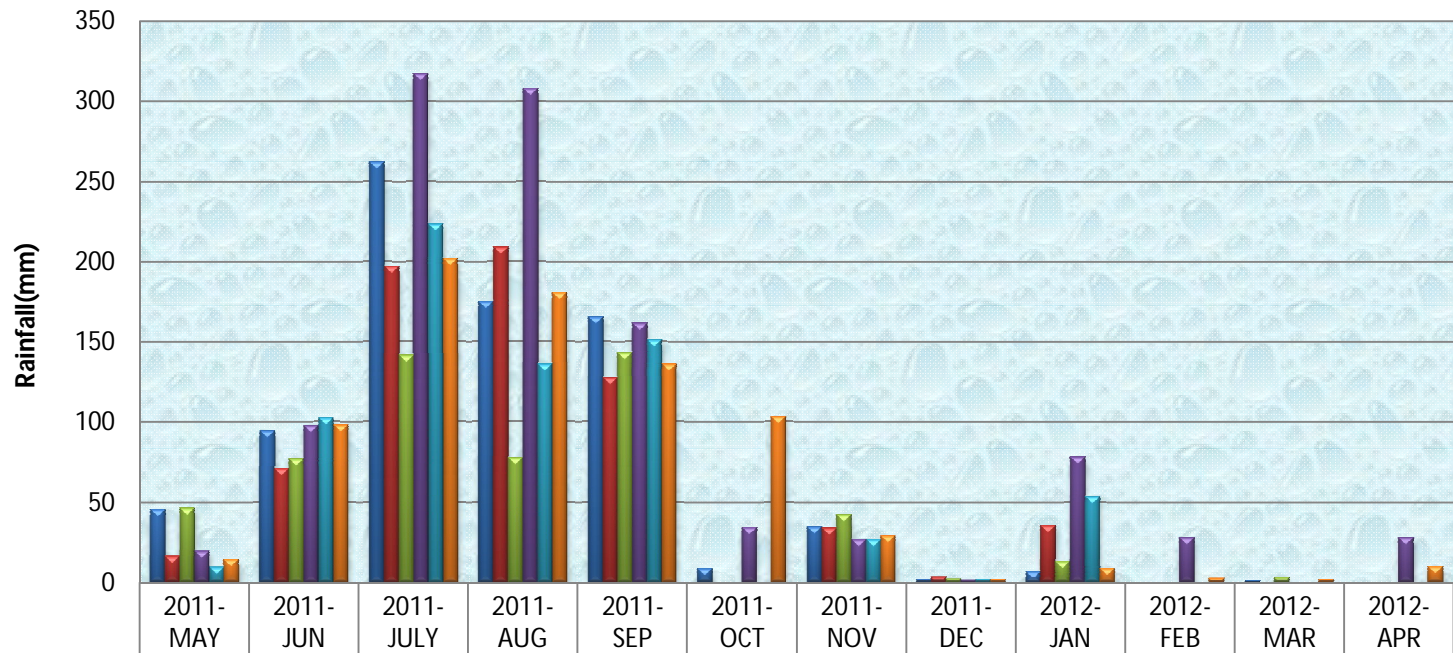
3.3.4 Fertilizer application

All farmers applied nitrogen fertilizer in the form of urea and complex fertilizer of DAP or 20-20-0-15. The fertilizers were applied in two to three splits and the last application (regardless of number of splits) was mainly urea with potassium (MOP) combination. Zinc sulphate was applied at an average of 25 kg ha⁻¹ by the farmers for crop.

Farmers applied DAP as basal during transplanting and other complex fertilizers like DAP were top dressed 20 days after transplanting (DAT). Urea was applied in two splits either as basal and at panicle initiation (PI) stage or 20 days after transplanting and panicle initiation (PI) stage or in three splits i.e., as basal, 20 DAT and at PI stage. Potassium in the form of MOP was applied either at PI stage or in two splits as basal during seedlings transplanting and at PI stage.

During the year of study, same farmers were interviewed and they explained that for *kharif* season every year they apply the same quantity of fertilizer. The fertilizer dose applied by the farmers was brought into uniformity (per hectare) and is presented in the appendix III. The average fertilizer dose applied by the farmers was 175-117-44 and 155-108-66 kg NPK ha⁻¹ in right and left main canal respectively.

RAIN FALL DATA OF MUSI COMMAND AREA DURING 2011-12



	2011- MAY	2011- JUN	2011- JULY	2011- AUG	2011- SEP	2011- OCT	2011- NOV	2011- DEC	2012- JAN	2012- FEB	2012- MAR	2012- APR
RF CANAL KETHEPALLE	45.4	94.3	262	175.2	165.3	8.6	34.4	1.7	6.6	0	1	0
RF CANAL VEMULAPALLE	16	70.8	197	209	127.7	0	33.6	3.3	35.2	0	0	0
RF CANAL THIPPARTHI	46	76.9	141.4	77.8	143.2	0	42	2.4	13	0	3.2	0
LF CANAL SURYAPET	19.2	97.8	317.2	308	161.5	34	26.7	1.3	78	27.8	0	27.8
LF CANAL PENPAHAD	9.4	102.5	223.4	136	151.1	0	26.7	2	53.4	0	0	0
LF CANAL CHIVVEMLA	14.4	98.1	201.7	180.7	135.8	103.4	29.1	1.9	8.7	2.5	1.8	10

Figure: 3.2 Mandal wise rain fall data of Musi command area during 2011-2012

3.3.5 Irrigation

Irrigation water supply is a major production factor. There was shortage of water supply and the farmers did experience water shortage. In head region due to leakage of water from Musi project they are getting sufficient amount of water and there is a decline in water availability as it proceeds from head to tail end.

3.3.6 Weeding

Most of the farmers did weeding once before first top dressing and second 40 DAT. The first and second weeding was done by hand in all fields.

3.3.7 Pest and diseases

Farmers explained that diseases were problem during *kharif* season due to high relative humidity and lower sunshine hours. Pesticides and fungicides were applied as preventive measure. Still, few farmers experienced pest and disease attacks in their fields especially during *kharif* 2010. The pests reported were brown plant hopper, stem borer, leaf folders and diseases reported were blast and sheath rot.

3.3.8 Harvesting

The crop was harvested during *kharif* November last week to December first fortnight depending on the availability of labour since machine harvesting is not possible in these fields with standing water in the fields in head region and harvesting was delayed for 10 days when compared with the other parts of command area. On the other hand, harvesting was mostly done by mechanical harvesters during December first fortnight. During *rabi* Season harvesting was done from 15th April onwards by mechanical harvesters and completed within few days in Musi command area

3.4 Data base

The database and instruments used during the present investigation are detailed below.

3.4.1. Satellite data

The multispectral images from LISS-III sensor of IRS –P6 (Resourcesat-1) was acquired from National Remote Sensing Centre, Balanagar, Hyderabad. The LISS-III sensor operate in four spectral bands, viz., B2 (green), B3 (Red) and B4 (NIR) in the visible region and near infrared region (0.520-0.590 μm , 0.620-0.680 μm and 0.77-0.860 μm respectively) and B5 in the short wave infrared (1.550-1.700 μm). The LISS-III sensor has radiometric quantization of 7 bits and provides a combined swath of 141 km with a spatial resolution of 23.5 m. This image is presented in Fig.3.3.

The image was utilized for preparation of land use land cover map, delineation of major crops grown in the study area. The details of the satellite data used for the investigation are given in Table 3.1.

Table 3.1.Details of the satellite data used for the investigation

satellite	Sensor	Path/orbit	Row/sector	Date of pass
IRS P6	LISS-III	101	61	6 th February, 2012.

3.4.2 Topographical maps of the study area

The Survey of India (SOI) topographical maps of 570₇, 570₈, 570₁₁, 570₁₂ on 1:50,000 scale covering Musi command area in Nalgonda district, Andhra Pradesh were used as reference maps for geo referencing of the remote sensing data and demarcating study area. These maps helped in proper orientation in the field and served as good base, complementary to FCC to locate and plot blocks for ground truth collection.

3.4.3 Canal distributary map

The canal distributaries map (Fig 3.4) was collected from DEE office, suryapet, Nalgonda district. This map was used as a reference map for digitization of main canals and its distributaries. It formed a basis for selection of distributaries for conducting crop cut experiments. The canal network and the distributor boundaries were digitized from the canal distributaries map using Arc GIS ver.9.3.

3.4.4 Water release data

The data on daily water release to the command area were collected from the Musi Project office located at Suryapet, Nalgonda district.

3.5. Equipments and software used

3.5.1. Global Position System (GPS) – (Model- Garmin72H)

Global Positioning System (GPS) which is a constellation of 24 satellites orbiting the Earth at a very high altitude of 20,200 km, allows anyone with a GPS receiver to determine the precise 3-D location. It offers advantages of accuracy, speed, versatility and economy while in use as an aid for position based data collection. GPS owes its popularity to the dependable high accuracy with which position and time can be determined. The GPS was conceived as a ranging system from known positions of satellites in space to unknown positions on land, sea and space. GPS uses pseudo ranges derived from the broadcast satellites. The pseudo ranges were derived either from measuring the travel time of the (coded) signal and multiplying it by its velocity or by measuring the phase of the signal. The antenna detects the electromagnetic waves arriving from the satellites, converts the wave energy into an electric current, amplifies the signal strength and sends the signals to the receiver electronics.

The GARMIN, **GPS 72H** GPS receiver in stand-alone mode was used to collect the information regarding the geographical location of the ground truth sites and water and soil sampling sites during the present investigation.

3.5.2 Computer hardware and software

In the present study, De-scan scanner was used for scanning of the toposheets pertaining to the study area and saved as JPEG format and imported into Erdas software as *.img* format for further use. For digital image processing and analysis of Remote sensing data HP desktop having 4 GB RAM work station with ERDAS Imagine version 9.3 software was used. Geographic Information System (GIS) software, ARC GIS version 9.3 was used for mapping the processed image.

3.6. Delineation of the study area

Study area was delineated with the help of command area boundaries, the geo referenced topo sheet and distributaries map. The data pertaining to the command area was extracted as a subset for further processing. The procedure followed for geo referencing of 570₇, 570₈, 570₁₁, 570₁₂ toposheets presented as flow diagram in Fig 3.5 by using Erdas 9.3 software and merging of toposheets procedure followed are presented as flow diagram in Fig 3.6.

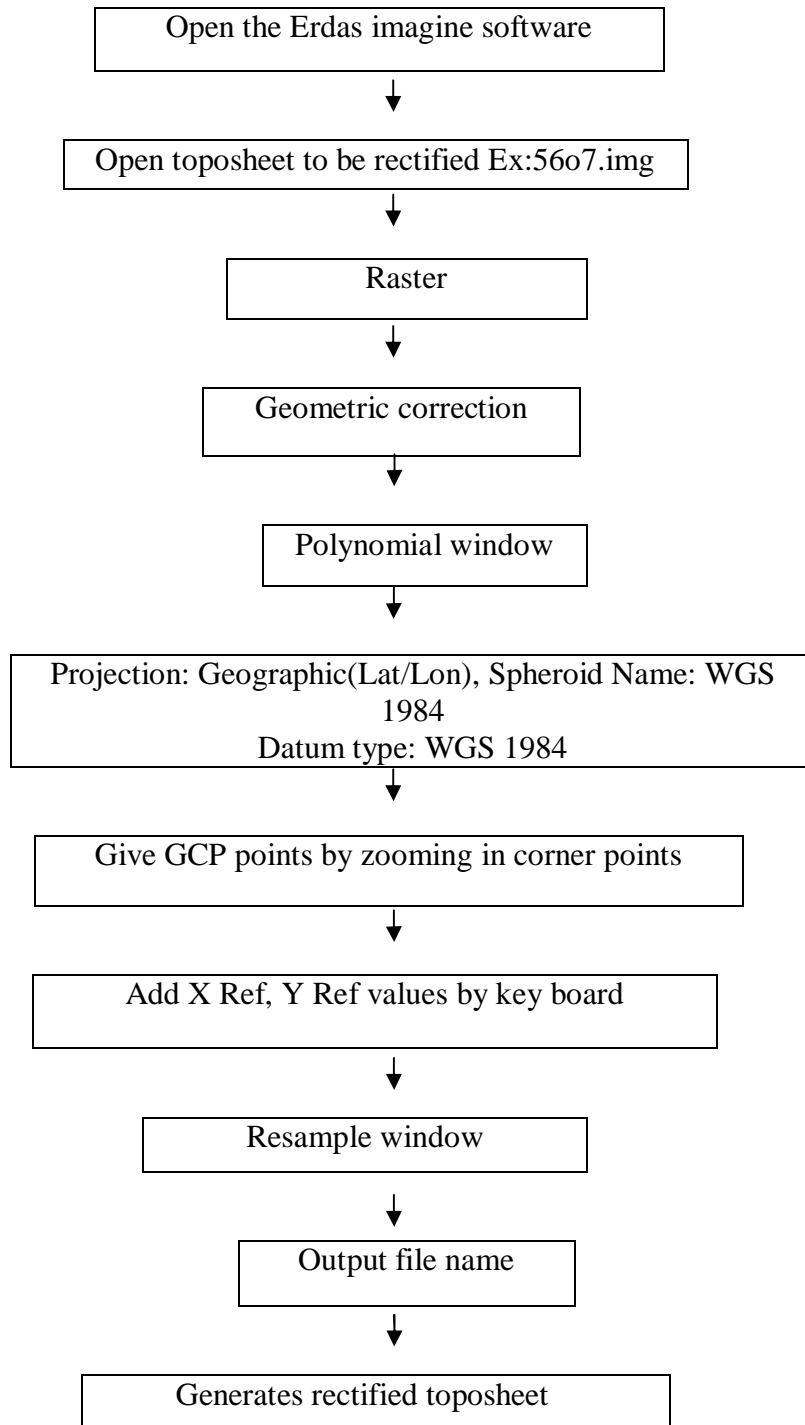


Fig: 3.5.Flow diagram of rectification of the toposheets in Erdas imagine 9.3.software

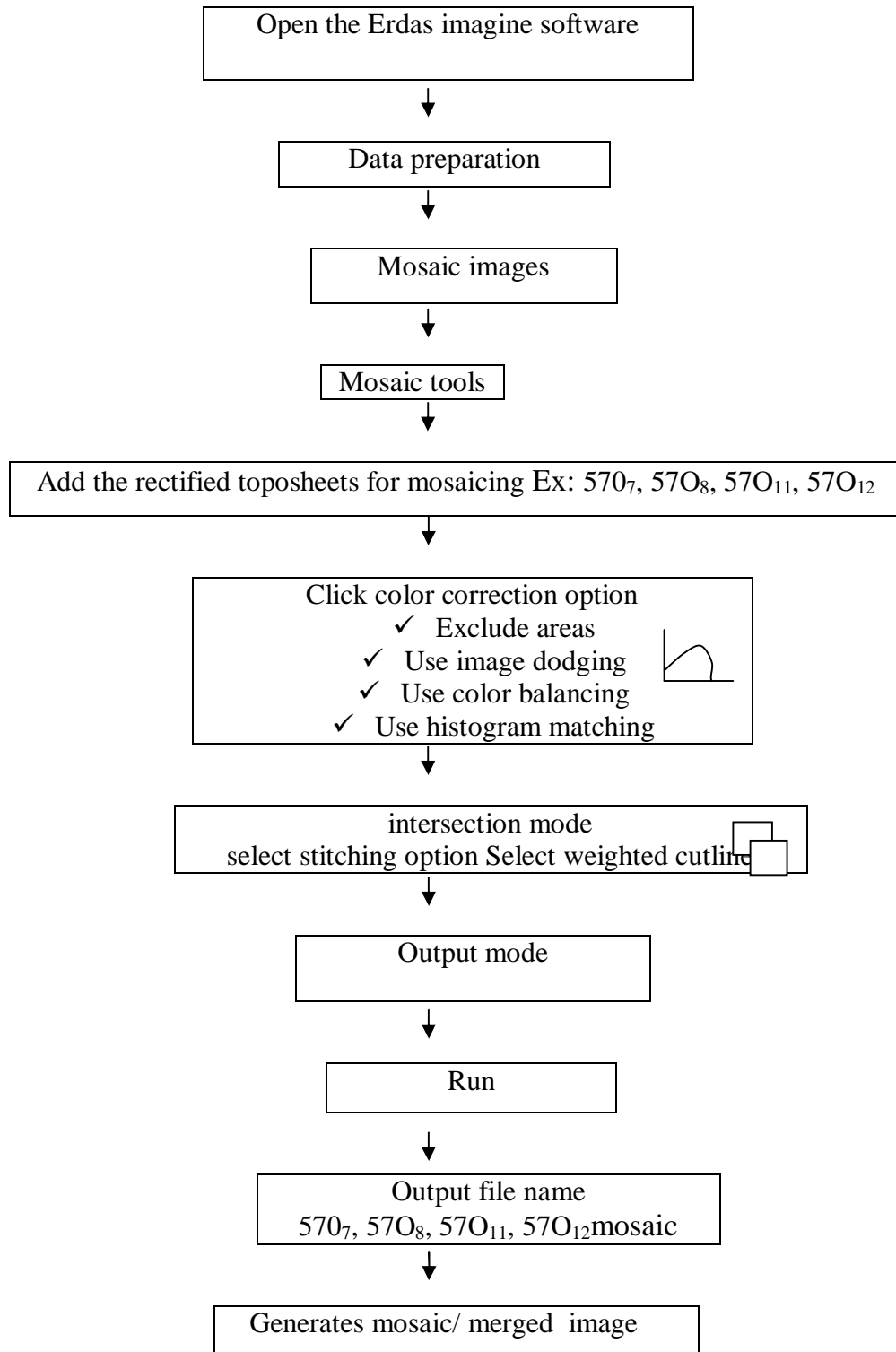


Fig: 3.6.Flow diagram of mosaicing (merging) of the toposheets in Erdas imagine 9.3.software

3.7. Preparation of study area boundary:

The study area boundary vector shape file has been generated as explained under flow diagram (Fig.3.6.) similarly vector layer showing the tanks in the study area was also created. The study area boundary overlaid on merged toposheets (570₇, 570₈, 570₁₁, 570₁₂) is presented in Fig.3.7

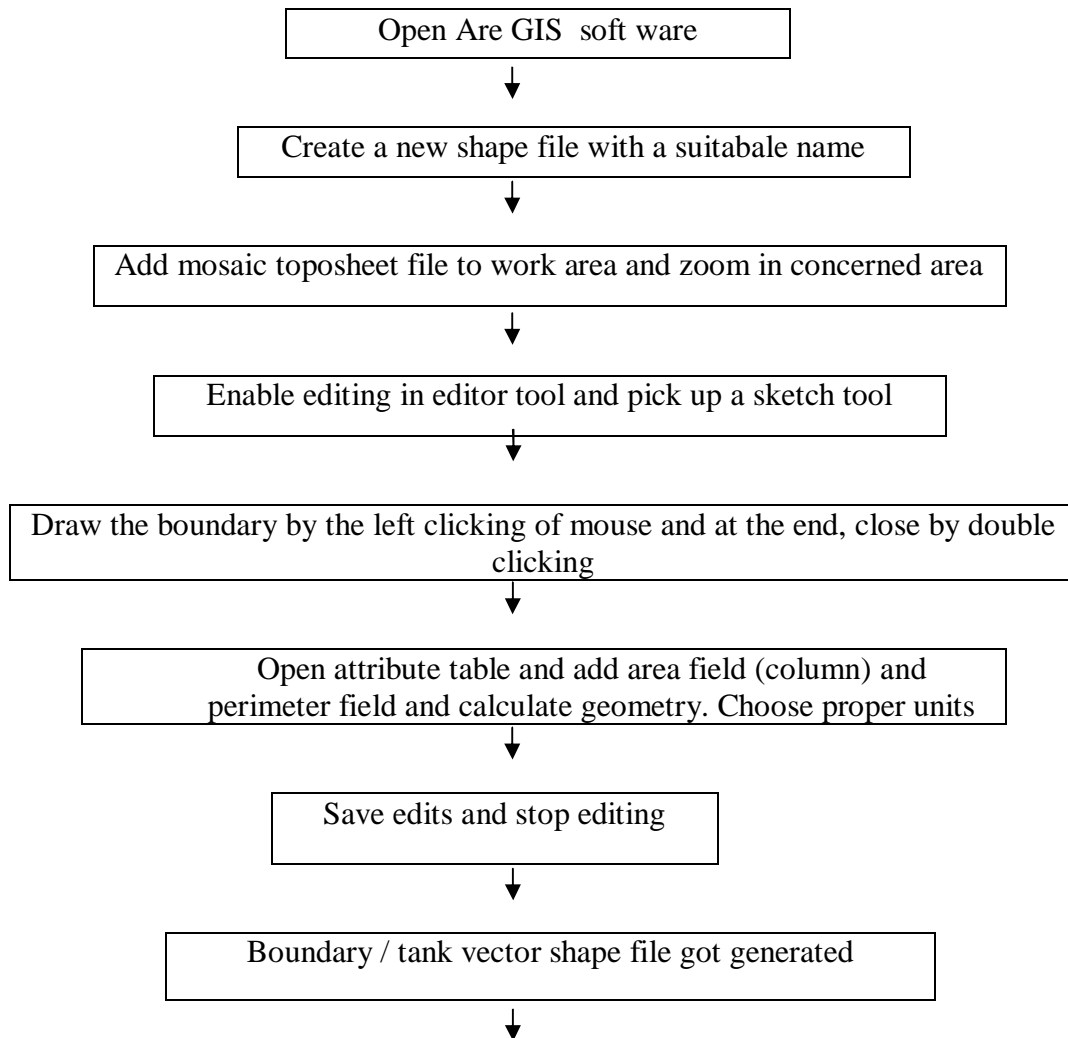


Fig: 3.7. Preparation of vector layer (shape file) of study area boundary, tanks etc. using Arc GIS

3.8. Ground truth data collection

3.8.1. Initially, preliminary survey of the command area was conducted by moving through the Right (41 km) and Left (39 km) main canals with collection of the GPS readings at each off take point of the distributaries from the main canal to know the number of working distributaries, their length and ayacut under cultivated under each distributaries. Information regarding crops and cropping systems followed in the command area was also collected by interviews with farmers.

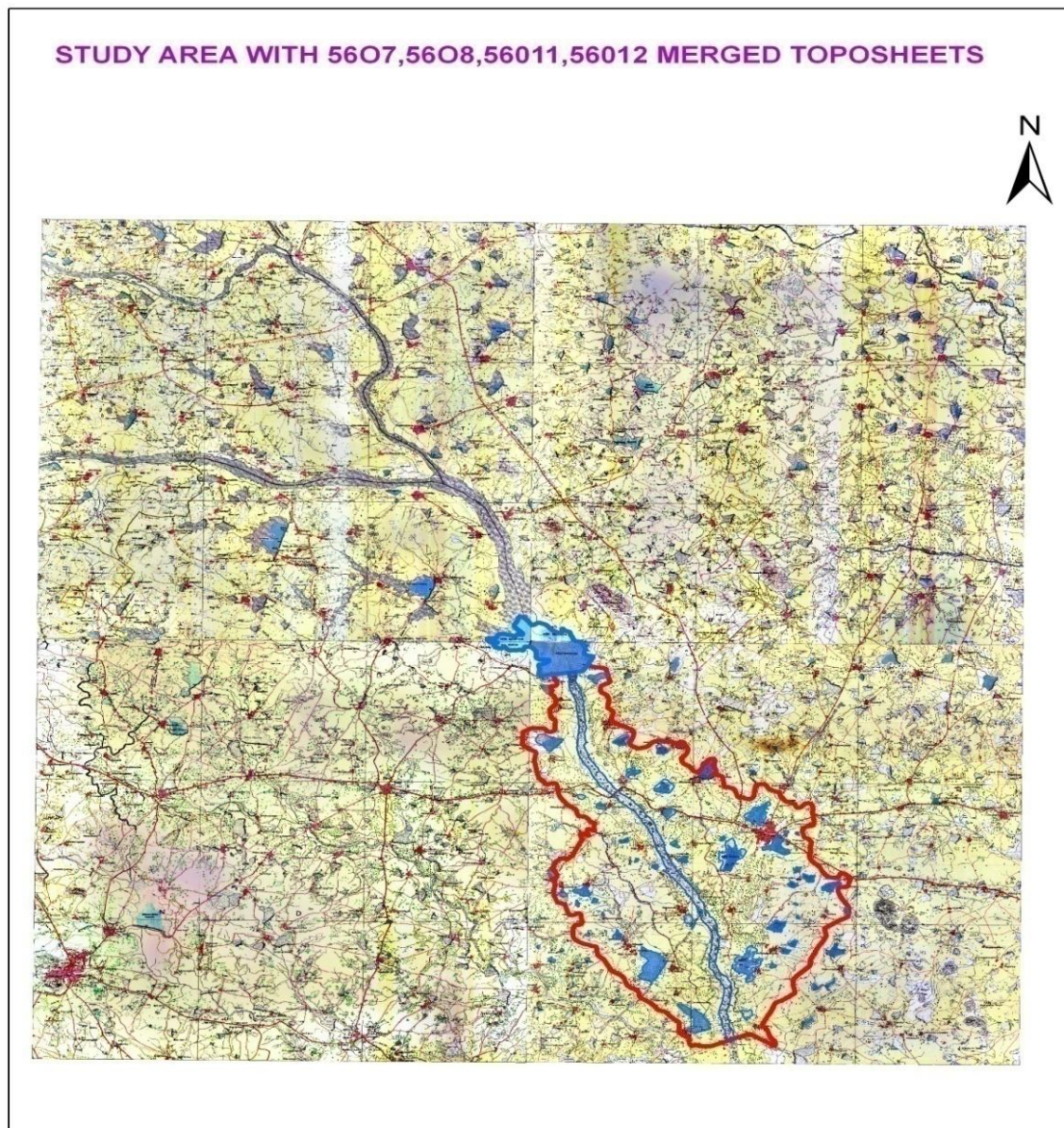


Fig: 3.8. Study area (Musi command area) with merged toposheets

3.8.2 Collection of Samples

3.8.2.1. Soil: Ninety five soil samples were collected from the farmers fields in the entire command area in the pre monsoon season (last week of June to first week of July) and thoroughly shade dried, sieved through 2 mm sieve. The details of farmers, villages added in Appendix.



Plate: 3.1. Collecting the Soil Samples in Musi Command Area of Nalgonda District

3.8.2.2. Water: Water sampling was carried out two times i.e. during pre monsoon and post monsoon water samples were collected in a clean stoppard polythene bottles after rinsing it with the same water 3-4 times and about 300 ml of the two samples for each was properly collected and labeled. While collecting water sample, the GPS readings at each off take point of the distributaries from the main canal were noted. The ground water samples (open well-28, bore weel-23) and canal water samples (leakage water-6) were collected in pre monsoon period (month June, 2011). In post monsoon period (month January,2012) canal water (49) and ground water samples (open well-23, bore well-13) were collected from the farmer fields. Information regarding crops and cropping systems followed in the command area was also collected.



Plate: 3.2. Variation in soil samples collected in Musi command area of Nalgonda district



Plate: 3.3. Collecting the ground water sample from open well



Plate: 3.4. Collection of Musi canal water in distributaries

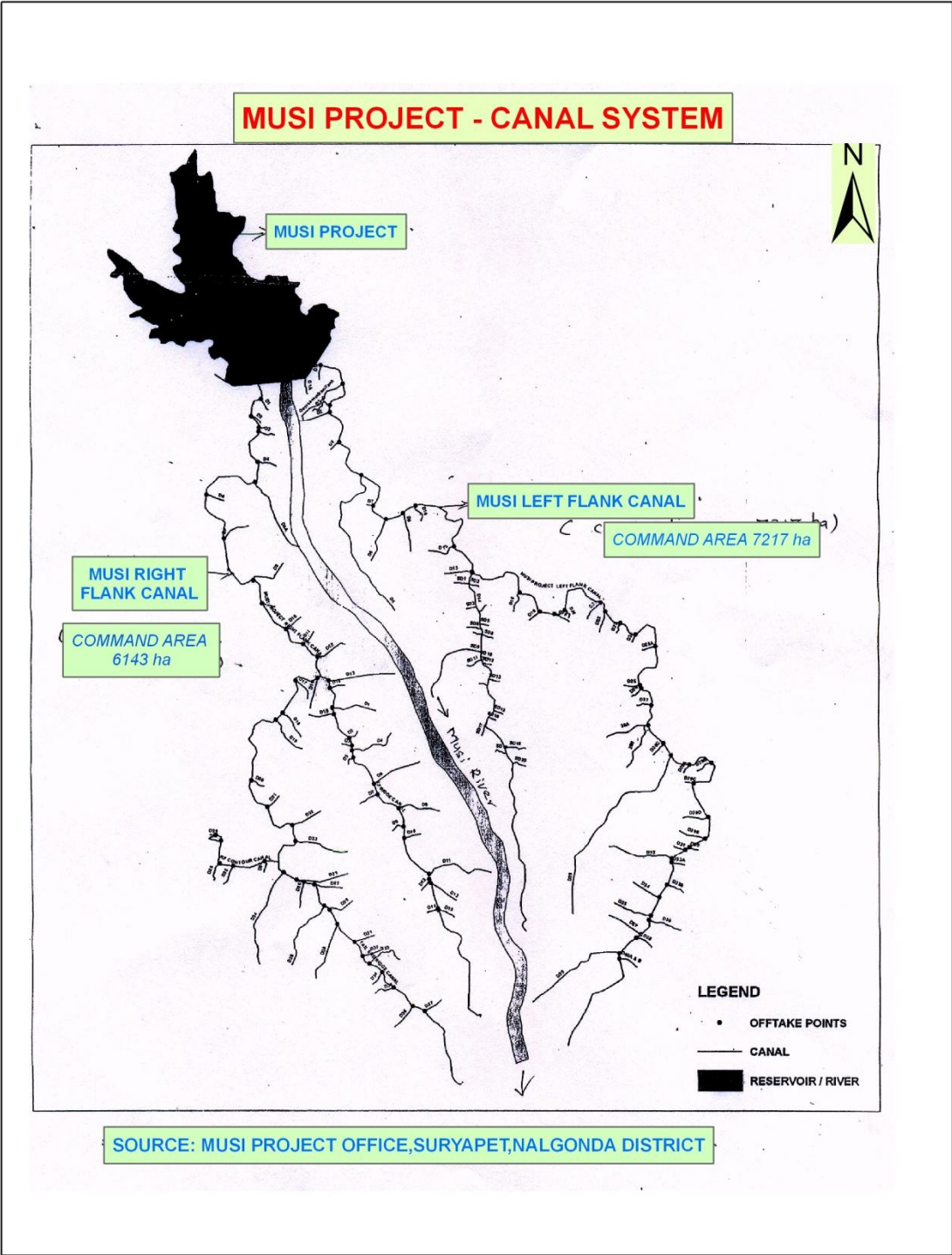


Fig: 3.4.Musi Project-canal network

3.9. Plants

Based on the preliminary information, collected from farmers location for crop cut experiments from rice grown areas in the entire command area was selected. The exact harvesting time of the rice crop was noted for planning the crop cutting experiments (CCE) and these were conducted in an area of 3×3 m (9m²) of selected points during harvesting season (April 2012). GPS reading of the site of CCE was also noted and the representative crop sample was harvested and threshed on the spot to note the fresh weight of the Paddy. Accordingly the dry weight of the paddy grain at 16 per cent moisture was calculated and expressed the grain yield in kg ha⁻¹ the collected paddy. Grain and straw samples are oven dried and powdered for analysis of nutrient and heavy metals composition.



Plate: 3.5.Crop cut experiment in Musi command area

3.10. Preparation of point map:

The location of samples sites of soil, canal and ground water (open well and bore well) all were collected in study area by using a hand held GPS instrument GARMIN **GPS72H** receiver. The GPS technology proved to be very useful for enhancing the spatial accuracy of the data integrated in the GIS.

The ArcGIS9.3 software was used in this study. Based on the location data obtained, prepared point feature showing the position of samples in MSexcel format and linked with the spatial data by join option in ArcMap. The spatial and the non-spatial

database developed bare integrated for the generation of spatial distribution maps of the water and soil quality parameters. The steps for generation of point map was using ArcGIS 9.3 indicated in flow diagram in fig 3.8 and the resultant map generated is presented in Fig 3.9.



Plate No: 3.6. Collecting the GPS locations

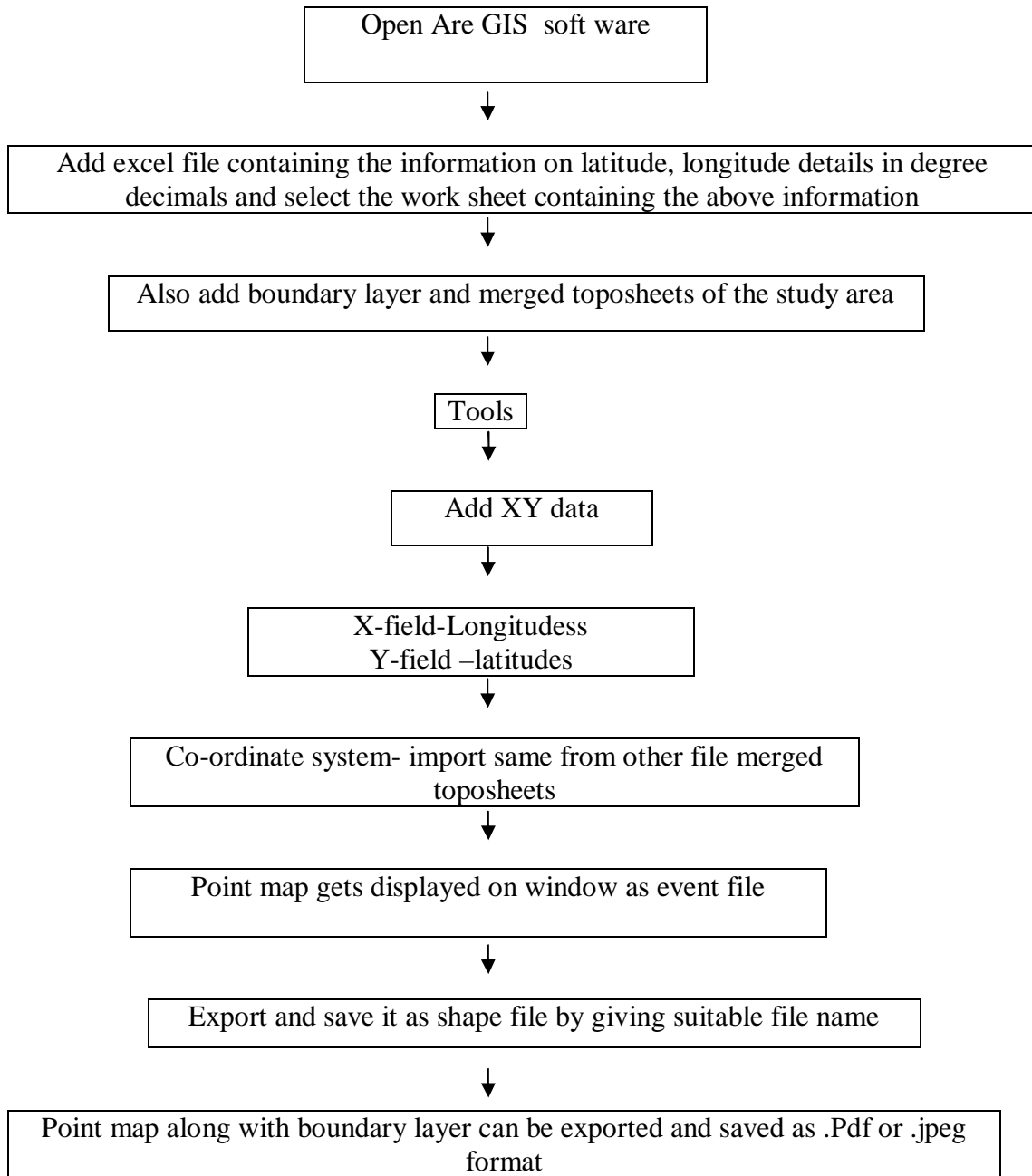


Fig: 3.9. Preparation of point map showing sampling sites using Arc GIS

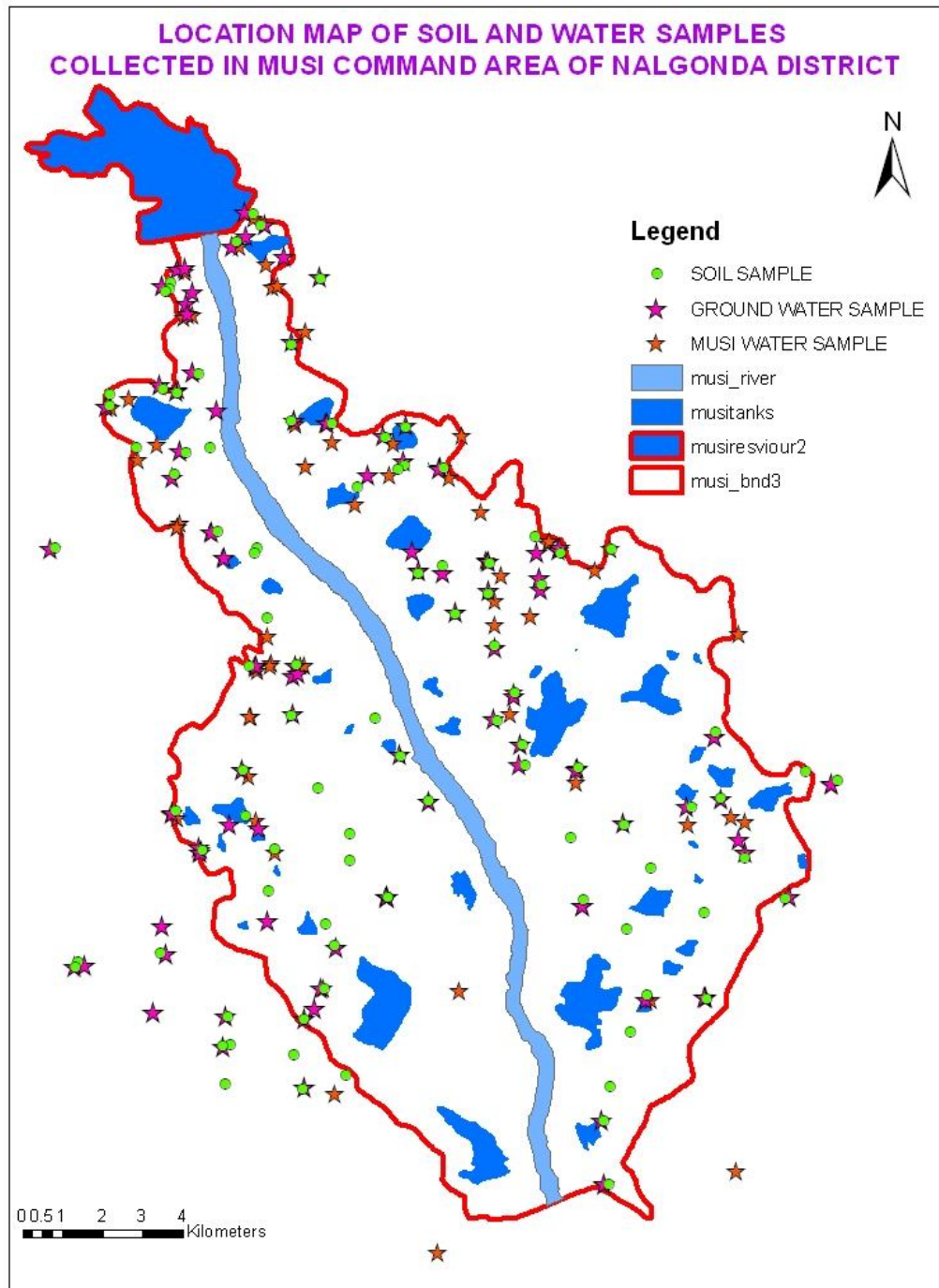


Fig: 3.10. Location map of soil ,water samples collected in Musi command area

(Note: Samples were also collected outside the boundary area also to facilitate map making perfectly in Arc GIS.)

3.11. Preparation of water quality and soil fertility maps using Arc GIS

Kriging is based on the presence of a spatial structure where observations close to each other are more alike than those that are far apart (spatial autocorrelation). In this method the experimental variogram measures the average degree of dissimilarity between un sampled values and a nearby data value and thus can depict autocorrelation at various distances. From analysis of the experimental variogram, a suitable model (for example spherical and exponential) is derived by using weighted least squares and the parameters.

Some advantages of this method are the incorporation of variable interdependence and the available error surface output. A disadvantage is that it requires substantially more computing and modeling time and Krigging requires more input from the user. In Arc GIS, the spline interpolation is a Radial Basis Function (RBF). These functions allow analysts to decide between smooth curves or tight straight edges between measured points. Advantages of splining functions are that they can generate sufficiently accurate surfaces from only a few sampled points and they retain small features. A disadvantage is that they may have different minimum and maximum values than the data set and the functions are sensitive to outliers due to the inclusion of the original data values at the sample points. The steps for krigging using Arc GIS 9.3 is presented as a flow diagram in Fig 3.10 after the map is prepared, it is clipped to the study area shape and final mapping was carried out as per the flow diagram given in Fig 3.10 and exported as *.jpeg* or *.pdf* format.

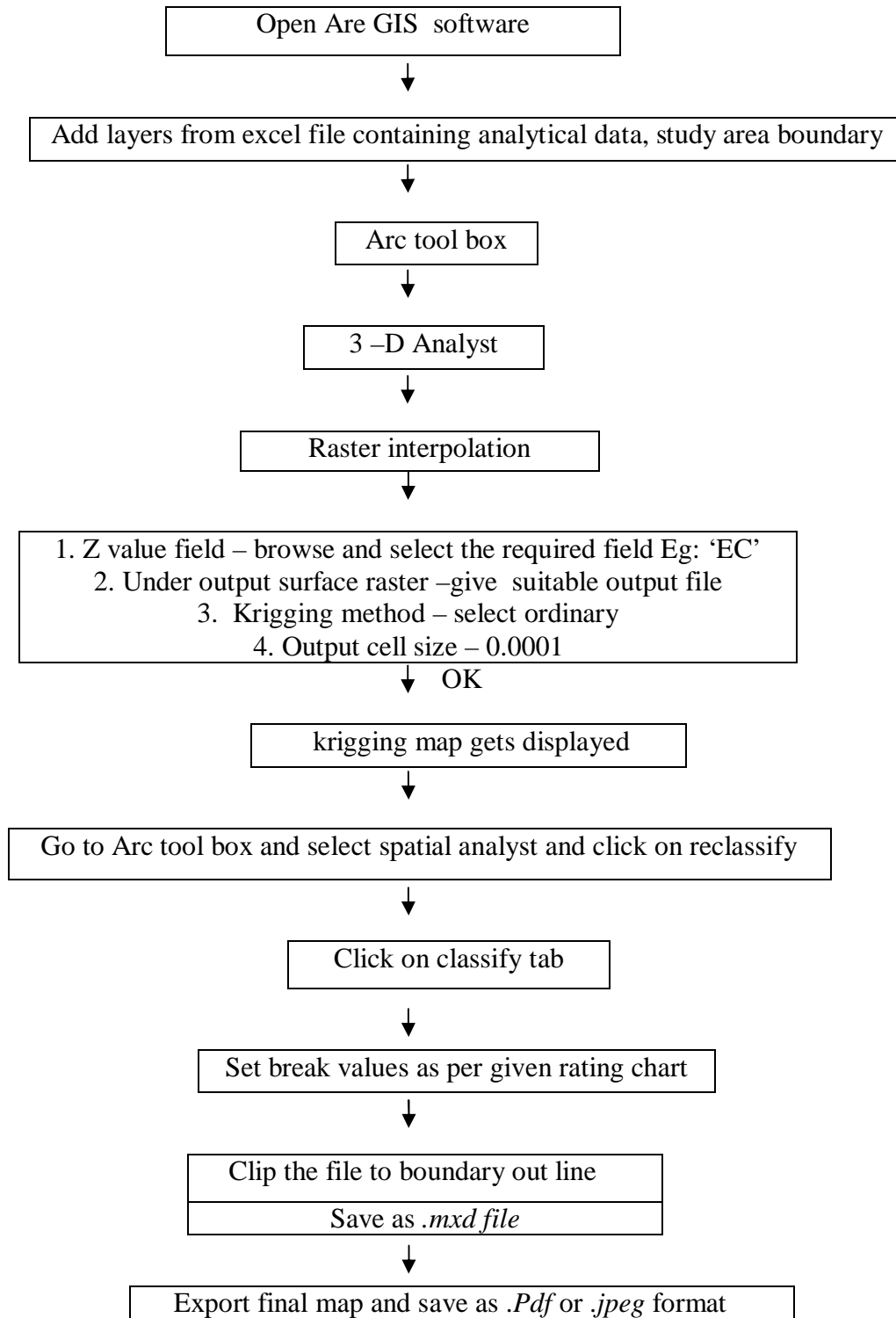


Fig: 3.11. Flow diagram showing methodology for generation of water quality / soil fertility map using kriging function in Arc GIS

3.12. Digital image analysis for generation of land use / land cover map

Initially the digital image (satellite) data were processed to transform it for improving the image contrast and to generate photo-products for subsequent interpretation. The standard monoscopic visual interpretation was employed to realize the objectives.

3.12.1. Land use land cover map of study area

The LISS-III of IRS-P6 image was imported with ERDAS IMAGINE 9.3 image analysis software. Initially the study area was identified and extracted in the datasets. Using map to image transformation algorithm, ground control points (GCPs) were identified both on LISS-III image as well as on the topographic map and the former was geo-referenced with a sub-pixel accuracy using polynomial transformation. Later on, the other data sets (satellite image) were registered to each other with sub-pixel accuracy and data was resampled using nearest neighborhood algorithm. Thus, all the data sets were brought to a common projection. The procedure followed for land use/ land cover map is presented as flow diagram in Fig.3.11. Using ground truth data collected during the sampling survey the spectral signatures details of ground truth data are presented in Fig.3.12

3.12.2. Accuracy assessment

3.12.2.1. Separability analysis of signature files: A measure of statistical separation between category response pattern was computed by module for all pairs of classes and presented in the form of matrix. The statistical parameter, used for this purpose is transformed divergence, a covariance weighted distance between category means. In general larger the transformed divergence, greater the statistical distance between training patterns and higher probability of correct classification of classes.

3.12.2.2. Confusion error matrix: One of the common means of expressing classification accuracy is the preparation of classification error matrix (error matrix).By using the ground truth information, a raster image of ground truth was prepared and used

for error analysis in final classified land cover maps. Error matrices compare on a category by category basis. The relationship between known reference data (ground truth) and the corresponding results of automated classification. These matrices are square, with the number of rows and columns equal to the number of crop classes, whose classification accuracy is being assessed. The error matrix tabulates the relationship between the true crop cover classes and classes mapped. It also tabulates error of omission (producer's accuracy) and error of commission (users' accuracy) as well as the overall proportional error.

Classification error matrix which is one of the most common means of expressing classification accuracy was prepared. The commission error and omission error were calculated by following the formulae as indicated below.

$$\text{Commission error} = \frac{\text{Total number of correctly classified pixels in row}}{\text{Total no of classified pixels in row}}$$

(Users accuracy)

$$\text{Omission error} = \frac{\text{Total number of correctly classified pixels in column}}{\text{Total no off classified pixels in column}}$$

(Producers accuracy)

Overall accuracy was computed by dividing the number of correctly classified pixels by number of reference pixels.

Another discrete multivariable technique for accuracy assessment is Kappa analysis (KHAT statistics) which is a basis for determining the statistical significance of the given matrix (or) the difference among the matrices (Lillisand and Kiefer, 2000).

$$\text{KHAT statistics is computed as } K = \frac{N \sum_{i=1}^r x_{ii} - \sum_{i=1}^r (x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+} \times x_{+i})}$$

K = Kappa co-efficient (KHAT statistics)

N = Total number of observations included in the error matrix

x_{i+} = Total of observations in row i (shown as marginal total to right of matrix)

x_{+i} = Total of observations in column i (shown as marginal total at bottom of the Matrix)

x_{ii} = Number of observations in row i and column i (on the major diagonal)

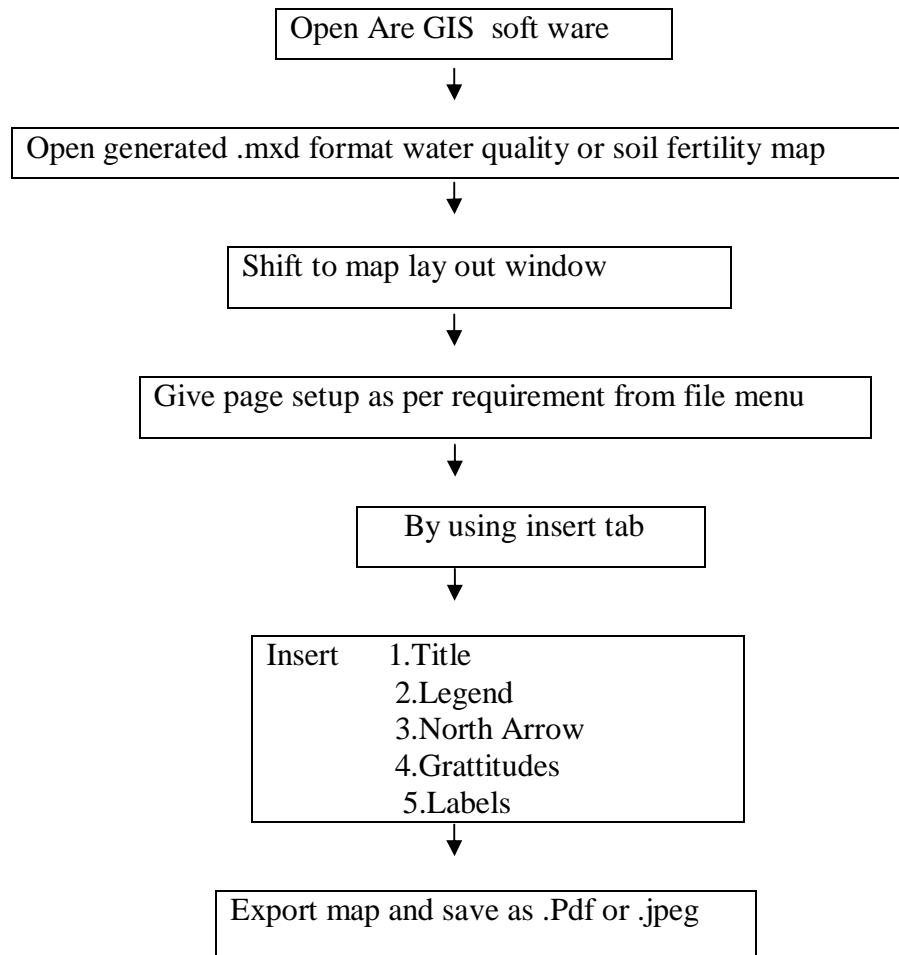


Fig: 3.13 .Flow diagram showing of map layout using Arc GIS

3.13. Characterization of water, soil and plant samples

The collected water, soil and paddy straw and grain samples were analyzed following the standard procedures indicated in the tables

Table: 3.2. Methods used for analysis of various elements in crop samples

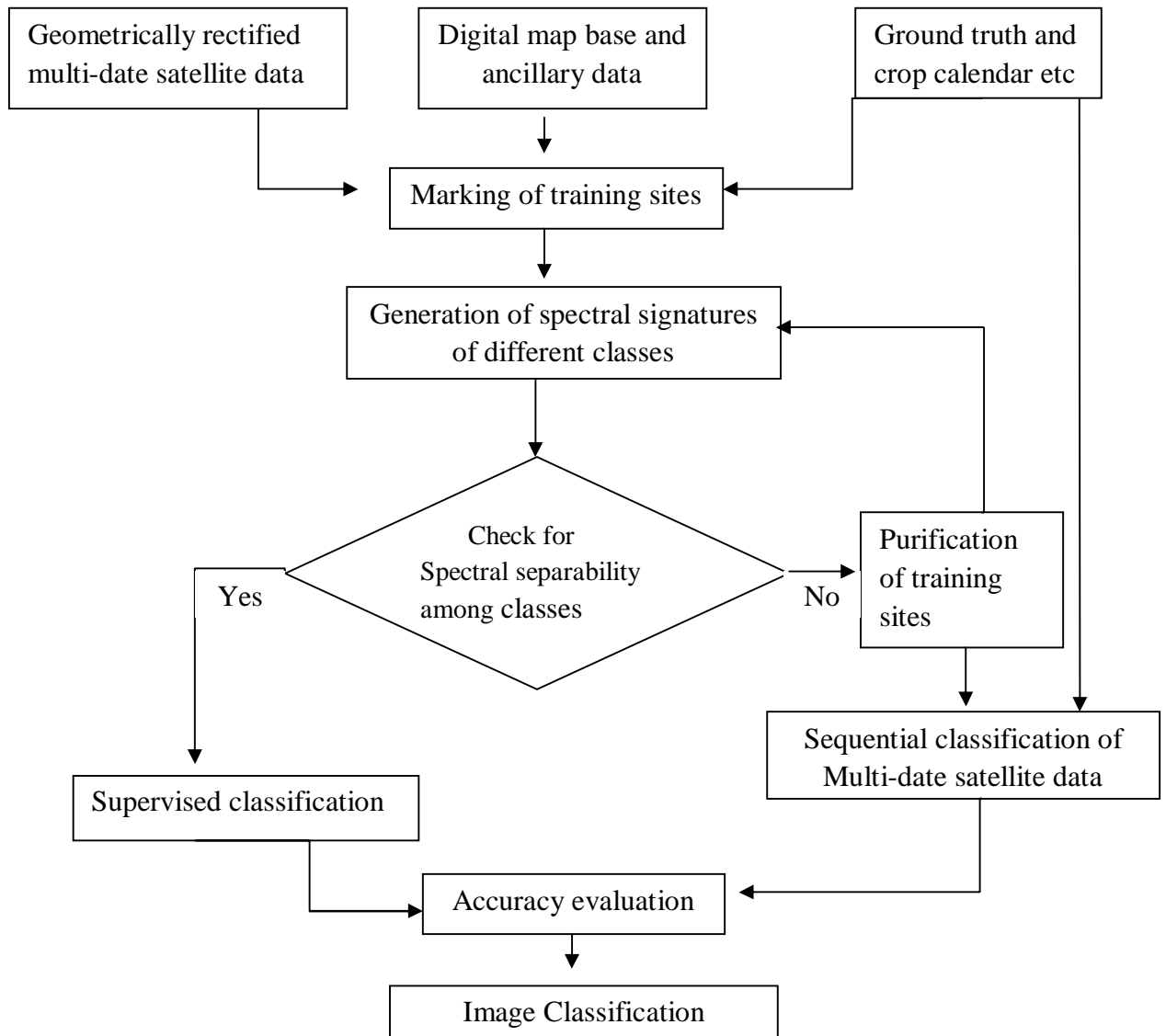
S.No.	Parameter	Method	Reference	Model
1	Total Nitrogen (%)	Kelplus- analyser distillation method by destroying the organic matter using H ₂ SO ₄ . Digestion: H ₂ SO ₄ and K ₂ SO ₄ + CuSO ₄ 1:4 ratio in Kelplus block digester.	Subbiah and Asija, 1956.	N-Kelplus-Supra Lx
2	Total Phosphorous (%)	Vanadomolybdophosporic yellow colour method with Bartons reagent. The intensity of the yellow colour was determined by using UV-VIS Spectrometer at 420 nm.	Piper, 1996.	Elico-Water Analyser-Pe-138
3	Total Potassium (%)	Di acid digest was determined by using flame photometer	Piper, 1996.	Elico-CI-361
4	Total Micronutrients and heavy metals (mg kg ¹)	Sequential extraction of micro nutrients ((Fe, Mn, Zn & Cu) and Heavy metals (Cd, Ni, Co,Cr & Pb) in di acid digest were determined by using Atomic Absorption Spectrophotometer and expressed as mg kg ⁻¹	Lindsay and Norwell, 1978.	Varain,AA-240

Table: 3.3.Methods used for analysis of different parameters in soil

S.No	Parameter	Principle of the method/ Instrument	Reference	Model
1.	Soil texture	Bouyoucous hydrometer	Piper, 1966.	-
2.	Soil reaction (pH)	Soil and water suspension (1:2) used in digital P ^H meter	Jackson, 1967.	Elico-Li612
3.	Electrical conductivity (dS m ⁻¹)	Soil and water suspension (1:2) filtrate used in digital conductivity bridge	Jackson, 1967.	Systronics-308
4.	Organic carbon (g kg ⁻¹)	Chromic acid wet digestion (Walkey and Black method)	Walkley and Black, 1934.	-
5.	Nitrogen (N) (kg N ha ⁻¹)	Alkaline permanganate method	Subbiah and Asija, 1956.	N-Kelplus-Supra Lx
6.	Phosphorus (kg P ha ⁻¹)	Olsen's extractant method, Ascorbic acid of estimation ,Spectrophotometer	Olsen and Watanabe, 1965.	Elico-Water Analyser – Pe-138
7.	Potassium (K) (kg K ha ⁻¹)	Neutral normal ammonium acetate in 1:5 ratio, Flame photometer	Tandon, 1999.	Elico-CI-361
8.	DTPA-extractable micronutrients (Zn, Cu, Mn and Fe) heavy metals. mg kg ⁻¹	DTPA+CaCl ₂ + TEA with P ^H adjusted to 7.3 using Atomic Absorption Spectrophotometer	Lindsay and Norwell, 1978.	Varian AA-240

Table: 3.4. Methods used for analysis of different parameters in water samples

S.No	Parameter	Unit	Principle of the method / Instrument	Reference	Model
1.	P ^H		Digital P ^H meter	Jackson, 1967.	Elico-Li612
2.	Electrical conductivity	dS m ⁻¹	Digital conductivity bridge	Jackson, 1967.	Systronics-308
3.	Carbonates (CO ₃ ⁻²)	me l ⁻¹	Titration with Std H ₂ SO ₄ using phenolphthalein as indicator	Tandon, 1999.	-----
4.	Bicarbonates (HCO ₃)	me l ⁻¹	Titration with Std H ₂ SO ₄ using methyl orange as indicator	Tandon, 1999.	-----
5.	Sodium (Na)	me l ⁻¹	Flame photometer	Tandon, 1999.	Elico-CI-361
6.	Calcium and Magnesium	me l ⁻¹	Titration with versinate solution using mixed indicator	Tandon, 1999.	-----
7.	Chlorides (Cl ⁻¹)	mg l ⁻¹	Titration with standard AgNO ₃ using K ₂ Cr ₂ O ₇ as indicator	Tandon, 1999.	-----
8.	Fluorides(F ⁻¹), Ammonia	mg l ⁻¹	Ion selective electrode meter method	Tandon, 1999.	Orion 4 Star Thermo Fischer
9.	Micro nutrients(Fe, Zn,Cu,Mn)and heavy metals(Cr,Co,Pb,Ni,Cd)	mg l ⁻¹	Atomic absorption spectro photo meter	Lindsay and Norwell, 1978.	Varian, AA 240



3.14. Flow diagram showing the preparation of land use land cover map in Erdas software.

3.14. Correlation

Correlation between yield (dependent variable) different water quality parameters (independent variable), Soil quality parameters and uptake of nutrients were carried out by using the procedure given by Gupta and Kapoor (1970).

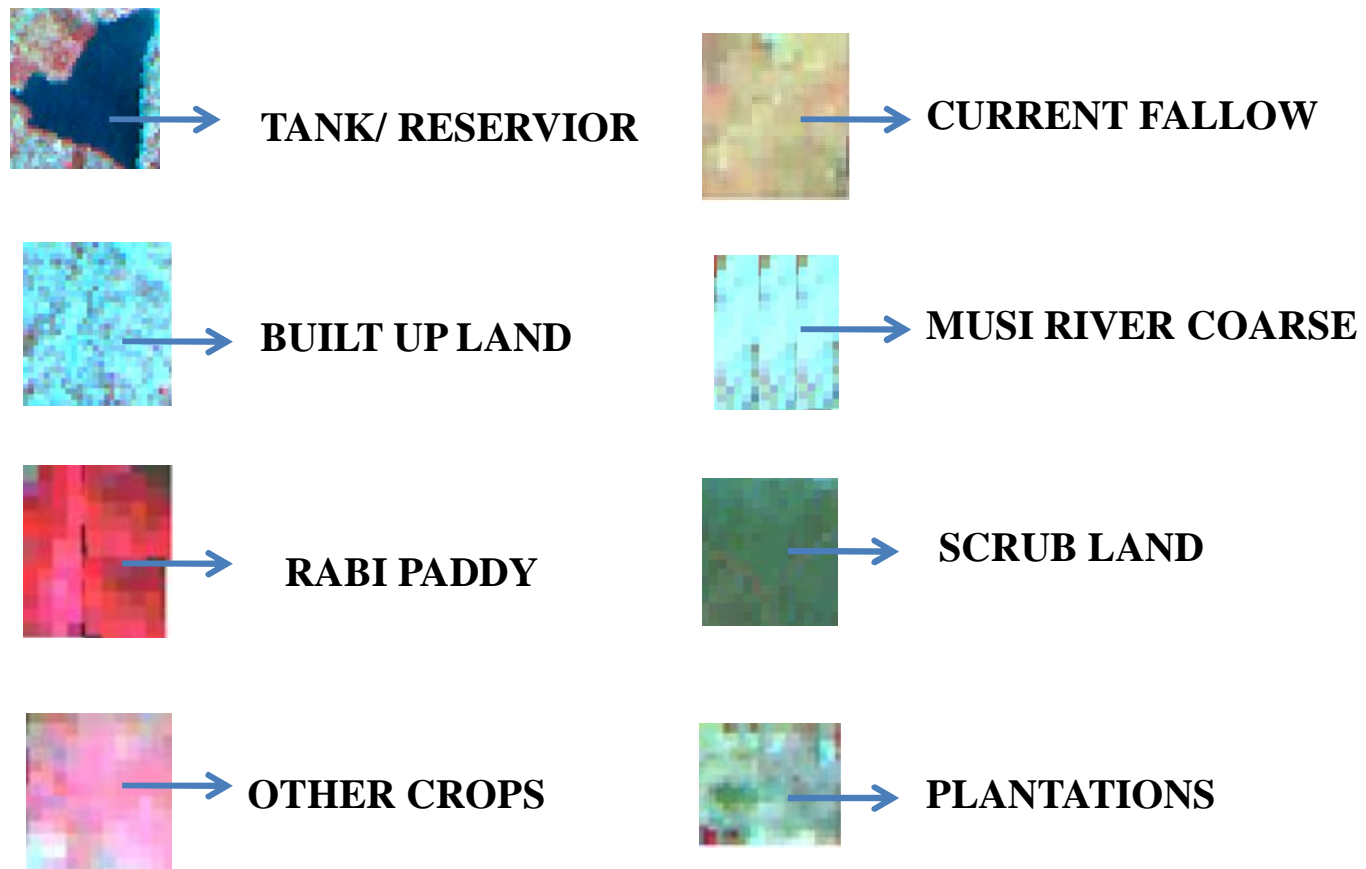


Fig: 3.12.Spectral signatures of satellite (IRS P-6, LISS-III) data in Musi command area of Nalgonda distirct

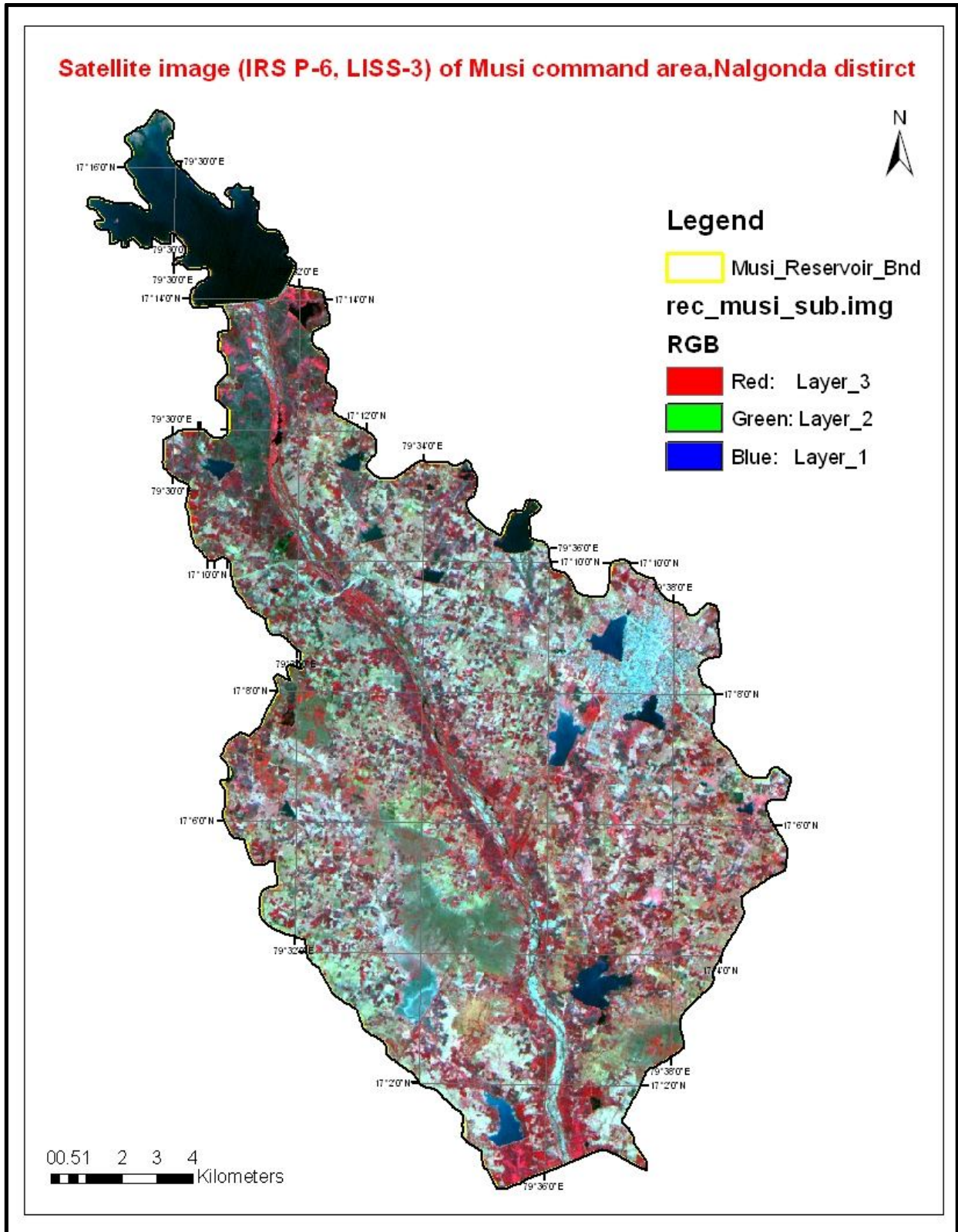


Fig: 3.3.Satellite image (IRS P-6, LISS III, Feb 6th) of Musi command area, Nalgonda district

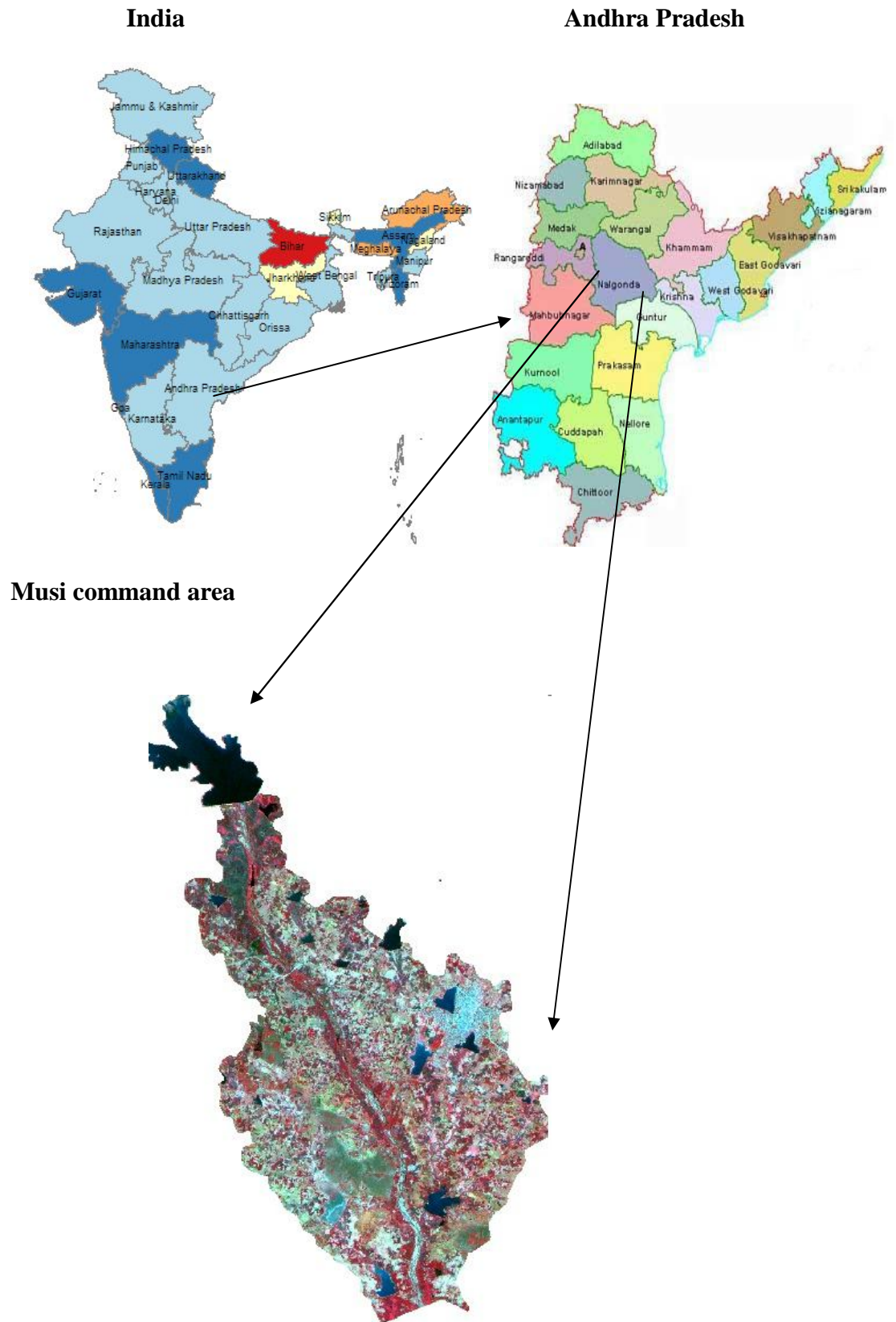


Fig.3.1 Location map of Musi command area, Nalgonda, district, Andhra Pradesh

Chapter IV

RESULTS AND DISCUSSION

The present study was conducted during 2011-12 in Musi project command area in Nalgonda district of Andhra Pradesh. The main objective is to characterize the Musi project canal water as well ground water (open wells and bore wells) and soils spread over in Musi command area and to map them by using GIS tools. In addition a land use / land cover map of Musi command area was also generated by using remote sensing and GIS tools to assess the current land use pattern. An attempt was made to record the rice yield variations in the entire command area by collecting crop cut data in selected farmer's fields. The results of the study are presented in this chapter.

4.1. Water quality in Musi command area

Water samples from three different sources viz., canal, bore wells and open wells, collected during two seasons i.e. pre (June, 2011) and post monsoon (January, 2012) were analysed for different quality parameters. They were pH, EC, $\text{CO}_3^{2-} + \text{HCO}_3^{-}$, Ca+ Mg, Na, Cl, F, B, Micro nutrients (Fe, Mn, Cu and Zn). The residual sodium carbonate (RSC) and sodium absorption ratio (SAR) were computed. Heavy metals (Cr, Co, Ni, Cd and Pb) were also analysed. The results obtained are presented in detail in Annexure III to VI, their ranges and means in Tables 4.1 to 4.3 and their spatial distribution maps generated are presented in Fig 4.2 to 4.7. The results were interpreted as per USDA Hand Book on Agriculture No. 60 for irrigation water quality parameters and FAO irrigation and drainage paper 47 for threshold levels of trace elements for crop production. The threshold levels followed for trace elements are 5 mg kg⁻¹ for Fe, 0.2 mg kg⁻¹ for Mn, 0.2 mg kg⁻¹ for Cu, 2.0 mg kg⁻¹ for Zn, 0.05 mg kg⁻¹ for Co, 0.10 mg kg⁻¹ for Cr, 0.2 mg kg⁻¹ for Ni, 0.01 mg kg⁻¹ for Cd and 5.0 mg kg⁻¹ for Pb.

4.1.1. Reaction (pH):

It was observed that alkalinity in all the three sources of water samples, increased during post monsoon period when compared to pre monsoon. (Table 4.1 and 4.2)

The pH of the canal water in pre monsoon season (June, 2011) varied from 8.02 to 8.70 with overall mean of 8.49. During post monsoon season (January, 2012) it varied from 8.08 to

8.86 with overall mean of 8.67. All the collected samples were alkaline in nature. The mean pH of post monsoon period slightly increased from 8.49 to 8.67.

The pH of the bore well water in pre monsoon season varied from 6.81 to 8.40 with overall mean of 8.28 and in post monsoon season varied from 7.31 to 8.79 with over all mean of 7.54. During pre monsoon about 61 per cent of samples were in alkaline range whereas by post monsoon season, it increased to 93 per cent. During pre monsoon, about 39% of samples were in neutral range which got reduced to 7 per cent by post monsoon period.

The pH of the open well water during pre monsoon season varied from 6.84 to 8.13 with overall mean of 7.52 and in post monsoon season varied from 7.79 to 8.97 with over all mean of 8.278. When, during pre monsoon season, 52 per cent samples were neutral and 48 per cent were alkaline, during post monsoon season all the samples were alkaline.

Alkalinity can be caused due to the weathering of carbonate rocks in the river catchment (Deepa *et al.* 2007). The rain fall received during 2011 is nearly 25 to 30 % less than normal years in Musi catchment and command area, which might have caused increase in alkalinity during post monsoon samples when compared to pre monsoon samples. Buechler and Gayathri Devi (2005) reported that pH of the pre-monsoon water quality samples from the Musi river in the urban, peri-urban and rural research sites was higher than those recommended by the FAO guidelines. Rajesh *et al.* (2012) reported that the pH of the groundwater samples of Nalgonda area ranged from 6.9 to 7.8. Thus groundwater of this area is generally alkaline in nature.

4.1.2 Salinity hazard

4.1.2.1 Electrical conductivity (dS m^{-1}): The EC (Table 4.1 and 4.2) of the pre monsoon canal water varied from 1.61 dS m^{-1} to 1.86 dS m^{-1} with overall mean value of 1.75 dS m^{-1} . During post monsoon, it varied from 1.41 dS m^{-1} to 2.53 dS m^{-1} with overall mean value of 1.52 dS m^{-1} . All the samples collected were under C3 (EC 0.75 to 2.25 dS m^{-1}) class (doubtful) during both the seasons. Sample collected from Dasaram tank under right flank (RF) canal is in C4 ($>2.25 \text{ dS m}^{-1}$) class (not useful). The EC of the Musi river water indicated that it can be used for irrigation with restrictions.

The EC of the bore well waters collected during pre monsoon varied from 1.48 to 2.80 dS m^{-1} with overall mean of 1.93 dS m^{-1} and in post monsoon season varied from 1.35 to 2.94

dS m⁻¹ with over all mean of 1.84 dS m⁻¹. It was observed that during pre monsoon 92 per cent of the samples collected were under C3 category, which got reduced to 31 per cent during post monsoon. Whereas 8 per cent of samples under C4 category during pre monsoon changed to 69 per cent during post monsoon indicating the deterioration of water quality during post monsoon when compared to pre monsoon.

The EC of the open well water collected in pre monsoon season varied from 1.28 to 5.36 dS m⁻¹ with overall mean value of 2.019 dS m⁻¹ and in post monsoon season varied from 1.43 to 3.57 dS m⁻¹ with over all mean of 1.98 dS m⁻¹. Among the collected samples, during pre monsoon 81 per cent of the samples were in C3 category which changed to 78 per cent during post monsoon. Where as 19 % of the samples during pre monsoon were under C4 category changed to 22 % by post monsoon.

During pre monsoon season, it was observed that water in the open wells got accumulated due to no / less usage as there was no crop in the fields due to summer and the ground water levels were very shallow (within 2 to 3 m depth) due to recharge of well waters with *rabi* 2010-11 released Musi canal water seepage. Where as, water levels gone down relatively by post monsoon due to non release of Musi canal in time during *rabi* 2011-12 due to shortage of rains and hence more usage of well waters for paddy or other crops.

Buechler and Gayathri devi (2005) reported that the pre-monsoon water quality samples from the Musi river were taken in the urban, peri-urban and rural research, EC and TDS values were higher than those recommended by the FAO guidelines. Priyanie amerasinghe *et al.* (2006) also shown the same results along a 40 km stretch of the Musi River, EC levels (1272.1 – 1672.4 $\mu\text{S cm}^{-1}$) increased. High EC levels downstream could be due to evaporative water level of significances, and run-off from agricultural fields with high levels of chemical fertilizers.

There is increased in the EC of bore well water samples due to release of canal water having high salts and ions may leads to increase in the EC. In general, the evaporation process would cause an increase in concentration of all mineral species in water in post monsoon season. The high concentration of salts as indicated by high EC in sewage water adversely effect germination and growth of crop plants (Ramesh, 2003).

Rajesh *et.al*, 2012 reported that the general order of dominance of cations in the groundwater of the study area are Na^+ , Ca^{+2} , Mg^{2+} , K^+ while that for anions is HCO_3^- , SO_4^{-2} , Cl^- , CO_3^{3-} Ca-HCO₃, Na-Cl, Ca-Na-HCO₃ and Ca-Mg-Cl.

4.1.3 Sodium hazard

4.1.3.1 Sodium Absorption Ratio (SAR): The SAR (Table 4.1 and 4.2) of the pre monsoon canal water of Musi command area varied from 2.67 to 4.30 with overall mean of 3.586. During post monsoon it varied from 1.19 to 5.45 with overall mean value of 2.87. All the samples during both the seasons are under S1 category (low Na hazard). The overall mean decreased from 3.586 during pre monsoon to 2.870 during post monsoon.

The SAR of bore wells during pre monsoon ranged from 2.11 to 5.30 with overall mean of 2.78 and in post monsoon season varied from 0.13 to 5.01 with overall mean of 3.03. Here also all the samples during both the seasons are under S1 category (low Na hazard).

The SAR of the open well water collected in pre monsoon season of Musi command area varied from 1.20 to 11.70 with overall mean value of 3.535 and in post monsoon season varied from 0.19 to 4.22 with overall mean of 2.713. During the pre monsoon except 4% of samples all the rest of the samples were in S1 category and during post monsoon all the samples were observed to be under S1 category. In case of open wells, higher SAR values during pre monsoon were observed because the water got accumulated due to less usage which on storage resulted in dropping of water quality. Whereas during post monsoon, due to non release of Musi canal in time due to water shortage, the open wells were put to use and there is an improvement in water quality due to usage which is reflected in improvement of SAR of water from June, 2011 to January, 2012.

4.1.4 Bicarbonate hazard

4.1.4.1. Residual Sodium Carbonate: It is another alternative measure of the sodium content in relation with Ca and Mg. Bicarbonate and carbonate ions combined with calcium or magnesium will precipitate as calcium carbonate (CaCO_3) or magnesium carbonate (MgCO_3) when the soil solution concentrates in drying conditions. The concentration of Ca and Mg decreases relative to sodium and the SAR index will be bigger. This will cause an alkalizing effect and increase the

pH. Therefore when a water analysis indicates high pH level, it may be a sign of a high content of carbonate and bicarbonates ions.

The residual sodium carbonate (RSC) content of canal water (Table 4.1 and 4.2) during pre-monsoon period were in the range of -8.4 to 0.4 me l⁻¹ with a mean of -2.1 me l⁻¹ and in post-monsoon period were in the range of -4.6 to 4.4 me l⁻¹ with a mean value of -0.13 me l⁻¹. All the samples were in safe category (<1.25 me l⁻¹) during pre monsoon, which got reduced to 79 (%) under safe, and the rest were distributed under moderate (1.25 to 2.50 me l⁻¹) (17%) and unsafe category (>2.5 me l⁻¹). The spatial distribution of RSC in Musi command area are presented in Fig 4.4.

The RSC of the bore well water during pre monsoon season varied from -14.6 to 9.0 me l⁻¹ with overall mean value of -3.36 me l⁻¹ and in post monsoon season varied from -11.0 to 1.4 me l⁻¹ with over all mean of -3.364 me l⁻¹ (Table 4.4 and 4.6). Among the samples collected, during pre monsoon period, 83 % of samples were in safe category and 17 % were moderate. During post monsoon period, all the samples were in safe category. There is an improvement in water quality of bore well water samples from pre monsoon to post monsoon.

The RSC of the open well waters pre monsoon varied from -28.2 to 11.7 with overall mean value of -4.069 and in post monsoon season varied from -15.0 to 2.2 with over all mean of -3.364. During pre monsoon 90 % were safe and 10 % were unsafe and in post monsoon season, 83 % were safe and 17 % were moderate. Darvishi *et al.* (2010) reported that RSC varied from traces to 1.2, (safe category).

4.1.5. Specific ions

4.1.5.1 Chlorides (Cl⁻) : The chloride content of canal waters (Table 4.1 and 4.2) samples during pre-monsoon were in the range of 8.4 to 10.0 me l⁻¹ with a mean value of 9.40 me l⁻¹ (Table 4.1) and in post-monsoon period were in the range of 5.2 to 24 me l⁻¹ with a mean value of 9.71 me l⁻¹. Spatial distribution of chlorides in command area are presented in Fig 4.7. All the samples were in slight to moderate category (4-10 me l⁻¹) during pre monsoon but during post monsoon, 70 % of the samples were in slight to moderate category and rest (30%) were under unsafe (>10 me l⁻¹) category.

The chlorides content of bore well water samples during pre-monsoon period was in the range of 6.8 to 22.0 me l⁻¹ with a mean value of 12.54 me l⁻¹ and in post-monsoon period were in the range of 6.8 to 22.8 me l⁻¹ with a mean value of 11.90 me l⁻¹. During pre monsoon season when 54 per cent were under light to moderate and 46 per cent under unsafe category, during post monsoon season samples under slight to moderate category decreased to 36 % and under unsafe category increased to 64%..

In open wells, during pre monsoon chlorides ranged from 6.8 to 25.2 me l⁻¹ with a mean of 12.359 me l⁻¹. During post monsoon, it ranged from 9.20 to 29.6 me l⁻¹, with a mean of 14.62 me l⁻¹. During pre monsoon, about 34 % of samples were under slight to moderate category with 66 % of samples under unsafe category. Even during post monsoon also same trend followed. Shanthi *et al.* (2002) reported that the higher concentration of chlorides is considered to be an indicator of pollution due to higher animal waste.

4.1.5.2 Fluorides (F): All the water samples from three sources (canal, bore well and open well) during both the seasons (pre and post monsoon) were under safe category (< 1.0 mg l⁻¹). In canal waters during pre-monsoon period it ranged from 0.24 to 0.30 me l⁻¹ with a mean of 0.26 me l⁻¹ and in post-monsoon period were in the range of 0.1 to 0.4 me l⁻¹ with a mean value of 0.29 me l⁻¹ (Table 4.1 and 4.2).

The fluorides of the bore well water collected in pre monsoon season varied from 0.026 to 0.95 (mg l⁻¹) with overall mean value of 0.26 (mg l⁻¹) and in post monsoon season varied from 0.1 to 0.7 (mg l⁻¹) with overall mean of 0.257 (mg l⁻¹)

The fluorides of the open well water during pre monsoon season varied from 0.064 to 1.2 (mg l⁻¹) with overall mean value of 0.33 (mg l⁻¹) and in post monsoon season varied from 0.1 to 0.7 (mg l⁻¹) with overall mean of 0.257 (mg l⁻¹). Usha Rani *et al.* (2007) expressed that although the fluoride in ground water is in safe range but it exists fairly abundantly in earth crust and can enter ground water by natural process.

4.1.5.3 Nitrates : The nitrates of the canal water varied from 2 to 6 mg l⁻¹ in pre monsoon period with an overall mean of 5 (mg l⁻¹) and in post monsoon period varied from 10 to 100 mg l⁻¹ with overall mean of 36.33 (Table 4.1 and 4.2) and the frequency distribution are presented in Fig 4.3 and 4.6. Among all the samples, during pre monsoon, 33 % were under safe category (< 5 mg NO₃ l⁻¹) and 67 % were under slight to moderate (5 – 30 mg NO₃ l⁻¹) and in post monsoon

period they were 62 per cent under slight to moderate but 33 % under unsafe ($> 30 \text{ mg NO}_3 \text{ l}^{-1}$) category.

The nitrates of the bore well waters during pre monsoon season varied from 4 to 9 (mg l^{-1}) with overall mean value of 5.79 (mg l^{-1}) and in post monsoon season varied from 20 to 100 (mg l^{-1}) with over all mean of 35.71 (mg l^{-1}). During pre monsoon season 17 per cent were safe, 83 per cent were under slight to moderate and during post monsoon 57 per cent are slight to moderate and 43 per cent were unsafe.

The nitrates of the open well water collected during pre monsoon varied from 4 to 8 (mg l^{-1}) with overall mean of 5.207 (mg l^{-1}) and in post monsoon season varied from 20 to 300 mg l^{-1} with over all mean of 47.91 mg l^{-1} . During pre monsoon season 28 % were under safe and 72 % were under slight to moderate and during post monsoon season 55 % were under slight to moderate and 45 per cent were unsafe.

Yadav *et al.* (2003) reported that due to lesser nitrification, high amounts of nitrates in winter (January) and during summer (May) lesser amounts due to higher nitrification.

4.1.5.4 Ammonia: In all the three sources of water during both the seasons, the ammonia contents were in safe limits ($< 1.44 \text{ mg l}^{-1}$). In canal waters it varied from 0.05 to 0.08 (mg l^{-1}) during pre monsoon period with an overall mean of 0.165 (mg l^{-1}) and in post monsoon, varied from 0.01 to 0.7 (mg l^{-1}) with a mean of 0.07 mg l^{-1} . (Table 4.1 and 4.2).

The ammonia of the bore wells during pre monsoon varied from 0.01 to 0.70 (mg l^{-1}) with a mean of 0.10 mg l^{-1} and in post monsoon season varied from 0.01 to 0.7 mg l^{-1} with over all mean of 0.3 mg l^{-1} . The ammonia of open wells during pre monsoon also varied from 0.01 to 0.70 (mg l^{-1}) with a mean of 0.10 mg l^{-1} and in post monsoon season varied from 0.01 to 0.7 mg l^{-1} with over all mean of 0.0971 mg l^{-1} .

4.1.5.5 Trace elements (Cu, Zn, Fe, Mn, Cr, Co, Ni, Cd and Pb):

Limited number of collected samples from canals, bore wells and open wells were analysed to know the trend with regard to the composition of different trace elements in Musi command area. The data in detail are presented in Annexure III to VI and their ranges and means in Table 4.3. For interpretation of the results, the phototoxic threshold levels presented in

FAO irrigation and drainage paper, 47 (1992) adopted from National Academy of Sciences (1972) and Pratt (1972) were followed.

The canal water samples collected during pre monsoon were safe with regard to Cu, Zn, Fe, Mn, Cr, Co and Pb. All the samples were found to contain unsafe levels of Ni and Cd. The Bopparam tank of the study area under Right Flank canal was found to contain higher amounts of Cu. The contents of Cu, Zn, Fe and Mn ranged from traces to 6.8, traces to 0.043, traces to 1.234 mg l⁻¹ and traces, respectively. The contents of Cr, Co, Ni, Cd and Pb varied from 0.005 to 0.017, 0.044 to 0.053, 0.477 to 0.479, 0.273 to 0.274 and 2.878 to 2.888 mg l⁻¹, respectively.

The canal water samples collected during post monsoon were safe with regard to Zn, Fe, Mn, Cr, and Pb. All the samples were found to contain unsafe levels of Ni and Cd. About 57 % of the samples collected were found to contain safe amounts of Cu and the rest (43 %) were having unsafe amounts of Cu. With regard to Co, 64 % of the collected samples were safe and the rest (36%) were unsafe. The contents of Cu, Zn, Fe and Mn ranged from traces to 32.72, 0.031 to 0.107, traces to 0.512 mg l⁻¹ and traces respectively. The contents of Cr, Co, Ni, Cd and Pb varied from 0.005 to 0.018, 0.036 to 0.47, 0.569 to 0.577, 0.278 to 0.281 and 2.892 to 2.911 mg l⁻¹ respectively.

Similar trends were noticed with regard to the water samples collected from bore wells and open wells collected during post monsoon. In bore wells, during post monsoon, the contents of Cu, Zn, Fe and Mn ranged from traces to 9.410, 0.031 to 0.107, traces to 0.512 mg l⁻¹ and traces respectively. The contents of Cr, Co, Ni, Cd and Pb varied from 0.003 to 0.07, 0.04 to 0.05, 0.47 to 0.577, 0.242 to 0.278 and 2.881 to 2.903 mg l⁻¹ respectively.

In open wells, during post monsoon, the contents of Cu, Zn, Fe and Mn ranged from traces to 15.24, 0.045 to 0.057 mg l⁻¹, traces, respectively. The contents of Cr, Co, Ni, Cd and Pb varied from 0.005 to 0.012, 0.039 to 0.063, 0.473 to 0.481, 0.274 to 0.276 and 2.868 to 2.900 mg l⁻¹ respectively.

In general, the geochemical processes and temporal variation of groundwater in this area (Nalgonda) are influenced by evaporation processes, ion exchange and dissolution of minerals. (Rajesh *et al.* 2012). Presence of higher amounts of trace elements like Ni and Cd indicating the pollution caused by the release of untreated industrial effluents in to Musi river during its course. Dixit *et al.* (2008) reported that Cu, Cr, Pb, Cd and Mn are present in relatively higher

concentrations as compared to their permissible limits. Rattan *et al.*(2005) undertaken the studied the long-term effect of sewage irrigation on heavy metal content in soils, plants and ground water peri-urban agricultural lands under Keshopur Effluent Irrigation Scheme (KEIS) of Delhi, India & results indicated that sewage effluents contained much higher amount of P, K, S, Zn, Cu, Fe, Mn and Ni compared to groundwater.

4.2. Surface Soil (0-15 cm) Characteristics of Musi command area

The soil properties viz., texture, pH, EC, organic carbon, available N,P,K, DTPA extractable micro nutrient elements like Fe, Mn, Cu, Zn, Pollutant elements like Co, Cr, Ni, Cd and Pb were estimated and presented in detail in Annexure VII, their ranges and means are presented in Table 4.6 and 4.7. The frequency distribution of samples falling under different categories are presented in Fig 4.10.

4.2.1. Soil Texture

Soil texture of Musi command area surface samples (0-15 cm) ranged from sandy loam to clayey (Table 4.4). Majority of the soils are sandy clay loam (70 %) followed by sandy loam (14%), sandy clay (7%), loamy (4%), clayey (3%) and clay loam (2%) (Fig 4.7). The overall means of sand, silt and clay contents were 61.88 per cent, 7.69 per cent and 30.42 per cent respectively. The clay soil particles deposited while irrigating the crops with Musi water might be responsible for the higher per centage of soils having relatively fine texture. Rattan *et al.* (2005) indicated that fields irrigated with sewage irrigation water around the peri urban areas of Keshopur Sewage Treatment Plant were sandy loam in texture.

4.2.2. Soil reaction (pH)

The pH of the surface soils of Musi command area varied from 6.78 to 9.15 with overall mean of 7.94, (Annexure VII, Table 4.6). Majority of the soil samples (55%) were moderately alkaline followed by slightly alkaline (29%), strongly alkaline (12%) and very less per centage of samples are in neutral range (4%) (Fig 4.6). The alkalinity of irrigation water in Musi command area (Musi canal / bore wells / open wells) might be responsible for the higher per centage of soils having alkalinity. Tiwari *et al.* (1996) observed that soils irrigated with treated sewage water had relatively higher pH (8.0) and alkaline in reaction as compared with soils irrigated with tube well water (7.5) at Banaras Hindu University, Varanasi, and U.P.

4.2.3. Electrical Conductivity (EC)

The electrical conductivity of the soils (Annexure) ranged from 0.112 dS m⁻¹ to 3.53 dS m⁻¹, with a mean value of 1.44 d S m⁻¹ (Annexure VII, Table 4.6). Majority of the soils (99%) are non saline and moderate salinity was noticed in only one per cent of soils (Fig 4.6). As paddy is the dominating crop grown in the study area which requires continuous water level in the fields, responsible for leaching of salts added by irrigation water (Musi canal / bore wells / open well) water and maintaining the total soluble salts content in the study area at relatively safer levels. However Tiwari *et al.* (1996) and Ramesh (2003) reported relatively higher total soluble contents in sewage water irrigated fields than soils irrigated with normal water.

4.2.4. Organic carbon (%)

Organic matter can also be expressed as the content of organic carbon in the soil. On an average, organic matter contains about 58% organic carbon. The organic carbon content of surface soils in Musi command area ranged from 12 to 31 g kg⁻¹ with overall mean value of 24.32 g kg⁻¹ (Annexure VII and Table 4.6). In the semi arid climatic conditions existing in the study area, it is expected low level of organic carbon contents. But the Musi canal water carrying sufficient loads of suspended organic matter might be responsible for higher organic carbon contents in the study area.

It was similar with the findings of Ramesh (2003), who reported higher organic carbon contents in soils irrigated with sewage water than with normal water. The increase in organic carbon content was due to continuous irrigation with waste water was largely confined to top soils. Kharche *et al.* (2011) who reported improvement in soil organic carbon content in the soils, improvement in total porosity and aggregate stability in the sewage irrigated soils due to addition of organic matter which plays an important role in improving soil physical environment. The organic carbon content of sewage-irrigated soils was high is ascribed due to the addition of organic matter through long-term application of sewage effluents.

4.2.5 Available Nitrogen

The available nitrogen content ranged from 53 to 205 kg N ha⁻¹ (Annexure VII, Table4.4) with overall mean value of 144 kg N ha⁻¹. All soil samples in the Musi command area are low in available nitrogen content which is expected in the existing semi arid climatic

conditions of the study area. The higher organic carbon contents recorded in the study area did not reflect in terms of available nitrogen which could be mainly attributed to higher rate of decomposition of organic matter under tropical climatic conditions. Azad *et al.* (1987) also reported that the normal soils contained very low amounts of available nitrogen in surface and subsurface layers. While soils fed with sewage waste water had low to medium available nitrogen in surface, subsurface layers of the soils of villages around 'Budha Nallah', Ludhiana.

4.2.6. Available Phosphorus

The available phosphorus content of surface soils of Musi command area ranged from 18.9 to 209.8 kg P ha⁻¹ with a mean value of 74.38 kg P ha⁻¹ (Annexure VII, Table 4.4). Majority of the soils are having high available P (96%) and only 4 per cent of soils are found to fall under medium category (Fig4.6). None of the soils are deficit in their available P status. High available phosphorus content could be ascribed to enrichment of soils with sewage canal water, heavy application of phosphatic fertilizers by farmers through complex fertilizers applied as basal as well as top dressing (25 to 230 kg P₂O₅ ha⁻¹ for paddy crop) and organic matter, which favours the solubilisation of fixed phosphorus releasing more quantity to the available pool.

Karache *et al.* (2011) also concluded that higher available P in sewage-irrigated soils indicating significant addition of P through sewage and suggested use of sewage water as a low grade cheap fertilizer in agriculture which can markedly reduce the cost due to substitution of chemical fertilizers.

4.2.7 Available Potassium

The available K content of surface soils of Musi command area ranged from 430 to 1298 kg K ha⁻¹ with a mean value of 521 kg K ha⁻¹ (Annexure VII and Table 4.4). The spatial distribution was depicted in figure 4.12. All the soils are found to be high to very high in available K status. Additions of potassium by Musi water could be responsible for such higher status of K in these soils. The results of high available potassium are in conformity with Priyanie amerasinghe *et al.* (2008) and Kharche *et al.* (2011). The available K status in these soils indicating the necessity of reducing the K fertilizer doses in the study area to all cultivated crops to reduce the cost of cultivation.

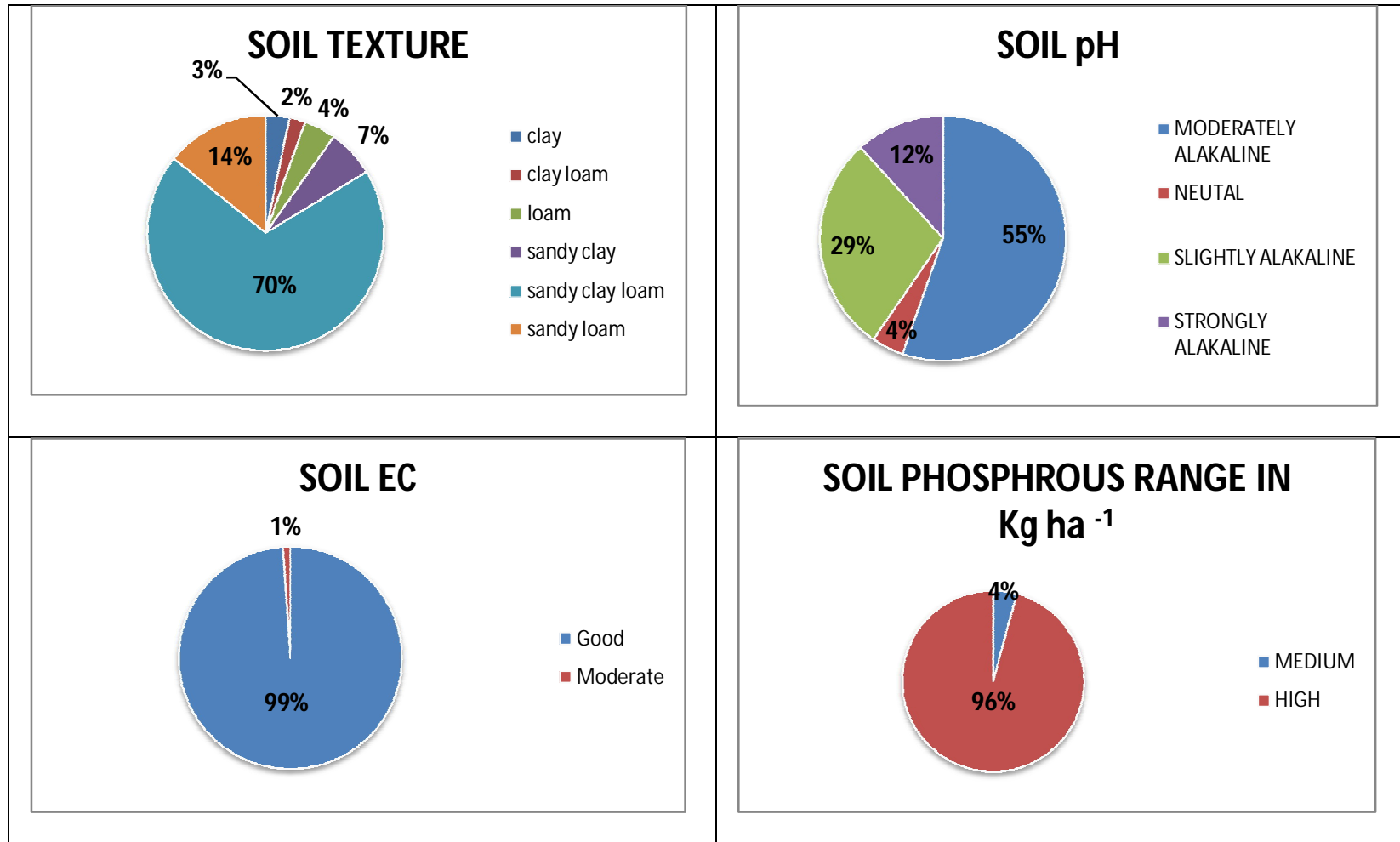


Fig:4.11.Frequency distribution of soil characteristics (0-15cm) in Musi command area of Nalgonda district during June,2011

4.2.8. Available micro nutrients

The DTPA extractable Fe, Mn, Cu and Zn were analysed in limited number of samples and their detailed results are presented in Annexure VII, their ranges and means in Table 4.5. The available Fe, Mn, Cu and Zn contents ranged from 1.4 to 33.4, 0.15 to 16.85, traces to 3.7 and 0.28 to 4.74 mg kg⁻¹ with mean values of 23.93, 11.39, 1.92 and 2.08 mg kg⁻¹ respectively. The critical values for Fe Mn, Cu and Zn were taken as 4.0, 2.0, 0.2 and 0.65 mg kg⁻¹ respectively (Bhupal Raj *et al.* 2009). It was observed that 100 per cent of samples were found to be sufficient in available Fe status. With regard to available Mn, 11 per cent of samples are found to be deficient and 89 per cent of samples were sufficient. With regard to Cu, 25 per cent of samples were deficient and 75 per cent of samples are sufficient. With regard to Zn, 22 per cent of samples are deficient and 88% of samples are sufficient.

Except four per cent of soils, all other soils were found to be alkaline in reaction ranging from slightly alkaline to strongly alkaline. Even higher levels of P and K were noticed, which also might be causing nutrient imbalances, for eq. higher P Vs lower Zn availability. As a result, these micronutrients are found to be less available and application of micronutrient mixtures (soil / foliar) is recommended in the study area, wherever these deficiencies are noticed. Application of liberal amounts of organic manures or green manuring will favour the solubility of these micro nutrients. In case of moderately and strongly alkaline soils, application of amendments like addition of suitable doses of gypsum will correct the soil reaction as well improve the availability of these micronutrients. Priyanie amerasinghe *et.al* (2008) reported reduced Zn bio-availability in soils with pH > 8.0. However, Simmons *et al.* (2006) reported that soils irrigated with sewage water for 20 years resulted into significant build-up of DTPA extractable Zn, Cu and Fe in sewage-irrigated soils over adjacent tube well water irrigated soils.

4.2.9. Availability of pollutant metals (Cr, Co, Ni, Cd and Pb)

The presence of heavy metals like Co, Cr, Ni, Cd and Pb will indicate the possible contamination of Musi water with urban industrialization. Limited number of samples were analysed for these parameters to understand the trend of these heavy metals in Musi command area. The detailed data are presented in Annexure VII, ranges and means in Table 4.5. The contents of Cr, Co, Ni, Cd and Pb in soils ranged from 0.04 to 0.118, 0.22 to 1.03, 0.96 to 1.521,

0.55 to 0.589 and 5.82 to 7.17 mg kg⁻¹ respectively. Their mean values were 0.068, 0.433, 1.195, 0.578 and 6.413 mg kg⁻¹ respectively. The critical limits for Cr, Co and Ni were taken as 2.0 mg kg⁻¹ and for Cd as 0.5 mg kg⁻¹ and for Pb as 5.0 mg kg⁻¹ (Chapman, 1975). It was noticed that all the samples were within permissible limits with regard to Cr, Co and Ni. But all the samples were having their Cd and Pb levels above the permissible limits.

Dikinya and Areola (2009) reported that favorable soil pH levels which range from slightly alkaline to slightly acidic, are probably serving as buffer against any heavy metal or trace element toxicity on the treated wastewater irrigated plots. Priyanie amerasinghe *et al.* 2008 reported that for those plots with total soil Cd and Pb exceeding or close to the EU MP (European Union maximum permissible) levels of metal concentrations are strongly correlated with soil Org-C. This suggests that Cd contamination in the aforementioned plots may in large part be due to the application and incorporation of a 'contaminated' organic amendment. Ambika *et al.* (2010) reported that Sewage water often have a high nutrient load, suspended solids, dissolved nitrates, pesticides, heavy metals and many other toxic materials / chemicals which may be hazardous and it may affect the soil micro-flora, soil texture and quality and also the plant growth and development. Mathavan (2001) reported that among the 25 samples studied for toxic metal contents, lead was found to be at toxic levels where as Cd, Ni, Cr and Co were in higher range when compared to the contents encountered in normal soils.

4.3 Rice Yields (kg ha⁻¹) in Musi command area

Data generated based on rice crop cuts in selected farmer's fields spread over in the entire Musi command area are presented in detail in Annexure VIII and their ranges and means in Table 4.7 The rice yields varied from 1050 to 8000 kg ha⁻¹ with the mean yield of 5120 kg ha⁻¹. The yields were higher in case of head region under both Left Flank and Right Flank canal due to sufficient / more water availability due to leakage from project and also enrichment of nutrients by Musi water to some extent. Tiwari *et al* (1996) reported relatively higher rice yield, test weight in treatments which received 50% fertilizer doses and irrigated with treated sewage water when compared to tube well irrigation.

Farmers raised rice in limited area during 2011-12 when compared to the previous years due to less rain fall during this year. The water from Musi project which is expected to be

released during September / October months was not released this year. During January, 2012, only for fifteen days the water was released with the main intension to fill the tanks in the command area. Farmer's used the available water from their bore wells / open wells to the possible extent. But in majority cases, the crop suffered with water stress. Some farmers left the crop unharvested. Hence wide variations in rice yields were noticed in the study area. Farmers shifted from rice crop to fodder grass in some instances due to water shortage.

Priyanie amerasinghe *et al.* (2008) reported that in long-term studies, directly irrigated fields from Musi river recorded significantly higher straw and grain yields with rice variety MTU 1001 as compared with MTU 1010 and IR64. Markandya and Murthy (2000), in their study of the Kanpur-Varanasi region in India, found that the positive effect on agricultural yield of nutrients present in partially treated wastewater when compared with crops grown using groundwater. Cao van Phung *et al.* (2009) reported that, the effect of the waste water irrigation was to reduce fertilizer inputs without affecting yield.

4.4. Composition of rice crop grown in Musi command area

From the crop cut sites of selected farmers grown during *rabi*, 2011-12, rice grain and straw samples were collected at harvest and analysed for their NPK contents. In limited number of samples micro nutrients and heavy metals were also analysed. The data in detail are presented in Annexure VIII and ranges and means are presented in Table 4.6 and 4.7. The results were interpreted as per the threshold levels indicated by Chapman (1975).

It was observed that, the N content in rice grain and straw samples ranged from 0.1 to 0.45 per cent and 0.20 to 1.58 per cent with a mean of 0.260 and 0.477 per cent respectively. The P content in grain and straw samples ranged from 0.081 to 0.140 % and 0.011 to 0.675 per cent with mean values of 0.115 and 0.096 per cent, respectively. The K contents in grain and straw ranged from 0.37 to 0.51 and 0.61 to 1.33 per cent with mean values of 0.446 and 0.882 per cent, respectively.

The Fe, Mn, Cu and Zn contents in rice grain samples ranged from 10.6 to 24.7, 0.18 to 1.21, traces to 0.54 and 0.54 to 1.68 mg kg⁻¹ with mean values of 15.57, 0.55, 0.54 and 1.19 mg kg⁻¹, respectively. In rice straw samples, these elements ranged from 11.5 to 20.6, traces to 0.18, traces to 0.07 and 0.94 to 3.19, respectively with mean values of 15.27, 0.18, 0.045 and 1.898 mg kg⁻¹, respectively.

The Cr, Co, Ni, Cd and Pb contents in rice grain samples ranged from 0.78 to 1.09, 7.80 to 10.9, 4.79 to 5.03, 2.69 to 2.77 and 28.90 to 29.01 mg kg⁻¹ with mean values of 0.94, 9.44, 4.91, 2.76 and 29.03 mg kg⁻¹ respectively. In rice straw samples, these elements ranged from 0.24 to 0.49, 2.4 to 4.9, 4.73 to 4.79, 2.75 to 2.82 and 28.73 to 29.04 respectively with mean values of 0.332, 3.32, 4.777, 2.776 and 28.855 mg kg⁻¹ respectively.

It was observed that the N, P, K, Fe, Mn, Cu and Zn contents were in deficit to normal range but except Cr, other heavy metals (Co, Ni, Cd and Pb) were found to be beyond the threshold levels. It can be inferred that the heavy metals entering in to the Musi River due to the entry of industrial pollutants from urban areas, along its course could be responsible for the presence of heavy metals in unsafe quantities in rice grain and straw samples.

Ali. A. Aljaloud (2010) study showed that reuse of treated municipal waste water for irrigation provided plants with sufficient levels of nutrients, such as nitrogen (N), phosphorus (P) and potassium (K), and other micro-nutrients. Dutta and Biossya, 1999 reported that study on effect of long-term application of sewage effluents on contents of heavy metals in crops grown indicated that cadmium and cobalt contents in tissues of all plants were below the limits of analytical detection. A study by Wang *et al.* (2003), showed Zn, Cu and Pb to be the main pollutants in the experiment sites and paddy soil and the rapid development of village/township industries to be the primary cause of severe environmental pollution in the Taihu Lake region in China, especially of irrigation river sediments. Rattan *et al.* (2005) observed that mean contents of metals in the dry matter of rice grain accumulated much higher amount of Zn and Cu grown on sewage irrigated soils compared to tube well water. While slight increase in Ni content was recorded. Manganese content in rice grain for sewage-irrigated soils was much lower than that for tube well water-irrigated soils. Although sewage effluent-irrigated soils exhibited much higher amount of DTPA-Fe, it was not reflected in Fe content of rice grain. Rice straw accumulated almost two times more Ni produced with sewage water over that of tube well water irrigation.

4.5 Uptake of N, P and K by rice crop in Musi command area

Data are presented in Annexure VIII and their ranges and means in Table 4.7. The uptake of N by rice (variety - MTU 1010) grain and straw ranged from 3.46 to 36.30 and 1.32 to

65.31 kg ha⁻¹ with mean values of 13.66 and 20.80 kg ha⁻¹ respectively. The total uptake of N ranged from 5.30 to 92.11 kg ha⁻¹ with mean of 34.46 kg ha⁻¹.

The P uptake by rice straw and grain ranged from 1.08 to 14.2 and 0.02 to 36.28 kg ha⁻¹ with mean values of 5.94 and 4.43 kg ha⁻¹ respectively. The total P uptake ranged from 1.22 to 42.5 kg ha⁻¹ with mean of 10.38 kg ha⁻¹.

The K uptake by rice grain and straw ranged from 3.88 to 51.76 and 3.65 to 97.3 kg ha⁻¹ with mean values of 22.91 and 37.19 kg ha⁻¹ respectively. The total K uptake ranged from 8.72 to 149 kg ha⁻¹ with mean of 60.10 kg ha⁻¹.

The wide variations in uptake of N, P and K by rice grown in Musi command area are due to wide variations in yield levels caused due to differences in availability of water and quality of bore wells / open wells in the study area. The head regions under both Right Flank and Left Flank canal areas in general recorded higher uptake of N,P and K when compared to the rice crop grown in middle and tail end regions of Musi command area.

Tiwari *et al* (1996) reported higher uptake of NPK by rice in treatments which received 50% of fertilizer dose and irrigated with treated sewage water indicating better utilization of applied fertilizers.

4.6. Correlations between water quality parameters, soil properties and crop yield

The study involved correlation analyses of the water quality data of pre-monsoon and post monsoon periods and also the soil quality data of Musi command area. The correlation matrix for different groundwater quality variables for pre-monsoon and post monsoon periods, and also the soil quality data of Musi command area are presented in respective Tables 4.8 to 4.10.

4.6.1 Interaction between the bore well water quality parameters in pre-monsoon period

The relationship between different bore well water quality parameters in pre-monsoon season was worked out at 1 per cent and 5 per cent level of significance for 21 water samples ($r = 0.526$) and ($r = 0.413$), respectively, through correlation analysis of the data. The correlations between different water quality parameters in pre-monsoon season were presented in Table 4.10.

The pH was positively and significantly correlated with SAR ($r = 0.626$), and fluorides ($r = 0.60$) at 1 per cent level of significance, the reason is higher SAR and RSC values result in higher pH and it was in accordance with Manjunatha Hebbara *et al.* 2010.

The EC was positively and non significantly correlated with SAR ($r = 0.17$), RSC ($r = 0.37$) and fluorides ($r = 0.07$). The EC was negatively and significantly correlated with nitrates ($r = -0.56$) at 1per cent and nitrates content was not affected by the EC.

The RSC was positively and non significantly correlated with fluorides ($r = 0.63$). The RSC is negatively and significantly correlated with chlorides ($r = -0.86$) at 1per cent level of significance and RSC is negatively and non significantly correlated with nitrates($r = -0.17$) at 1per cent and 5per cent level of significance.

Fluorides are negatively and non significantly correlated with nitrates ($r = -0.038$) and chlorides($r = -0.038$) at 1 per cent level of significance. Nitrates are positively and non significantly correlated with chlorides($r = -0.39$) at 1per cent level of significance.

In the study area, yield was not influenced with bore well water pH ($r = -0.19$), SAR ($r = -0.39$), nitrates ($r = -0.15$) and chlorides ($r = -0.24$), EC ($r = 0.09$), RSC ($r = 0.08$) and fluorides($r = 0.023$) at 1 per cent level of significance and correlation was non significant.

4.6.2. Interaction between the open well water quality parameters in pre-monsoon period

The relationship between different open well water quality parameters in pre-monsoon season was worked out at 1 per cent and 5 per cent level of significance for 28 water samples ($r = 0.526$) and ($r = 0.413$) respectively, through correlation analysis of the data. The correlations between different water quality parameters in pre-monsoon season are presented in Table 4.8. In open well water samples the correlations between pH and RSC were positive but non significant where as in bore wells pH and RSC were significantly and positively related. Similarly the EC vs Nitrates and chlorides was significant and positive in case of open wells and it was positive but non significant in case of bore wells.

The pH was positively correlated with RSC ($r = 0.36$) and fluorides($r = 0.38$) at 1 per cent level of significance but it was not significant. The EC was positively and significantly correlated with nitrates ($r = 0.45$), chlorides ($r = 0.63$) at 1 per cent level of significance and positively and non significantly correlated with fluorides ($r = 0.38$) at 1 per cent and 5 per cent

level of significance. Nitrates can add the dissolved salts to water so that EC can increase and it in in conformity with Joarder *et al.* 2008

Fluorides were positively and non significantly correlated with chlorides ($r = 0.38$) and RSC ($r = -0.40$) at 1 per cent and 5 per cent level of significance.

The yield was positively and significantly correlated with EC ($r = 0.42$) at 5 per cent level of significance although the higher EC levels i.e, C3 class it did not effected the rice crop which is relatively tolerant to salinity and positively and non significantly correlated with nitrates ($r = 0.14$), chlorides ($r = 0.34$) and SAR ($r = 0.14$) at 1 per cent and 5 per cent level of significance.

4.6.3. Interactions between the open well water quality parameters in post-monsoon period

The relationship between different open well water quality parameters in pre-monsoon season were worked out at 1 per cent and 5 per cent level of significance for 23 water samples ($r = 0.641$) and ($r = 0.514$), respectively, through correlation analysis of the data. The correlations between different water quality parameters in pre-monsoon season were presented in Table.4.9. The post monsoon water samples showed similar trend as that in pre monsoon with regard to RSC and fluorides. Positive relationships were obtained between pH vs SAR and RSC in both the cases but they were significant in case of pre monsoon samples and non significant in case of post monsoon samples. The EC showed positive relationship with SAR and RSC in both the cases but it was significant in case of pre monsoon and non significant in case of post monsoon.

The pH was positively and non significantly correlated with SAR ($r = 0.67$), RSC ($r = 0.73$), nitrates ($r = 0.16$) and chlorides ($r = 0.033$) at 1 per cent and 5 per cent level of significance. The EC was positively and significant with chlorides ($r = 0.74$) and ammonia ($r = 0.61$) at 1 per cent level of significance and reason is that chlorides and ammonia contributes salts to water.

The RSC was positively and non significantly correlated with fluorides ($r = 0.29$), nitrates($r = 0.025$), chlorides ($r = 0.12$) and ammonia ($r = 0.11$) at 1 per cent and 5 per cent level of significance.

Fluorides were positively and non significantly correlated with chlorides ($r = 0.50$) at 1 per cent and 5 per cent level of significance. Nitrates were positively correlated with ammonia

($r = 0.40$) but because of inter change of nitrates to ammonia the correlation was not significant. The chlorides were positively and non significantly correlated with ammonia ($r = 0.54$) at 1 per cent level of significance.

open well water pH ($r = 0.23$), RSC ($r = 0.68$), fluorides ($r = 0.28$), nitrates ($r = 0.28$) and ammonia ($r = 0.17$) were correlated positively with yield but it was non significant.

The yield was positively and significantly correlated with EC ($r = 0.42$) at 5 per cent level of significance although the higher EC levels i.e, C3 class it did not effected the rice crop which is relatively tolerant to salinity and positively and non significantly correlated with nitrates ($r = 0.14$), chlorides ($r = 0.34$) and SAR ($r = 0.14$) at 1 per cent and 5 per cent level of significance.

4.6.4 Interactions between soil quality parameters in Musi command area

The relationship between different soil quality parameters was worked out at 1 per cent level of significance for 95 soil samples ($r = 0.260$) through correlation of the data. The correlations between soil properties and nutrients were presented in Table 4.11.

Within the soil properties soil reaction (pH) was positively correlated with EC ($r = 0.0540$), organic carbon ($r = 0.042$), nitrogen ($r = 0.11$) and potassium ($r = 0.045$) and pH was negatively correlated with phosphorus ($r = -0.076$). However the correlations were not significant.

The EC was positively and significantly correlated with organic carbon ($r = 0.29$), and phosphorus ($r = 0.5$), at 1 per cent level of significance. Phosphorus is positively and significantly correlated with potassium at 1 per cent level of significance.

Yield was positively correlated with pH, OC and potassium and however the correlations were not significant. Yield was negatively and significantly correlated with phosphorus at 1 per cent level of significance. The reason might be due to higher levels of P which can cause nutrient imbalances like zinc deficiency and affects the yields.

4.6.5 Correlations between uptake of N, P, K and rice yield in Musi command area

The relationship between uptake of N, P, K and yield were worked out at 1 per cent level of significance for 51 samples ($r = 0.363$) through correlation of the data. (Table.4.12.)

The N, P, K uptakes were positively and significantly correlated among themselves and the correlation was significant. Yield is positively and significantly correlated with nitrogen, phosphorus and potassium uptakes at 1 per cent level of significance indicates that with increase in N, P, K uptakes, the yield factor shows a positive response.

4.7 Land use / land cover map in Musi command area

The land use / land cover map was prepared from the LISS-III FCC (False colour composite) through digital image processing. Initial processing of the data was carried out in ERDAS imagine 9.3 software. Ground truth observations made in the study area during multiple number of survey works for collection of samples and during crop growth period were used for generating the training sets. The image characteristics like colour, texture, shape, size, pattern and association and also the collateral data from the toposheets were also used to prepare land use / land cover map and final map composition was made by using Arc GIS 9.3 software. The map is presented in the Figure 4.14 and data in Table 4.13. A total number of eight distinct land use / land cover types were classified, namely river/tanks, built up land, *rabi* paddy, other crops, scrub land, current fallow, plantations and Musi river coarse (sandy mass). Among the eight classes, the rice crop occupied the highest area among all crops, covering 20.1 per cent (5043 ha) of the gross command area (24,906 ha) followed by other crops 19.7 per cent (4925 ha), plantations 7.5 per cent (1875 ha). The built up area also (22.2 %) occupied a major portion of command area (5534 ha) followed by current fallow of 12.4 per cent (3106 ha), Musi river coarse i.e.sandy mass of 10.2 per cent (2608 ha) and to a small extent scrub land of 0.024 per cent (60 ha).

Part of the ground truth data collected was used for accuracy estimation of the land use / land cover map generated. The error matrix generated is presented in Table 4.14 . Based on the data generated in error matrix table, producer's accuracy / classification accuracy /omission error, user's accuracy / mapping accuracy / commission error, over all accuracy and kappa co-efficient were computed and presented in Table 4.15. The producer's accuracy (classification accuracy / omission error) ranged from 75 to 100 % and user's accuracy (mapping accuracy / commission error) from 55 and 100 %. The overall accuracy obtained was 94.2 % with kappa's co-efficient of 0.91. Within individual classes the highest accuracy (100 %) was obtained from *rabi* paddy, other crops and tanks classes. It was followed by built up land (92 to 92.3 %) and

plantations (86 to 90.4 %). Low accuracy was obtained with regard to shrub land (60-75 %), current fallow (76 – 83 %) and Musi river course i.e sand mass (55 to 84%).

Based on the results summarized it can be conclude that

As per USDA Hand Book on Agriculture No. 60, about all the Musi canal water samples were classified as C_3S_1 (Class II) which requires good water management practices. Among bore wells and open wells, during pre monsoon, majority of samples (81 – 92 %) were classified as C_3S_1 (Class III) and the remaining were under C_4S_1 (Class III). Though, this class III water is not suitable normally, can be used for tolerant crops (example paddy) with good drainage facility and good management practices. With regard to specific ions, the nitrates and chlorides were in moderate category. The heavy metals Ni and Cd were found to be beyond the phytotoxic threshold levels.

Majority of the soil samples (55%) were moderately alkaline followed by slightly alkaline (29%), strongly alkaline (12%) and very less per centage of samples are in neutral range (4%). All soils are non saline, high in organic carbon, low in available N, high in available P and potassium. Among the micronutrients, about 22 to 25 % of samples were found to be deficit in available Cu and Zn and in these deficit soils, it needs to include these elements in fertilizer schedules. However there is a threat from pollution point of view with regard to the heavy metals, specially Cd and Pb.

The rice yields were high in the head region of Musi command area due to more availability of Musi project canal water, whereas in middle and tail end regions, crop suffered due to water stress. Analytical reports of rice grain and straw samples indicated the presence of heavy metals (Co, Ni, Cd and Pb) beyond the threshold levels.

The information generated from current existing land use/ land cover map of Musi command area can serve as a guide for computing irrigation crop water requirements as per the areas occupied by agricultural crops (rice and other crops) and irrigation planning can be done by the authorities, more scientifically for better water use efficiency.

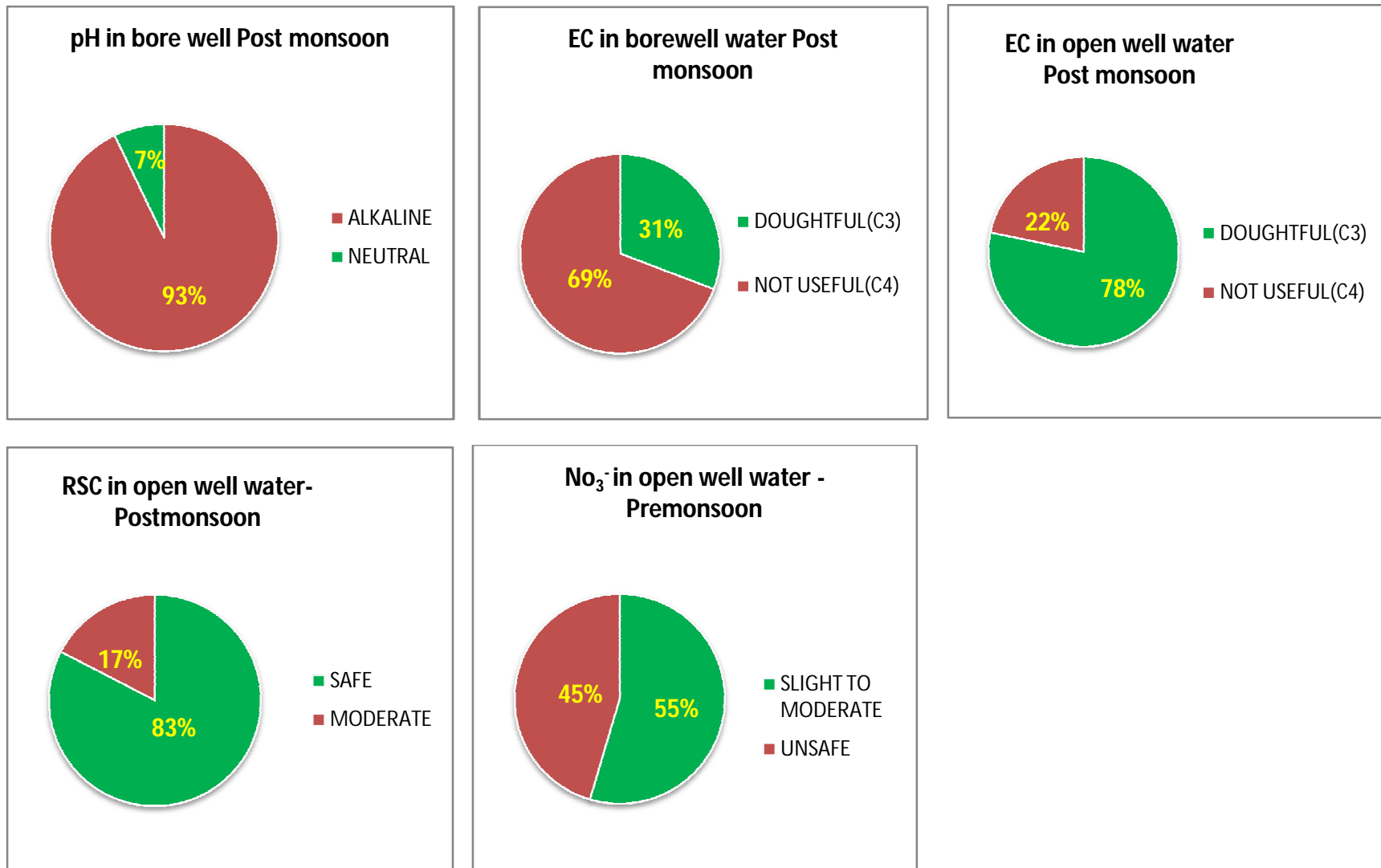


Fig. 4.3.Frequency distribution of water quality parameters in Musi command area in post monsoon (January,2012)

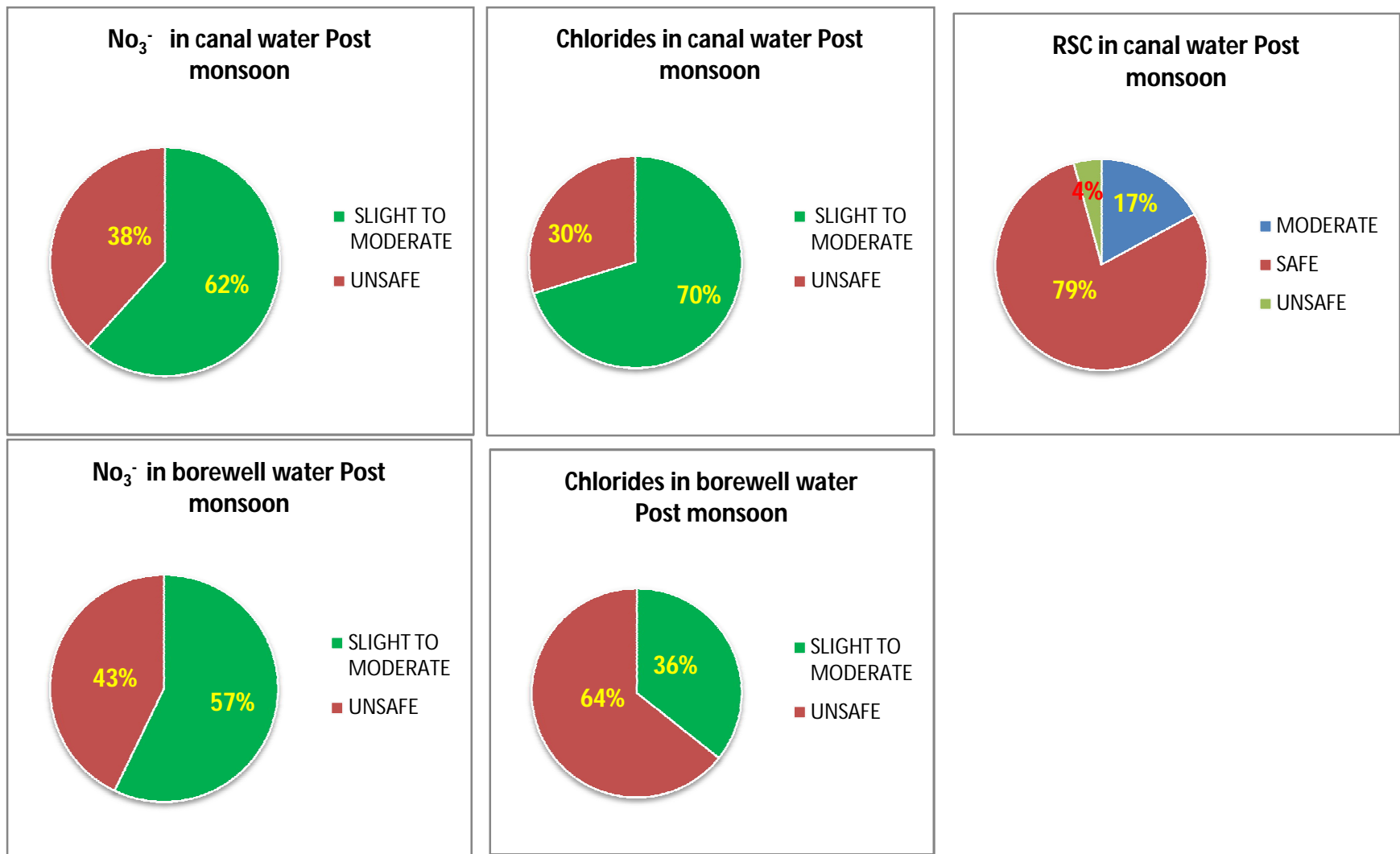


Fig. 4.6. Frequency distribution of nitrates, chlorides, RSC in Musi command area in post monsoon (January, 2012)

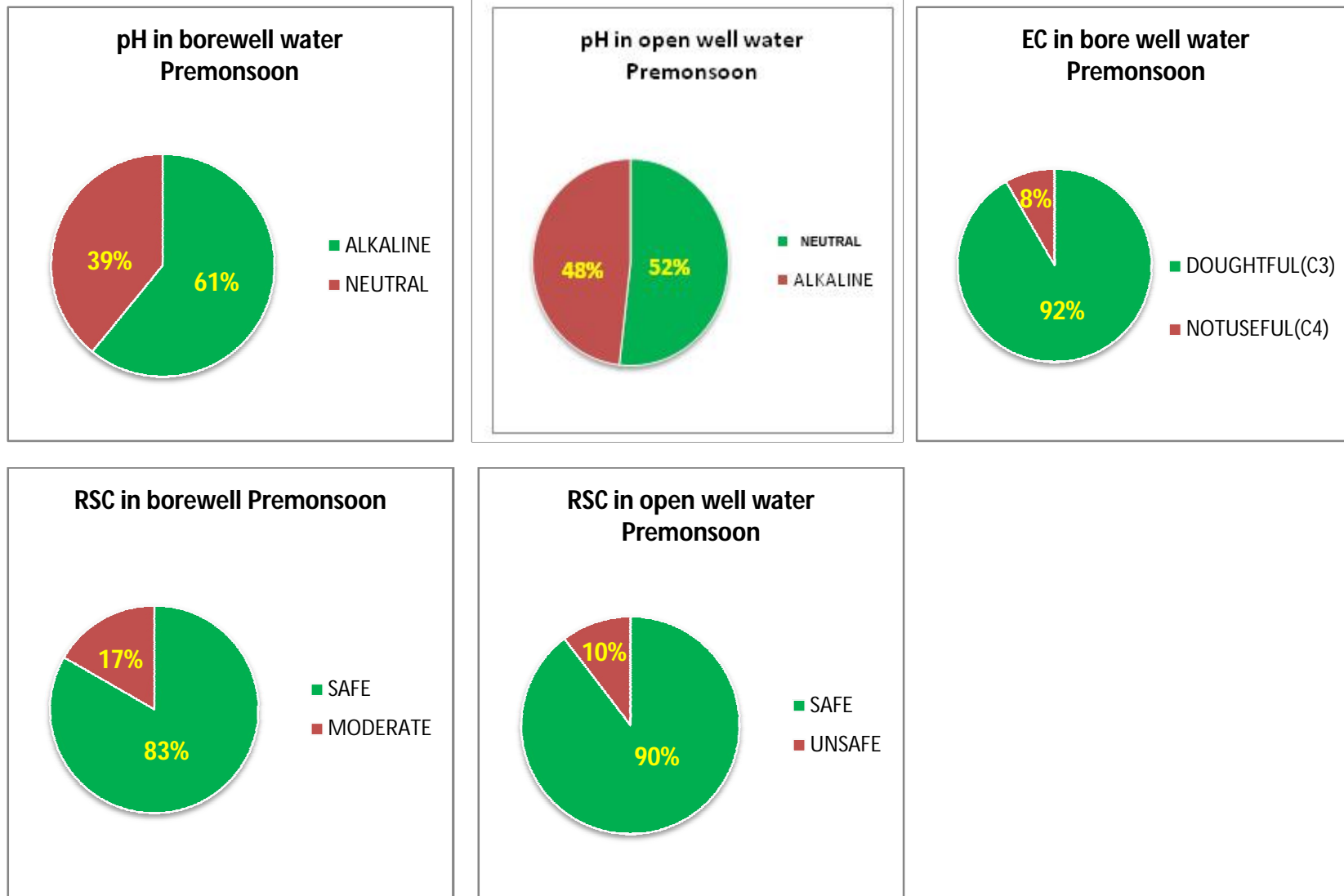


Fig.4.1 Frequency distribution of pH, EC, RSC in bore and open well in Musi command area in pre monsoon (June, 2011)

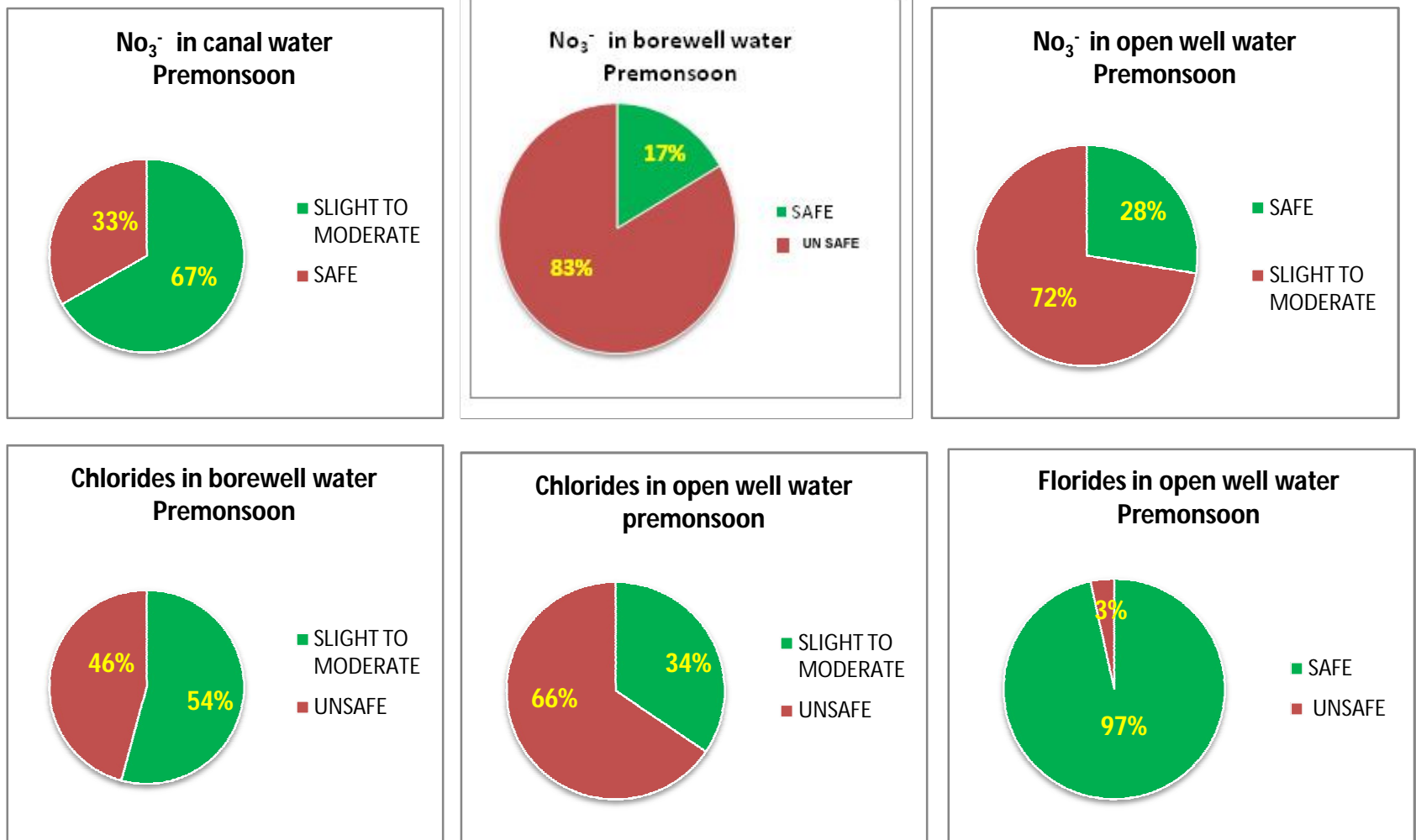


Fig.4.5. Frequency distribution of nitrates, chlorides, fluorides in Musi command area in pre monsoon (June, 2011)

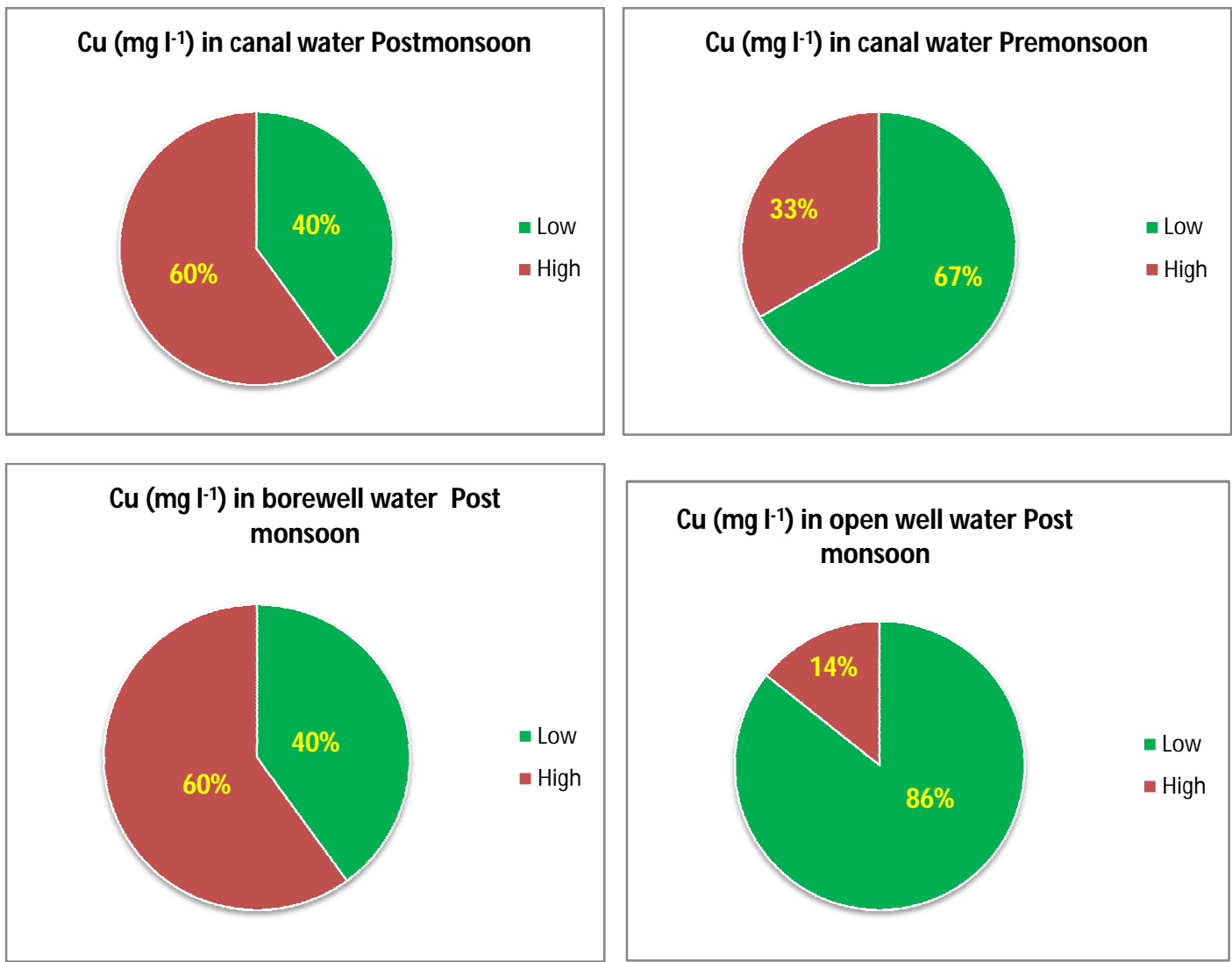


Fig: 4.9. Frequency distribution of Cu (mg L⁻¹) in water samples of Musi command area

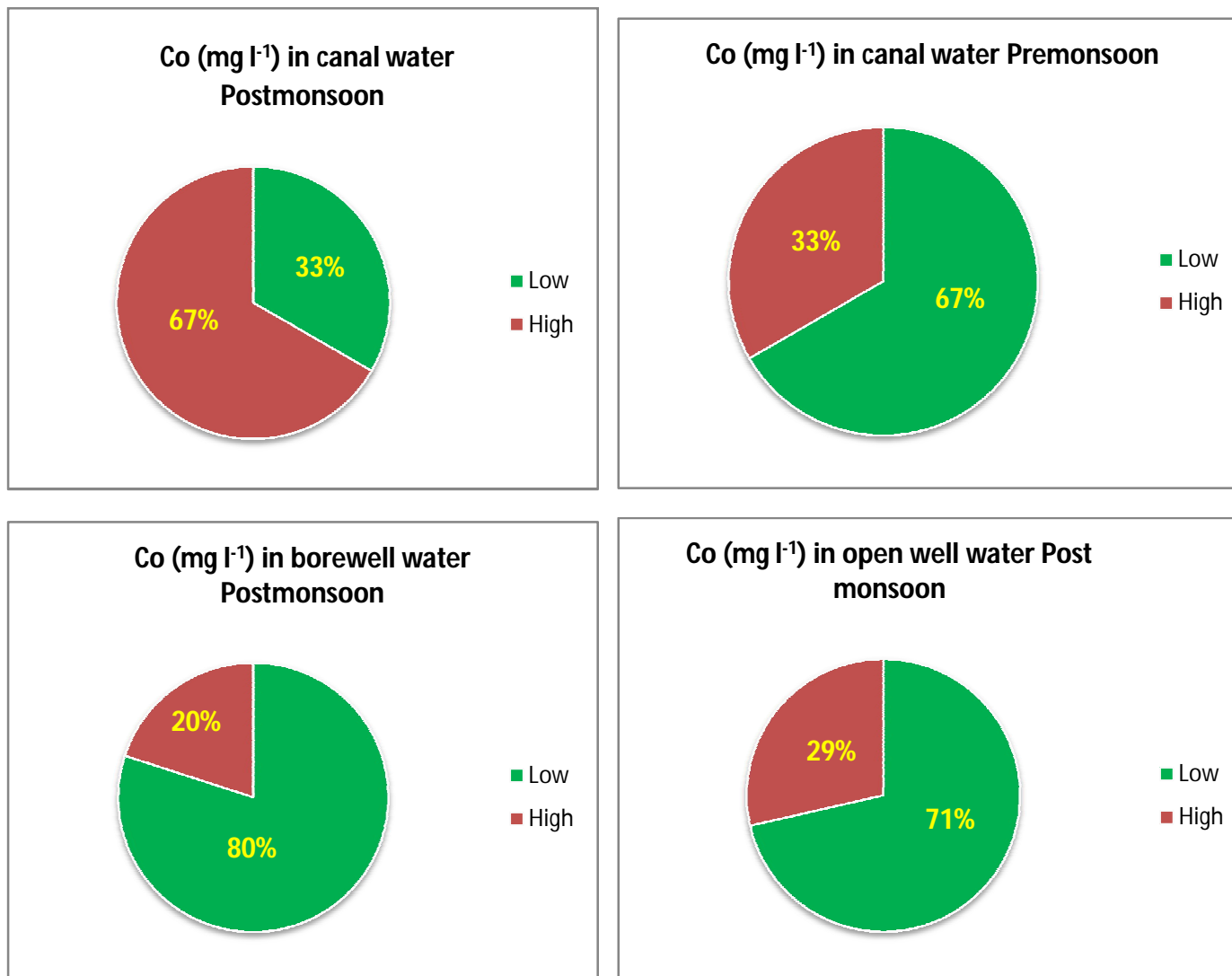


Fig: 4.10. Frequency distribution of Co (mg L^{-1}) in water samples of Musi command area

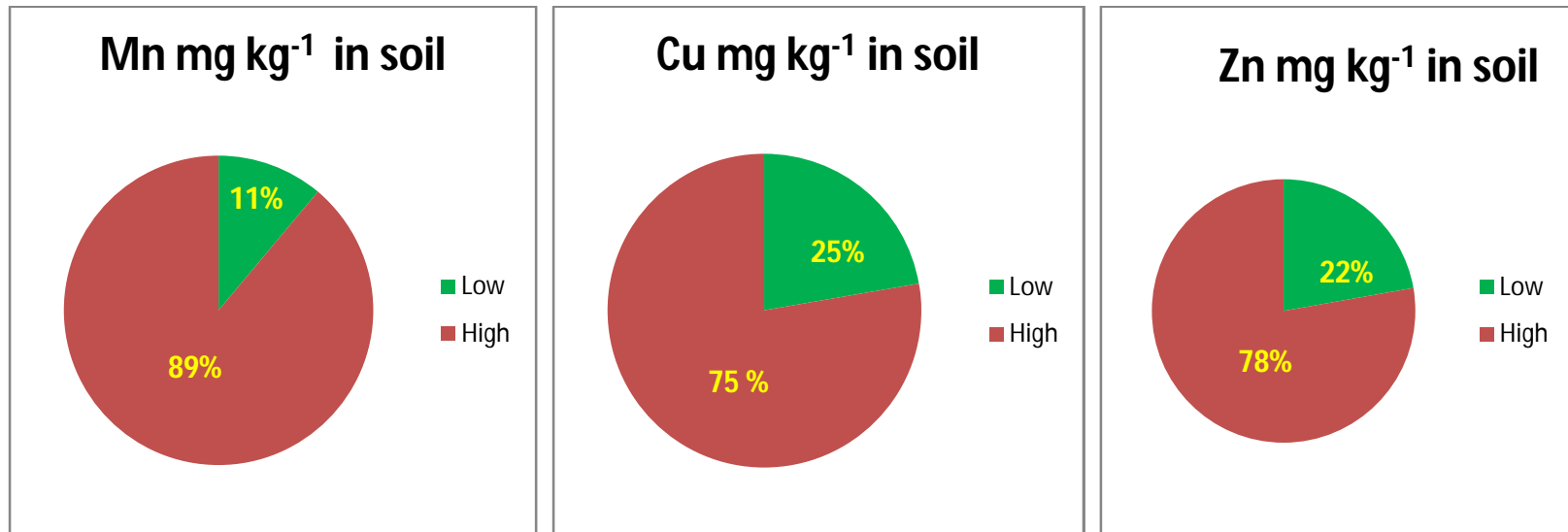


Fig.4.14. Frequency distribution of micronutrients in soils (0-15 cm) of Musi command area (June, 2011)

Table: 4.1.Ranges and means of irrigation water quality of bore wells, open wells and left and right flank canal water in Musi command area during pre monsoon (June, 2011).

	pH	EC (dS m ⁻¹)	SAR	RSC	Ca+Mg (me l ⁻¹)	Fluorides (mg l ⁻¹)	Nitrates (mg l ⁻¹)	Chlorides (mg l ⁻¹)	Ammonia (mg l ⁻¹)
Bore Wells – Pre monsoon									
Range	6.81-8.40	1.48-2.80	2.1-5.30	-146 -9.0	6-20	0.026-0.95	4-9	6.8-22.4	0.01-0.70
Mean	8.28	1.93	2.78	-3.36	9.96	0.26	7.0	12.54	0.10
SD+/-	0.35	0.51	1.33	3.71	3.38	0.17	21.02	5.10	0.18
Open wells – Pre monsoon									
Range	6.84-8.13	1.28-5.36	1.20-11.7	-17.0 - 11.2	5.8-16.0	0.064 -1.2	4-8	6.8-25.2	0.01-0.7
Mean	7.520	2.019	3.535	-4.069	9.586	0.33	5.207	12.359	0.10
SD+/-	0.334	0.731	2.157	7.445	2.467	0.27	1.264	4.445	0.18
Left and Right flank canal water – Pre monsoon									
Range	8.0-8.70	1.61 - 1.86	2.6 - 4.30	-8.4 - 0.4	6.6 - 16	0.24 - 0.30	2-5	9.2 - 10	0.05 - 0.08
Mean	8.49	1.75	3.586	-2.1	10.033	0.262	3.2	9.4	0.42
SD+/-	0.243	0.095	0.629	3.131	3.860	0.024	2.000	0.607	0.263

Table: 4.2. Ranges and means of irrigation water quality of bore wells, open wells and left and right flank canal water in Musi command area during post monsoon (January, 2012).

	pH	EC (dSm ⁻¹)	SAR	RSC	Ca +Mg (me l ⁻¹)	Fluorides (mg l ⁻¹)	Nitrates (mg l ⁻¹)	Chlorides (mg l ⁻¹)	Ammonia (mg l ⁻¹)
Bore Wells – Post monsoon									
Range	7.3-8.8	1.35-2.94	0.13-5.01	-11.6 - 1.4	6-20	0.1 -0.7	20-100	6.8 – 22.8	0.01-0.7
Mean	7.54	1.84	3.03	-3.23	10.04	0.26	40.0	11.90	0.3
SD+/-	0.44	0.32	1.24	6.19	3.23	0.18	1.35	4.66	0.12
Open wells – Post monsoon									
Range	7.80-8.91	1.453-3.57	0.19-4.22	-15.0 -2.2	4.4-21.4	0.1-0.7	20-300	9.2-29.6	0.01-0.70
Mean	8.278	1.929	2.713	-3.364	9.964	0.257	60	14.62	0.0971
SD+/-	0.353	0.509	1.331	3.710	3.375	0.169	21.018	5.097	0.175
Left and Right flank canal water – Post monsoon									
Range	8.1 -8.9	1.41 -2.53	1.19- 5.45	-4.6 to 4.4	0.2 – 9.8	0.1 to 0.4	10 to 100	5.2 to 24	0.01 – 0.7
Mean	8.67	1.52	2.87	-0.13	6.36	0.29	36.33	9.71	0.07
SD+/-	0.16	0.17	0.81	1.89	2.49	0.06	25.06	3.03	0.10

Table: 4.3. Ranges and means of micro nutrients and heavy metals in water samples in Musi command area during pre (June, 2011) and post monsoon (Jan, 2012).

	Cu (mg l ⁻¹)	Zn (mg l ⁻¹)	Fe (mg l ⁻¹)	Mn (mg l ⁻¹)	Cr (mg l ⁻¹)	Co (mg l ⁻¹)	Ni (mg l ⁻¹)	Cd (mg l ⁻¹)	Pb (mg l ⁻¹)
Left and Right flank canal water – Pre monsoon									
Range	Traces – 6.8	Traces- 0.04	Traces-1.23	Traces	0.005-0.017	0.044-0.053	0.477-0.479	0.0278-0.274	2.873-2.888
Mean	6.8	0.04	1.23	Traces	0.011	0.049	0.478	0.274	2.883
SD+/-	-	-	-	-	0.006	0.005	0.001	0.001	0.005
Bore wells – Post monsoon									
Range	Traces - 15.24	0.045 - 0.057	Traces	Traces	0.003-0.07	0.046-0.058	0.47-0.477	0.242-0.278	2.881-2.903
Mean	6.607	0.052	Traces	Traces	0.04	0.0502	0.474	0.270	2.885
SD+/-	7.63265	0.005	-	-	0.03	0.005	0.003	0.015	0.013
Open wells – Post monsoon									
Range	Traces- 15.24	0.04-0.057	Traces	Traces	0.005-0.012	0.039-0.063	0.473-0.481	0.274-0.276	2.868-2.9
Mean	8.24	0.029	Traces	Traces	0.009	0.049	0.477	0.275	2.881
SD+/-	-	0.006	-	Traces	0.003	0.007	0.003	0.001	0.014
Left and Right flank canal water – Post monsoon									
Range	Traces - 32.72	0.031-0.107	Traces- 0.512	Traces	0.005-0.018	0.036-0.47	0.569-0.577	0.278-0.281	2.892-2.911
Mean	4.049	0.051	0.389	Traces	0.010	0.106	0.537	0.279	2.898
SD+/-	9.028	0.019	0.214	-	0.004	0.154	0.138	0.001	0.010

Table: 4.4 .Ranges and means of soil (0-15 cm) characteristics in Musi command area (June, 2011)

	pH	EC (dS m ⁻¹)	OC (g kg ⁻¹)	N (kg ha ⁻¹)	P (kg ha ⁻¹)	K (kg ha ⁻¹)
Range	6.78-9.15	0.112-3.26	12-49.5	53.75 -204.5	18.9-208.8	460-1298
Mean	7.9394	1.4413	24.3	143.841	74.378	990.14
SD+/-	0.9795	6.7252	0.416	36.144	40.488	213.5

Table: 4.5. Ranges and means of micronutrients and heavy metals in soils (0-15 cm) of Musi command area (June, 2011)

	Cu (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Cr (mg kg ⁻¹)	Co (mg kg ⁻¹)	Ni (mg kg ⁻¹)	Cd (mg kg ⁻¹)	Pb (mg kg ⁻¹)
Range	Traces -3.7	0.28-4.74	1.4-33.4	0.15-30.64	0.04-0.118	0.11-1.03	0.968-1.521	0.55-0.596	5.824-7.177
Mean	2.077	1.922	23.933	11.388	0.068	0.433	1.195	0.578	6.413
SD+/-	1.250	1.520	12.627	10.51	0.024	0.316	0.173	0.014	0.433

Table: 4.6. Ranges and means of rice (MTU – 1010) grain yields, total N,P,K contents, micro nutrients and heavy metals in grain and straw samples at harvest in Musi command area (*rabi*, 2011-12).

	Grain Yield (kg ha ⁻¹)	Straw Yield (kg ha ⁻¹)	N (%)		P (%)		K (%)	
			Grain	Straw	Grain	Straw	Grain	Straw
Range	1050-8000	1031-8390	0.098-0.448	0.196-1.582	0.081-0.140	0.0011-0.675	0.37-0.53	0.607-1.33
Mean	5244	4800	0.260	0.477	0.1149	0.096	0.446	0.882
SD+/-	1806	1928	0.083	0.240	0.0154	0.117	0.037	0.153

	Fe (mg kg ⁻¹)		Mn (mg kg ⁻¹)		Cu (mg kg ⁻¹)		Zn (mg kg ⁻¹)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Range	10.6-24.6	11.5-20.6	0.18-1.21	Neg-0.18	Neg-0.54	Neg-0.07	0.54-1.68	0.94-3.19
Mean	15.57	15.27	0.55	0.18	0.54	0.045	1.19	1.898
SD+/-	5.79	3.832	0.41	-	-	0.035	0.58	1.158

	Cr (mg kg ⁻¹)		Co (mg kg ⁻¹)		Ni (mg kg ⁻¹)		Cd (mg kg ⁻¹)		Pb (mg kg ⁻¹)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Range	0.78-1.09	0.24-0.49	7.8-10.9	2.4-4.9	4.85-5.03	4.73-4.79	2.69-2.77	2.75-2.82	28.9-29.01	28.73-29.04
Mean	0.94	0.332	9.44	3.32	4.91	4.777	2.76	2.776	29.03	28.855
SD+/-	0.15	0.094	1.46	0.936	0.10	0.025	0.03	0.027	0.07	0.115

Table: 4.7. Ranges and means of uptake of N,P and K by grain, straw and total by rice (MTU – 1010) at harvest in Musi command area (rabi, 2011-12).

	N Uptake (kg ha ⁻¹)			P Uptake (kg ha ⁻¹)			K Uptake (kg ha ⁻¹)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Range	3.46-36.30	1.32-65.31	5.3-92.11	1.08-14.2	0.02-36.28	1.22-42.5	3.88-51.76	3.65-97.3	8.72-149
Mean	13.66	20.80	34.46	5.94	4.43	10.38	22.91	37.19	60.10
SD+/-	7.665	15.0	20.79	2.447	6.1491	7.18	8.51	18.83	26.111

Table: 4.8. Correlations between pre monsoon (June, 2011) open wells water quality parameters with rice yield in Musi command area

	pH	EC	Fluorides	Nitrates	Chlorides	Ca+Mg	RSC	SAR	Yield (kg ha ⁻¹)
pH	1								
EC	-0.150	1							
Fluorides	0.380	0.390	1						
Nitrates	-0.337	0.451	-0.218	1					
Chlorides	-0.022	0.639	0.380	-0.191	1				
Ca+Mg	-0.235	0.582	-0.124	0.383	0.376	1			
RSC	0.363	-0.407	0.335	-0.369	-0.224	-0.938	1		
SAR	-0.374	-0.377	-0.341	-0.078	-0.150	-0.172	0.126	1	
Yield (kg ha ⁻¹)	-0.355	0.399	-0.082	0.142	0.349	0.723	-0.699	0.146	1

Table: 4.9. Corelations between post monsoon (January, 2012) open wells water quality parameters with rice yield in Musi command area

	pH	EC	SAR	RSC	Ca+Mg	Fluorides	Nitrates	Chlorides	Ammonia	Yield (kg ha ⁻¹)
pH	1									
EC	-0.287	1								
SAR	0.674	-0.415	1							
RSC	0.732	-0.388	0.162	1						
Ca+Mg	-0.548	0.549	-0.316	-0.655	1					
Fluorides	-0.060	0.258	-0.344	0.293	-0.360	1				
Nitrates	0.169	-0.611	-0.026	0.546	-0.157	-0.208	1			
Chlorides	0.033	0.748	-0.364	0.128	0.368	0.506	-0.163	1		
Ammonia	-0.069	0.611	-0.612	0.116	0.343	-0.035	0.041	0.546	1	
Yield (kg ha ⁻¹)	0.237	-0.325	-0.190	0.681	-0.571	0.284	0.279	-0.180	0.170	1

Table: 4.10. Corelations between pre monsoon (June, 2011) bore wells water quality parameters with rice yield in Musi command area

	pH	EC	SAR	RSC	Ca +Mg	Fluorides	Nitrates	Chlorides	yield (kg ha ⁻¹)
pH	1								
EC	-0.095	1							
SAR	0.627	0.173	1						
RSC	-0.295	0.380	-0.264	1					
Ca +Mg	-0.028	-0.513	-0.165	-0.639	1				
Fluorides	0.603	0.071	0.223	0.270	-0.111	1			
Nitrates	-0.175	-0.561	-0.178	-0.268	0.563	-0.039	1		
Chlorides	0.348	-0.305	0.276	-0.855	0.797	-0.066	0.393	1	
Yield(kg ha ⁻¹)	-0.199	0.093	-0.384	0.086	0.092	0.024	-0.156	-0.242	1

Table: 4.11. Corelations between soil characteristics (0-15 cm) with rice yield (kg ha⁻¹) in Musi command area

	pH	EC	OC (g kg ⁻¹)	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)	Yield (kg ha ⁻¹)
pH	1						
EC	0.054	1					
OC (g kg ⁻¹)	0.0423	0.295	1				
N (kg ha ⁻¹)	0.113	-0.026	0.004	1			
P (kg ha ⁻¹)	-0.076	0.268	0.303	-0.057	1		
K (kg ha ⁻¹)	0.045	-0.176	-0.030	-0.013	0.279	1	
Yield (kg ha ⁻¹)	0.0523	-0.173	0.109	-0.110	0.300	0.079	1

Table: 4.12. Correlations between total uptake of N, P and K (kg ha⁻¹) of rice with rice yield in Musi command area

Element	uptake			Yield (kg ha ⁻¹)
	Nitrogen (kg ha ⁻¹)	Phosphorus (kg ha ⁻¹)	Potassium (kg ha ⁻¹)	
Nitrogen (kg ha ⁻¹)	1			
Phosphorus (kg ha ⁻¹)	0.497369491	1		
Potassium (kg ha ⁻¹)	0.739715716	0.655362903	1	
Yield (kg ha ⁻¹)	0.781022524	0.584850052	0.89763	1

Table.4.13.Results of Land use/land cover information in Musi project command area, Nalgonda district.

	Area	Percent of area
River/tanks	1755 ha	7.04
Built upland	5534 ha	22.2
Rabi paddy	5043 ha	20.1
other crops	4925 ha	19.7
scrub land	60ha	0.66
current fallow	3106 ha	12.4
Plantations	1875 ha	7.5
Musi river coarse(sandy mass)	2608ha	10.4
Total	24906 ha	100

Table.4.14. Contingency error matrix table for land use / land cover map of Musi command area, Nalgonda district.

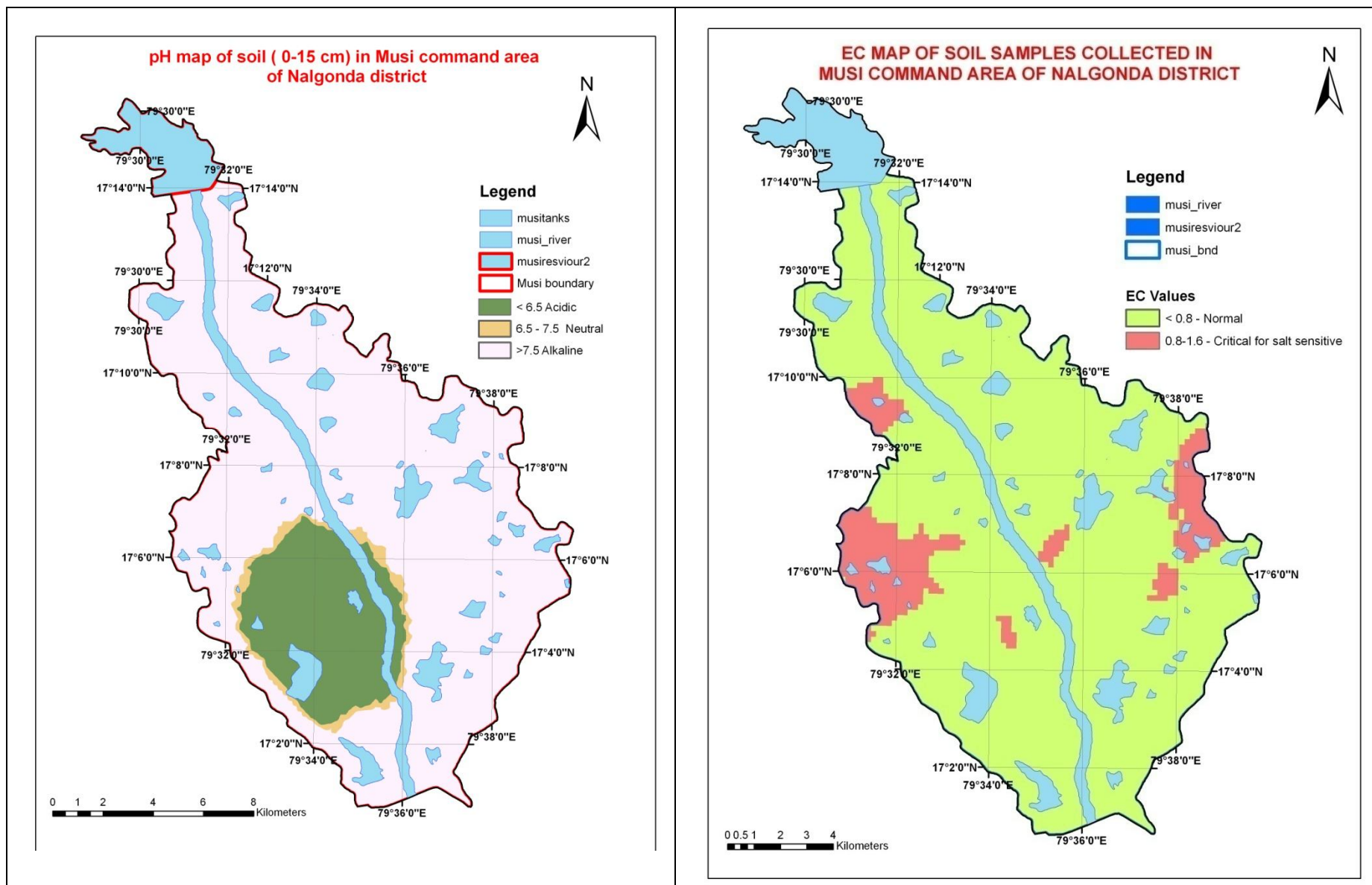
Data	Tanks/Rivers	Built upland	<i>Rabi</i> paddy	Plantation	Shrub land	Musi river coarse (sand mass)	Current fallow	Other crops	Row total
Tanks/River	95	0	0	0	0	0	0	0	95
Built upland	0	48	0	0	2	0	0	0	50
<i>Rabi</i> paddy	0	0	6	0	0	0	0	0	6
Plantation	0	0	0	19	1	1	0	0	21
Shrub land	0	2	0	3	6	0	0	0	10
Musi river coarse (sand mass)	0	0	0	0	1	5	3	0	9
Current fallow	0	2	0	0	0	0	10	0	12
Other crops	0	0	0	0	0	0	0	9	9
Column Total	95	52	6	22	8	6	13	9	210

Table: 4.15.Omission and Commission error of land use / land cover map of Nalgonda district

	Producers accuracy (Omission error %)	Users accuracy (Commission error %)
Tanks/River	100	100
Built upland	92.3	92
<i>Rabi</i> paddy	100	100
Plantation	86	90.4
Shrub land	75	60
Musi river coarse (sand mass)	84	55
Current fallow	76	83
Other crops	100	100

Overall accuracy = 94.2 %

Kappa's coefficient = 0.91



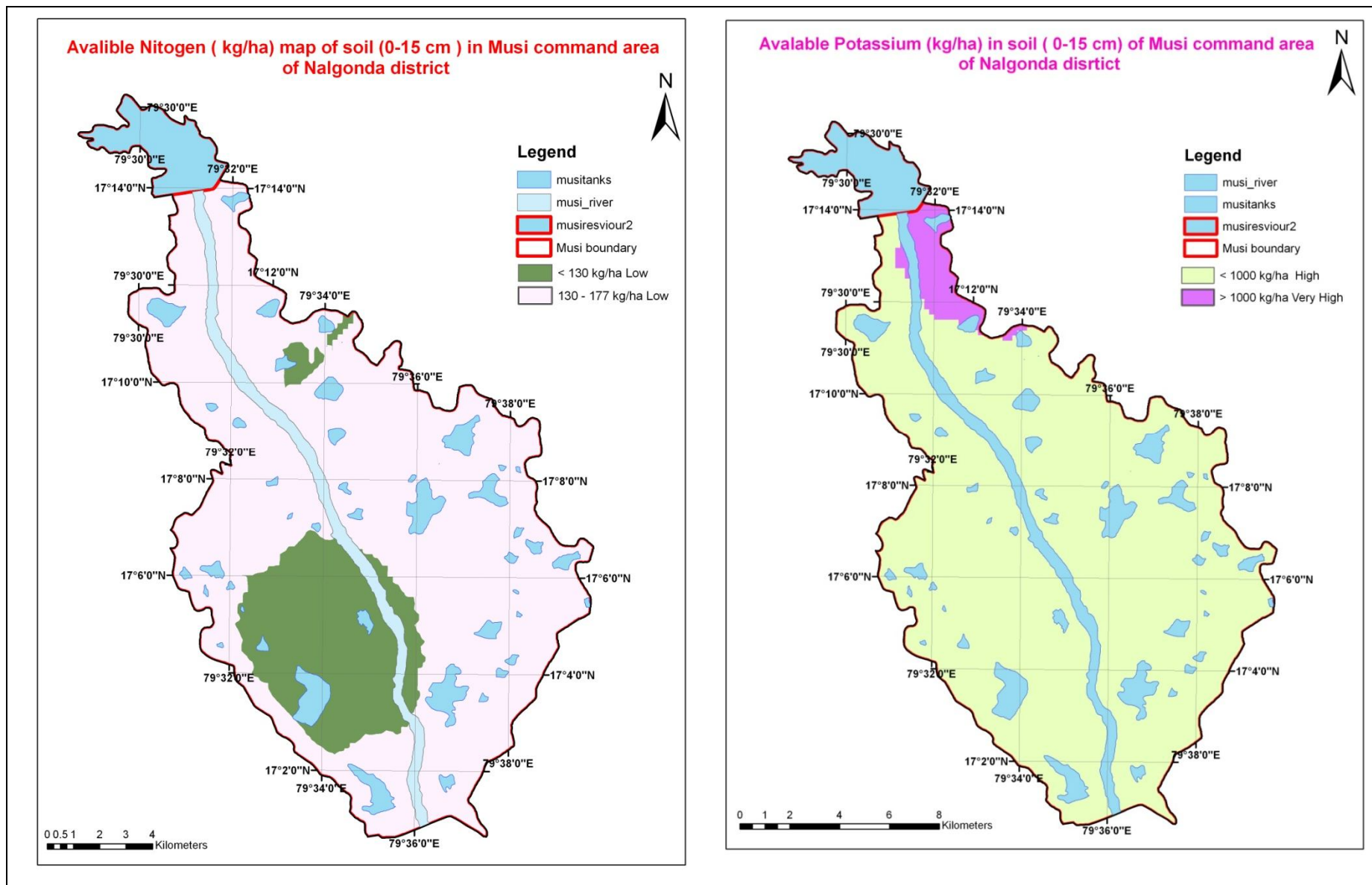


Fig. 4.13. Spatial distribution of soil (0-15 cm) available N and K in Musi command area of Nalgonda, district

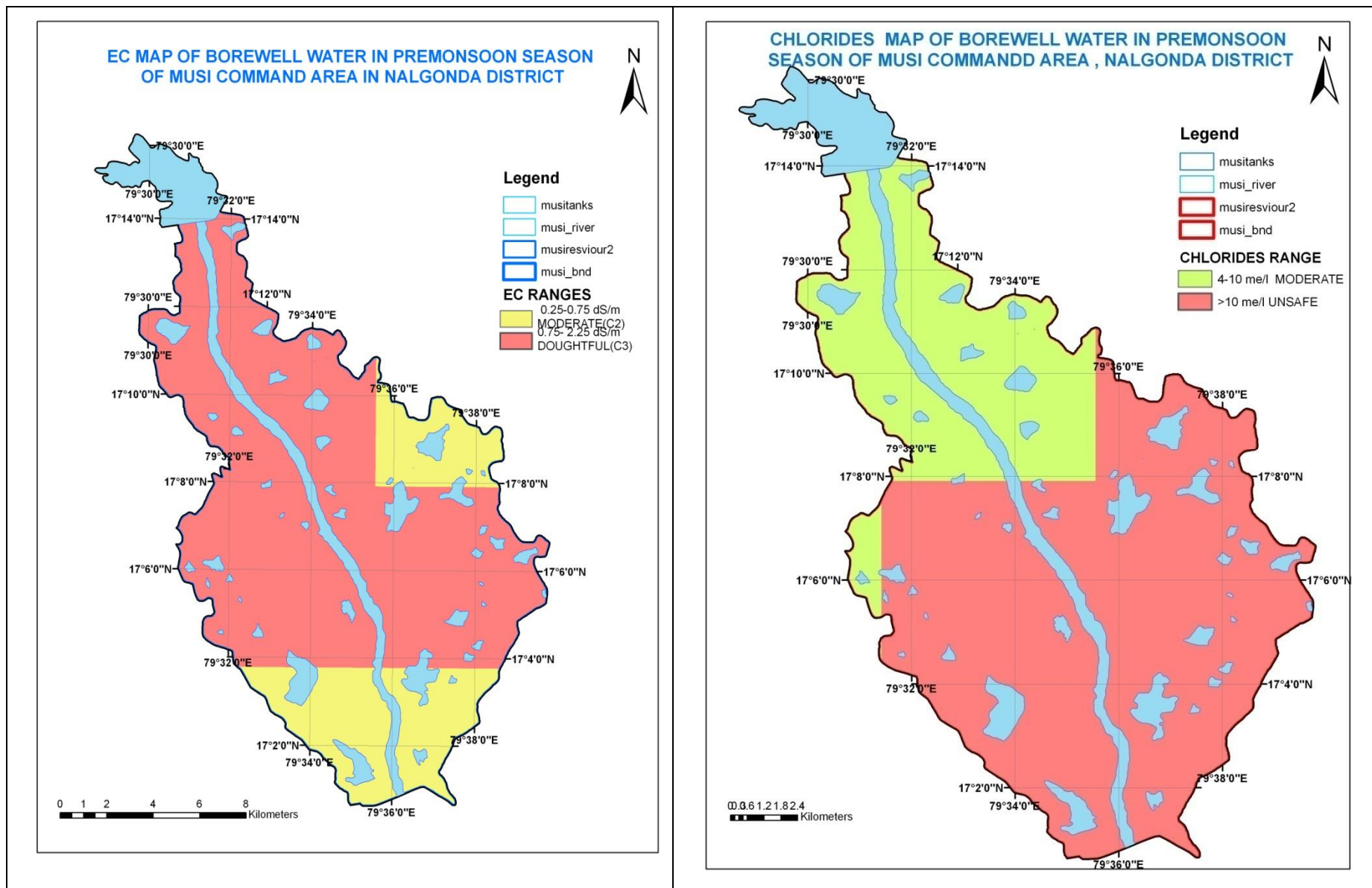


Fig: 4.2. Spatial distribution of pre monsoon bore well EC and chlorides in Musi command area of Nalgonda, district

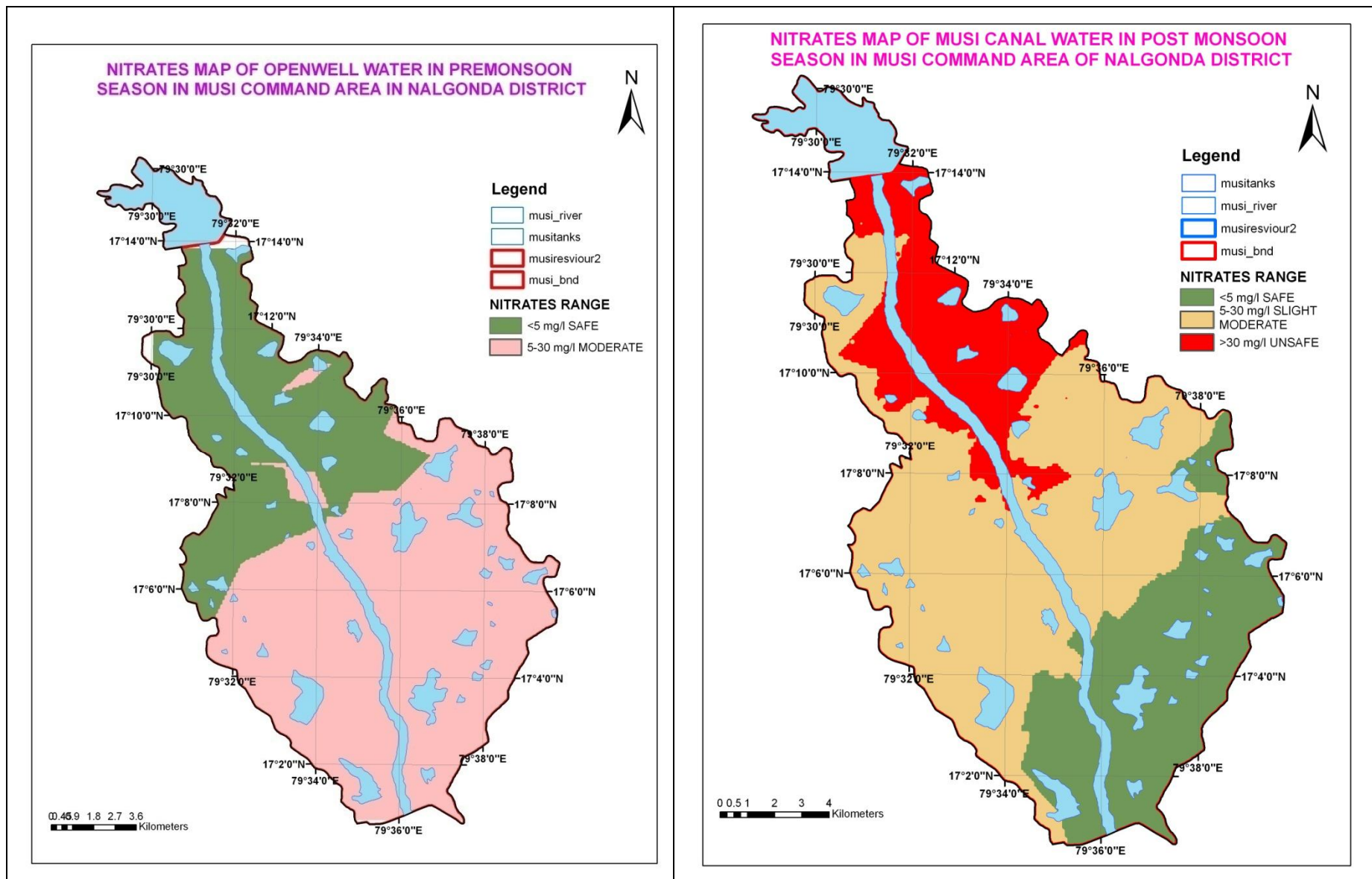


Fig: 4.6. Spatial distribution of Nitrates pre and post monsoon in Musi command area of Nalgonda, district

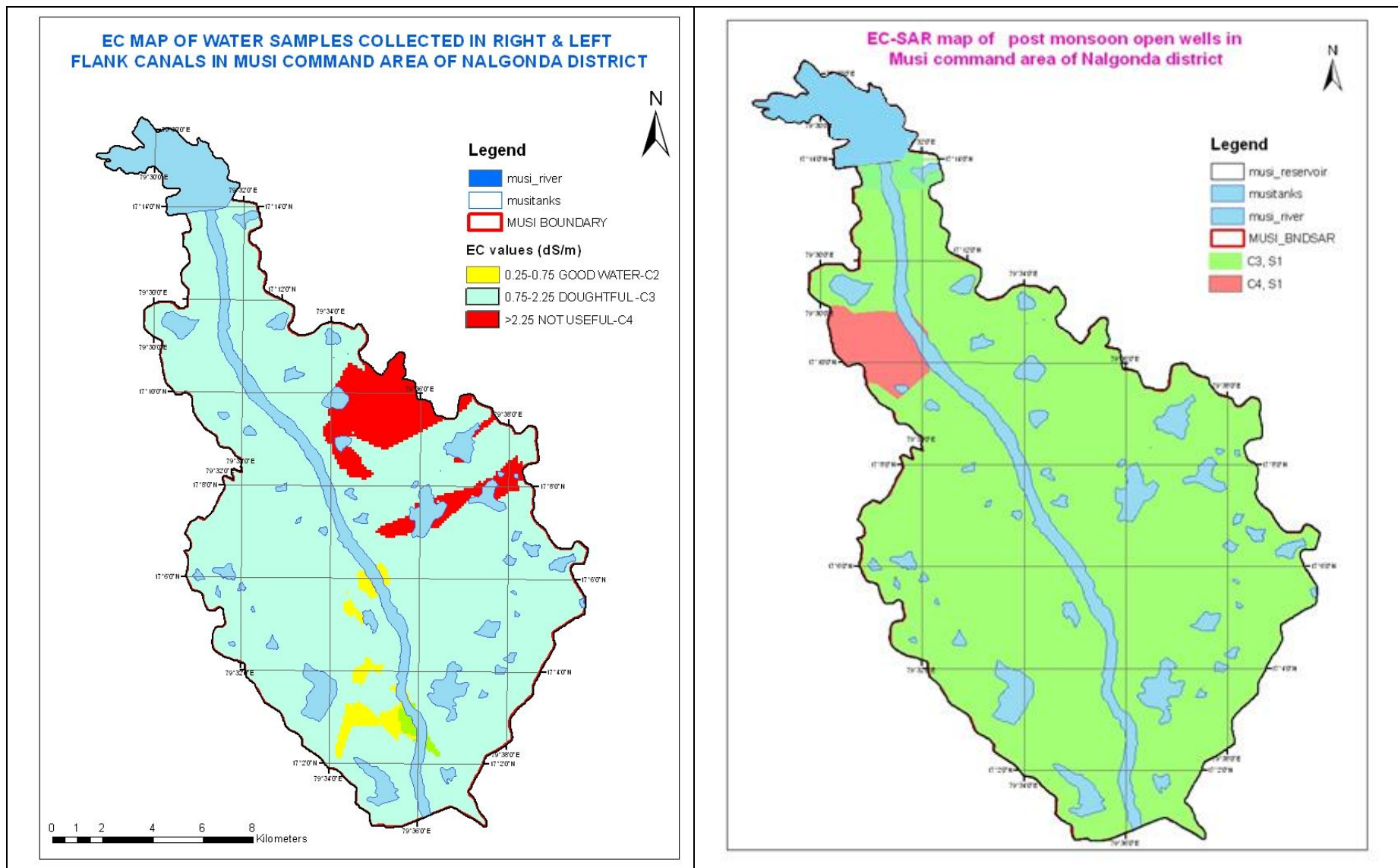


Fig.4.4. Spatial distribution of EC, EC-SAR map in post monsoon in Musi command area of Nalgonda, district

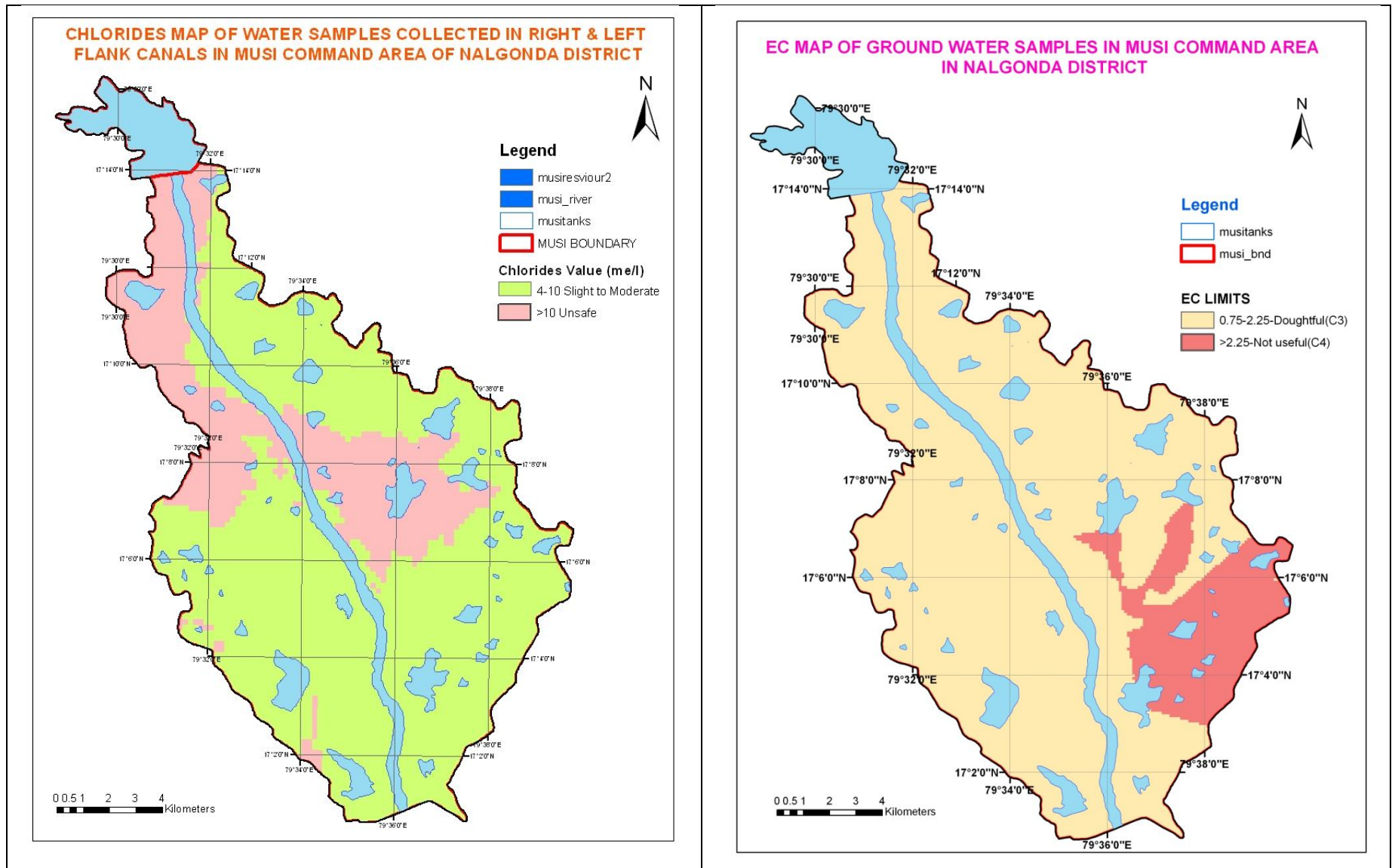


Fig. 4.7. Spatial distribution of chlorides and EC (ground water) in Musi command area, Nalgonda district

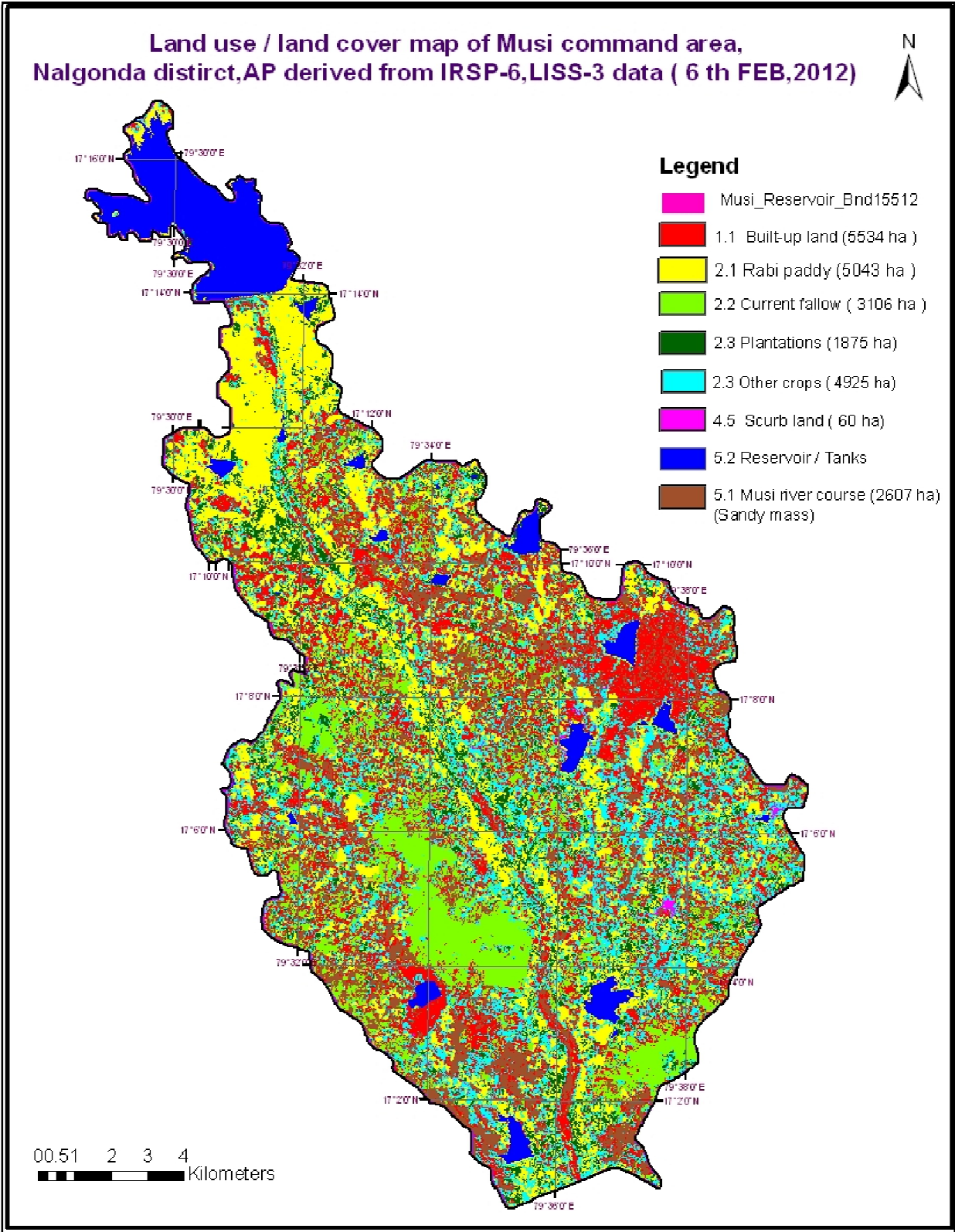


Fig.4.15. Land use / land cover map of Musi command area, Nalgonda district

CHAPTER V

SUMMARY AND CONCLUSIONS

A study has been conducted entitled “Characterization of water, soil, crops and land use/land cover mapping in Musi command area using remote sensing and GIS” during 2011-12. The irrigation water from three different sources viz., Musi project right and left flank canals during pre monsoon (June, 2011) (6) and post monsoon (January, 2012) (49), bore wells during pre monsoon (24) and post monsoon (14) and open wells during pre monsoon (28) and post monsoon (23) and surface (0-15 cm) soil samples (95) were collected during June, 2011, and rice plant samples (51) grown during *rabi* 2011-12 were analyzed for various constituents. Rice yield data was collected by crop cut in selected rice growing farmer’s fields (51) in Musi command area. Correlation among different water, soil quality parameters and rice yields were also worked out. Land use and land cover map of the study area was developed by using satellite data (LISS III of IRSP6. dated 6th February, 2012) using Erdas 9.3 and Arc GIS 9.3 softwares. Different water, soil and crop quality maps were generated by using the krigging function in Arc GIS.

The results obtained are summarized as below:

1. Regarding the **pH**, all the **canal** water samples collected during pre and post monsoon period were alkaline. **Bore well** water samples during both the seasons and open well samples during pre monsoon were neutral to alkaline. During post monsoon season all the **open well** samples were alkaline. In general pH increased from pre-monsoon to post monsoon period.
2. Regarding the **salinity hazard**, all **canal water** samples recorded high range of **EC** and majority (99%) of water samples were in C3 quality which can be used safely for rice but for other crops it should be used with certain limitations. Among the **bore wells** during pre monsoon 92 per cent of the samples collected were under C3 category which got reduced to 31% during post monsoon. Whereas, 8 per cent of samples under C4 category during pre monsoon changed to 69 per cent during post monsoon indicating the deterioration of water quality during post monsoon when compared to pre monsoon. Among the **open wells**, during pre monsoon, 81 per

cent of the samples were in C3 category which changed to 78 per cent during post monsoon. Whereas 19 % of the samples during pre monsoon were under C4 category changed to 22 % by post monsoon.

3. Related to sodium hazard, based on **sodium absorption ratio (SAR)**, almost all the samples from canal, bore wells and open wells during both the seasons were found to be under safe (S1) category.

4. Based on **EC and SAR**, among **canals**, all water samples collected during both the seasons were found to be under the class II (C_3S_1). Among **bore wells**, during pre monsoon, majority of samples (92%) were under class II (C_3S_1) and remaining 8 % were under class III (C_4S_1). But during post monsoon, only 31% were under class II (C_3S_1) and 69% were under class III (C_4S_1). Among **open wells**, during both the seasons, majority of samples (81 to 83 %) were under class II (C_3S_1) and remaining 17 to 19 % were under class III (C_4S_1).

5. Regarding bicarbonate hazard, during pre monsoon the **residual sodium carbonates (RSC)** were in safe category in **canal waters**, which got reduced to 79 (%) under safe (S1), and the rest were distributed under moderate (S2 : 17%) and unsafe category during post monsoon. Among the **bore well** samples, during pre monsoon period, 83 per cent of samples were in safe category and 17 per cent were moderate. During post monsoon period, all the samples were in safe category with regard to RSC. Among **open wells**, during pre monsoon only 10 per cent were safe and 90 per cent were unsafe and in post monsoon season, 83 % were moderate and 17 % were unsafe in open wells.

6. Among the specific ions, **chloride contents** were in slight to moderate category during pre monsoon in all the samples in **canal waters**, but during post monsoon, 70 per cent of the samples were in slight to moderate category and rest (30%) were under unsafe category. In **bore wells** during pre monsoon season, when 54 per cent were under slight to moderate and 46 per cent under unsafe category, during post monsoon season samples under slight to moderate category decreased to 36 % and under unsafe category increased to 64 per cent. Among **open wells**, about 34 per cent of samples were under slight to moderate category with 66 per cent of samples under

unsafe category in both pre and post monsoons respectively. **Fluoride** status in all the water samples was within the safe limits.

7. With regard to **nitrate contents**, among **canal water** samples, during pre monsoon, 33 per cent were under safe category and 67 per cent were under slight to moderate and during post monsoon, 62 per cent were under slight to moderate but 33 per cent were under unsafe category. Among **bore wells**, during pre monsoon season, 17 per cent were safe, 83 per cent were slight to moderate and during post monsoon 57 per cent were slight to moderate and 43 per cent were unsafe. Among **open wells**, during pre monsoon, 28 per cent were under safe and 72 per cent were under slight to moderate and during post monsoon season 55 per cent were under slight to moderate and 45 per cent were unsafe. **Ammonia** contents were within safe levels in all the water samples.

8. Limited samples were analysed for trace elements. The canal water samples collected during pre monsoon were safe with regard to **Cu, Zn, Fe, Mn, Cr, Co and Pb**. Among the canal waters, all the samples were found to contain unsafe levels of **Ni and Cd**, about 57 per cent of the samples collected were found to contain safe amounts of **Cu** and the rest (43 %) were having unsafe amounts of Cu. With regard to **Co**, 64 % of the collected samples were safe and the rest (36%) were unsafe in post monsoon period. Similar trends were noticed with regard to the water samples collected from bore wells and open wells collected during post monsoon.

9. Regarding **texture**, majority of the **soils** are sandy clay loam (70 %) followed by sandy loam (14%), sandy clay (7%), loamy (4%), clayey (3%) and clay loam (2%). Regarding **soil reaction** (pH-6.78 to 9.15) majority of the soil samples (55%) were moderately alkaline followed by slightly alkaline (29%), strongly alkaline (12%) and very less per centage of samples are in neutral range (4%). Majority of the soils (99%) are non saline and moderate salinity was noticed in only one per cent of soils ($EC-0.11-1.27 \text{ d S m}^{-1}$).

10. All the soil samples (0-15 cm) were found to be high ($12- 30 \text{ mg kg}^{-1}$) in **organic carbon**, low in **available N** ($129- 205 \text{ kg ha}^{-1}$) high to very high in **available P** ($18 -208 \text{ kg ha}^{-1}$) and

potassium (460-1298 kg ha⁻¹). There is a need to reduce the P and K fertilizer recommendation doses due to their high levels in soils.

11. Limited samples were analysed for trace elements. It was observed that all the samples were found to be sufficient in available **Fe** status. With regard to available **Mn**, 11 per cent of samples are found to be deficient and 89 per cent of samples were sufficient. With regard to **Cu**, 25 per cent of samples were deficient and 75 per cent of samples are sufficient. With regard to **Zn**, 22 per cent of samples are deficient and 88% of samples are sufficient. It was noticed that all the samples were within permissible limits with regard to **Cr, Co and Ni**. But all the samples were found to have **Cd and Pb** levels above the permissible limits.

12. **Thematic maps** on spatial variability of water quality (pH, EC, SAR, RSC, EC-SAR, Cl⁻, No₃⁻, F⁻) and soil fertility (pH, EC, available N and K) have been generated by ordinary krigging method available in the sub mode of interpolation in the spatial analyst tools of Arc map 9.3 GIS software

13. The **rabi paddy (variety - MTU 1010) yields** varied from 1050 kg ha⁻¹ to 8000 kg ha⁻¹ with the mean yield of 5120 kg ha⁻¹. The wide range of variations is attributed to insufficient availability of water due to limited release of canal water during the crop growth period. The yields were higher in case of head region (6025 to 8000 kg ha⁻¹) due to more water availability.

14. **In rice grain and straw samples**, it was observed that the **N, P, K, Fe, Mn, Cu and Zn contents** were in deficit to normal range but except **Cr**, other heavy metals (**Co, Ni, Cd and Pb**) were found to be beyond the threshold levels. It can be inferred that the heavy metals entering in to the Musi River due to the entry of industrial pollutants from urban areas, along its course could be responsible for the presence of heavy metals in unsafe quantities in rice grain and straw samples.

15. The **total uptake by rice** for N ranged from 5.30 to 92.11 kg ha⁻¹ with mean of 34.46 kg ha⁻¹. The total P uptake ranged from 1.22 to 42.5 kg ha⁻¹ with mean of 10.38 kg ha⁻¹. The total K uptake ranged from 8.72 to 149 kg ha⁻¹ with mean of 60.10 kg ha⁻¹.

16. Among **correlations**, the soil EC was positively and significantly correlated with organic carbon ($r = 0.29$), and available phosphorus ($r = 0.5$). Organic carbon was positively and significantly correlated with phosphorus at 1 per cent level of significance.

17. Paddy yield was positively and significantly correlated with available nitrogen, available phosphorus and potassium.

18. Post monsoon bore well pH was positively and significantly correlated with SAR, and fluorides. Post monsoon EC of bore well was positively and significantly correlated with nitrates, chlorides and ammonia. The SAR in open wells was negatively and significantly correlated with RSC in open wells.

19. Pre monsoon bore well pH was positively and significantly correlated with SAR ($r = 0.626$), and Fluorides ($r = 0.60$), EC was positively and significantly correlated with nitrates ($r = 0.45$) in open wells at 1 per cent level of significance. The RSC in bore wells was negatively and significantly correlated with chlorides.

20. From the **land use land cover map of Musi command area** developed, it could be inferred that among the eight classes, the rice crop occupied the highest area among all crops, covering 20.1 per cent (5043 ha) of the gross command area (24, 906 ha), followed by other crops 19.7 per cent (4925 ha), plantations 7.5 per cent (1875 ha). The built up area also (22.2 %) occupied a major portion of command area (5534 ha) followed by current fallow (12.4 %) (3106 ha), Musi river coarse (sandy mass) (10.2 %) (2608 ha) and to a small extent scrub land (0.024 %) (60 ha). The overall accuracy obtained was 94.2 % with kappa's co-efficient of 0.91.

Based on the results summarized it can be conclude that

As per USDA Hand Book on Agriculture No. 60, about all the Musi canal water samples were classified as C_3S_1 (Class II) which requires good water management practices. Among bore wells and open wells, during pre monsoon, majority of samples (81 – 92 %) were classified as C_3S_1 (Class III) and the remaining were under C_4S_1 (Class III). Though, this class III water is not suitable normally, can be used for tolerant crops (example paddy) with good drainage facility

and good management practices. With regard to specific ions, the nitrates and chlorides were in moderate category. The heavy metals Ni and Cd were found to be beyond the phytotoxic threshold levels.

Majority of the soil samples (55%) were moderately alkaline followed by slightly alkaline (29%), strongly alkaline (12%) and very less percentage of samples are in neutral range (4%). All soils are non saline, high in organic carbon, low in available N, high in available P and potassium. Among the micronutrients, about 22 to 25 % of samples were found to be deficit in available Cu and Zn and in these deficit soils, it needs to include these elements in fertilizer schedules. However there is a threat from pollution point of view with regard to the heavy metals, specially Cd and Pb.

The rice yields were high in the head region of Musi command area due to more availability of Musi project canal water, whereas in middle and tail end regions, crop suffered due to water stress. Analytical reports of rice grain and straw samples indicated the presence of heavy metals (Co, Ni, Cd and Pb) beyond the threshold levels.

The information generated from current existing land use/ land cover map of Musi command area can serve as a guide for computing irrigation crop water requirements as per the areas occupied by agricultural crops (rice and other crops) and irrigation planning can be done by the authorities, more scientifically for better water use efficiency.

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Note: The pattern of 'Literature cited' presented above is in accordance with the Guidelines for thesis presentation of Acharya N G Ranga Agricultural University, Hyderabad.

* Original not seen.

Annexure XI.A. Water quality limits for classification (USDA Hand book on Agriculture No - 60)

1. Critical limits for pH

pH of irrigation water	Indications
<6.0	Acidic
6.0-7.5	Neutral
>7.5	Alkaline

2. Critical Limits for EC

EC(dS m ⁻¹)	Class	Suitability for irrigation
<0.25	C1	Very good Water
0.25-0.75	C2	Good Water
0.75-2.25	C3	Doughtful
>2.25	C4	Not Useful

3. Critical Limits For SAR

Class	Sodium Hazard	SAR Value	Remarks
S1	Low	0-10	Little Or No Hazard
S2	Medium	10_18	Appreciable Hazard But Can Be Used With Appropriate Management
S3	High	18-26	Unsatisfactory For Most Crops
S4	Very High	>26	Unsatisfactory For Most Crops

4. Critical Limits For RSC

RSC value (me l ⁻¹)	Safety Limits	Remarks
<1.25	Safe	Water can be used safely
1.25-2.5	Moderate	Water can be used with certain management
>2.5	Unsafe	Unsuitable for irrigation

5. Critical Limits For Chlorides

Chlorides (me l ⁻¹)	Safety Limits
< 4	Safe
4 to 10	Slight to moderate
>10	Unsafe

7. Classification Of Water Based On EC & SAR

Class	Classes of irrigation waters considered	Suitability for irrigation
I	C1S1, C1S2, C2S1	Water is suitable for all types of soils crops, & in all conditions.
II	C2S2, C1S3, C2S3, C3S1, C3S2	This Water can be used for irrigation in case of good water management practices
III	C3S3, C1S4, C2S4, C4S1, C4S2	Though this water is not suitable normally, it can be used for tolerant crops with good drainage facility & management techniques
IV	C3S4, C4S3, C4S4	This Water is not suitable for irrigation.

6. Critical Limits for Nitrate-Nitrogen (FAO , Irrigation and drainage paper No 47)

Nitrate-N in mg l ⁻¹	Safety Limits
< 5	Safe
5 to 30	Slight to Moderate
> 30	Unsafe

8. The recommended maximum concentration for F is 1.0 mg/L

9. Threshold levels of trace elements for crop production

Element	Recommended maximum concentration (mg l ⁻¹)
Copper	0.20
Manganese	0.20
Iron	5.00
Zinc	2.00
chromium	0.10
Cobalt	0.05
Nickel	0.20
Lead	5.00
Cadmium	0.01

Annexure XI.B. Soil quality limits for classification

1. Soil Reaction

pH range	pH class
4.0 – 4.5	Extremely Acidic
4.5-5.0	Very Strongly Acidic
5.0-5.5	Strongly Acidic
5.5-6.0	Medium Acidic
6.0-6.5	Low Acidic
6.5-7.5	Neutral Soils
7.5-8.0	Low Alkaline
8.0-8.5	Medium Alkaline
8.5-9.0	Strong Alkaline
9.0-9.5	Very Strong Alkaline
9.5-10.5	Extremely Alkaline

2. Rating Chart for Electrical Conductivity in Soils

EC dS m ⁻¹	Remark
0 - 2	No adverse effect. Excellent growth
2 - 4	Sensitive. Some of the selective crops can be grown
4 - 8	Toxic. Growth of many crops affected
8 - 16	Very Toxic. Most of the crops fail
16 - 32	Extremely toxic. No plant growth

3. Soil organic carbon, available N, P, K ratings

Soil Nutrients	Soil Nutrients Fertility Ratings		
	Low	Medium	High
Organic carbon as a measure of available Nitrogen (%)	< 0.5	0.5-0.75	> 0.75
Available N as per alkaline permanganate method (kg ha ⁻¹)	< 280	280-560	> 560
Available P by Olsen's method (kg ha ⁻¹)	< 10	10-24.6	> 24.6
Available K by Neutral N, ammonia acetate method (kg ha ⁻¹)	< 108	108-280	> 280

4. Critical levels for micro nutrients in soils (Bhupal Raj *et.al*, 1996)

Nutrient (DTPA extractable)	Critical level (mg kg ⁻¹)	
	Red soil	Black soil
copper	0.20	0.30
Zinc	0.65	0.70
Iron	4.00	5.00
Manganese	2.00	3.00

5. Critical levels for heavy metals in soils (Chapman, 1975)

Metal	Soil (mg kg ⁻¹)
Cobalt	2.0
Nickel	2.0
Cadmium	0.5
Lead	5.0
Chromium	2.0

Annexure XI.C. Plant quality limits for classification

1. Critical levels for micro nutrients in plants

Nutrient (DTPA extractable)	Plant (mg kg ⁻¹)
copper	4
Zinc	10
Iron	50
Manganese	60

2. Critical levels for trace element in plants

Metal	Plant (mg kg ⁻¹)
Cobalt	0.1
Nickel	1.0
Cadmium	0.5
Lead	2.0
Chromium	1.0

Annexure II. Performa for collecting the information from farmers

S No	PARTICULARS	INFORMATION FROM FARMERS					
1	Name of the farmer						
2	Name of the village						
3	Latitudes(Easting's) (soil or water sample collection sites)						
4	Longitudes(Nothings)						
5	Elevation (meters above MSL)						
6	Source of irrigation						
7	No of wells						
8	Specification of motor (pump HP)						
9	Area under cultivation(acres/guntas /hactares)						
10	Soil type	Red soils / black soils					
11	Crops grown/ cropping history	paddy			ID Crops		
		2011-12	2010-11	2009-10	2011-12	2010-11	2009-10
11a	Kharif (crop name and variety/area)						
11b	Rabi (crop name and variety/area)						
11c	Summer (crop name and variety/area)						
12	Yields of the crops						
12a	Kharif (crop name and yield in bags /area)						
12b	Rabi (crop name and yield in bags /area)						
12c	Summer (crop name and yield in bags /area)						
13	Manures used for crops						

13a	Kharif (manure name /quantity-cart loads or truck loads/area)						
13b	Rabi (manure name /quantity-cart loads or truck loads/area)						
13c	Summer (manure name /quantity-cart loads or truck loads/area)						
14	Fertilizer used for the crops						
14a	Kharif (fertilizer name /quantity)						
14b	Rabi (fertilizer name /quantity)						
14c	Summer (fertilizer name /quantity)						
15	Opinion on quality of bore well water and experience						
16	Any other information						

S.NO	GPS NO	NAME OF FARMER	NORTHING	EASTINGS	ELEVATION	VILLAGE	MANDAL
1	472	ADAGUDI MALLIAH	17.30.30.0	79.30.44.5	612	BOPPARAI	KETHEPALL
2	238	SUNKARI YELLAIAH	17.13.19.8	79.30.37.8	595	BOPPARAI	KETHEPALL
3	245	SUNKARI KEASIAH	17.13.14.4	79.30.37.3	600	BOPPARAI	KETHEPALL
4	250	CHAKALI SATTIAH	17.13.12.5	79.30.33.5	616	KASANGH	KETHEPALL
5	253	V.CHINA VEKNATAYA	17.12.06.1	79.31.02.3	575	KASANGH	KETHEPALL
6	257	KANDULA NARASAIH	17.12.18.1	79.12.18.1	611	KASANGH	KETHEPALL
7	259	M.SUDARSHAN REDDY	17.11.49.8	79.30.44.6	594	KOSANGOI	KETHEPALL
8	262	BURGI .JITHENDER REDDY	17.11.53.5	79.30.31.9	589	KOSANGOI	KETHEPALL
9	265	CHITALURI.SAIDULU	17.11.48.5	79.29.47.5	602	GUDIWAD	KETHEPALL
10	266	RACHAKOND SAVAIAH	17.11.39.11	79.29.47.3	599	GUDIWAD	KETHEPALL
11	268	YADAV REDDY	17.11.5.1	79.30.10.3	746	KOTHAPET	KETHEPALL
12	269	K.VENAKATA NARASIAH	17.09.57.4	79.31.19.2	591	CHEKATIGI	KETHEPALL
13	270	CHINATAM RAMSUSEALA	17.09.44.6	79.31.52.4	794	RAMCHRAI	KETHEPALL
14	313	CH.NAGIAH	17.09.40.8	79.31.51.1	548	RAMCHRAI	KETHEPALL
15	271	NANDAYLA APPA REDDY	17.08.47.9	79.32.02.3	576	UPPALPAH	KETHEPALL
16	277	NANDAYLA SOMI REDDY	17.8.9.9	79.32.27.4	587	KOPPOLE	KETHEPALL
17	282	KOPPALA NARASIAH	17.07.26.6	79.33.33.4	534	KOPPOLE	KETHEPALL
18	283	JETTANGI VENKANNA	17.06.55.8	79.33.55.5	524	KOPPOLE	KETHEPALL
19	285	GADDAM MALLIAH	17.06.20.5	79.34.19.7	516	BHEMARAI	VEMULAP
20	293	SADACHARI.SALIKOLIMI	17.04.21.6	79.33.00.4	520	PAMULAP	VEMULAP
21	297	KONTHAM JAGAN REDDY	17.06.43.6	79.31.42.8	593	TUNGATUF	KETHEPALL
22	299	PALAVAI CHANDRAIAH	17.05.39.7	79.32.09.4	573	TUNGATUF	KETHEPALL
23	301	RAO NURSI REDDY	17.03.46.5	79.32.52.3	533	PAMULAP	VEMULAP
24	303	GOLI MARA REDDY	17.02.53.3	79.32.26.7	525	CHERLAGU	VEMULAP
25,26	305	N.JANAKI RAMIREDDY	17.03.01.2	79.31.33.5	530	BHEEMANI	VEMULAP
27	315	MUNTA LINGAREDDY	17.08.8.2	79.31.47.4	577	TUNGATUF	KETHEPALL
28	322	KORADALA LINGAYA	17.06.10.5	79.30.45.6	585	CHERUKU	KETHEPALL
29	324	PADURU RAGAVA REDDY	17.04.07.1	79.29.24.2	559	BATTUGUL	TIPPARTHI
30	328	NANDYALA SUDAKAR REDDY	17.04.2.7	79.29.22.1	610	YELLAMAG	TIPPARTHI
31	330	BHARATH REDDY	17.04.14.5	79.30.33.8	839	CHIRUMAF	VEMULAP
32	332	VENKAT REDDY	17.03.23.1	79.31.31.0	527	POREDDY	GUDEM
33	335	MEDA LAXMAYA	17.14.16.4	79.31.47.6	805	RATNAPUF	SURYAPET
34	336	MALA KRISHNA REDDY	17.13.53.5	79.31.33.8	670	R.PURAM	SURYAPET
35	339	BATTI NARAYANA	17.14.7.2	79.31.54.0	597	RATNAPUF	SURYAPET
36	341	DHARWATMANGTHA	17.13.23.5	79.32.45.2	628	RAMARAN	SURYAPET
37	345	PULSA DEVAIAH	17.11.27.7	79.32.21.5	605	YANDALAP	SURYAPET
38	350	JALA UPENDAER	17.11.26.0	79.32.55.1	603	TEKUMATL	SURYAPET
39	352	MADAGONDLA LAXAMIAH	17.11.14.9	79.33.40.3	598	DASARM	SURYAPET
40	354	GUNDAPALLI SAMALU	17.11.24.0	79.33.57.5	624	PINNAIPAL	SURYAPET
41	356	CHANDUPATLA VENKANA	17.10.50.3	79.34.30.6	593	PINNAIPAL	SURYAPET
42	359	VATTU VEERASWAMY	17.09.9.0	79.35.8.1	585	PILLALAM	SURYAPET
43	361	JAKKALI BUCHAYYA	17.09.33.6	79.35.09.6	615	PILLALAM	SURYAPET
44	369	HANUMANTHARAO	17.08.27.0	79.35.14.8	612	KUPPIREDY	SURYAPET
45	372	UNKNWN	17.09.23.0	79.35.31.7	514		
46	375	KOLLA SHEKAR REDDY	17.7.25.9	79.35.16.4	533	KT ANARAI	SURYAPET

47	376	NAGARA TEJA	17.07.06.0 79.35.38.7	536	SURYAPET SURYAPET
48	378	BANOTH SAKKU	17.06.49.7 79.35.41.1	551	NALA CHVI SURYAPET
49	380	SYOTHULA THOTAIAH	17.12.29.6 79.32.20.3	575	YANDALAP SURYAPET
50	382	NAKKA LINGAIAH	17.10.34.3 79.33.16.9	568	TEKUMATL SURYAPET
51	385	RACHAKONDA SATTIAH	17.10.52.7 79.33.57.3	560	PINNAIPAL SURYAPET
52	387	PABBU SAIDULU	17.10.49.9 79.33.51.1	567	PINNAIPAL SURYAPET
53	389	MALU INDRA REDDY	17.09.25.3 79.34.9.9	783	RAYANIGU SURYAPET
55	391	MALA RUKMA REDDY	17.09.30.8 79.34.29.8	567	RAYANIGU SURYAPET
56	393	M.RANGA REDDY	17.08.52.3 79.34.40.7	559	RAYANIGU SURYAPET
57	395	GONAGANTI VENKANNA	17.09.16.6 79.35.53.5	550	PILLALAM/ SURYAPET
58	403	MAHOBBOB VALI	17.09.55.9 79.35.48.3	585	PILLALAM/ SURYAPET
59	406	KAKKIRENI PICHYA GOUD	17.09.42.4 79.36.10.1	585	PILLALAM/ SURYAPET
60	407	CHINTAM RMSH RAMULU	17.09.45.7 79.36.52.5	575	SURYAPET SURYAPET
61	417	CH.MALLAIAH	17.10.43.9 79.30.43.1	570	KOTHAPET KETHEPALL
62	419	VEDA SANKAR	17.06.38.9 79.40.05.2	673	DURAJPALI CHIVMLA
63	421	VADLA UPENDAR	17.06.46.3 79.39.37.7	558	DURAJPALI CHIVMLA
64	422	BEZZAM SRINU	17.05.2.2 79.39.22.2	739	IMAMPET SURYAPET
65	424	NAGIRDY MOHAN REDDY	17.05.35.1 79.38.47.3	544	IMAMPET SURYAPET
66	431	JAMLA DHARAWAT	17.06.23.5 79.38.26.5	563	IDASAIGUI SURYAPET
67	433	JANUGI PICHYA	17.07.17.2 79.38.21.9	563	IDASAIGUI SURYAPET
68	436	METIBOINA VENKANNA	17.06.16.0 79.38.1.7	548	KESARAM SURYAPET
69	438	BUDIGA RAMULU	17.06.2.0 79.37.4.6	438	KESARAM SURYAPET
70	440	SANKARAMADDI RAM REDDY	17.05.50.6 79.36.20.4	500	KASARBAD SURYAPET
71	441	CHAKALI VENKANNA	17.06.47.8 79.36.26.2	511	KSMAVARI SURYAPET
72	444	JAKIR	17.09.43.6 79.29.02.0	641	KOPHLAPA KETHEPALL
73	446	DHARAWAT HUSSAIAN	17.05.27.2 79.37.27.9	524	RUPPALAT. SURYAPET
74	448	GURAKA VENKATRAMULU	17.05.0.4 79.36.30.9	484	SAKIPET SURYAPET
75	451	CHITTALURI SAIDULU	17.04.36.9 79.37.8.1	505	TKPAD SURYAPET
76	452	BOLKA LINGAIAH	17.03.40.2 79.38.16.0	518	ANAJPURA PENBAD
77	462	RAVULAPENTA SAIDULU	17.04.50.9 79.38.12.6	534	IMAMPET :PENBAD
78	463	LAKA PAKA JANKI RAMULU	17.03.43.8 79.37.25.2	522	IMAMPET :PENBAD
79	465	KALIVEMULA SAIDULU	17.3.13.9 79.37.12.0	452	ANAJPURA PENBAD
80	467	UTKUR NARSI REDDY	17.02.28.8 79.36.54.8	492	ANAJPURA PENBAD
81	468	UNKNOWN	17.02.1.0 79.36.49.8	477	DOSPAD DHANWAC
82	470	DONGARI SAMPATAIAH	17.01.9.2 79.36.54.5	463	DOSPAD DHANWAC
83	474	URA RAMANARAYANA	17.11.01.6 79.30.52.1	578	KOTHAPET KETHEPALL
84	476	URA YADAIAH	17.11.5.6 79.31.12.2	578	KOTHAPET KETHEPALL
85	477	NARRA VENKAT REDDY	17.07.29.0 79.32.22.7	580	TUNGATUF KETHEPALL
86	480	MANDADI RAMESH REDDY	17.06.29.8 79.32.45.7	586	TUNGATUF KETHEPALL
87	481	BADUGULA ANAND	17.05.52.8 79.33.13.4	552	BHEMARAI KETHEPALL
88	483	BOUNTHU SRIRAMULU	17.05.30.8 79.33.13.1	537	VEMULAP/ PAMULAP/
89	485	GOORA VENKATAIAH	17.04.39.2 79.32.53.0	516	PAMULAP/ VEMULAP/
90	486	PONNNAM NARASIAH	17.02.36.2 79.33.11.1	529	KALVALAP/ VEMULAP/
91	489	GOLIVENKAT REDDY	17.03.21.4 79.32.35.1	552	AMANGAL VEMULAP/
92	492	GADDAMEDI MALLAIH	17.02.24.8 79.32.35.0	503	KALVALAP/ VEMULAP/
93	495	HANUMALA SUDHAKAR REDD	17.02.28.6 79.31.29.3	503	BHEMANP/ VEMULAP/
94	496	POREDDY PRATAP REDDY	17.023.24.7 79.30.25.7	513	POREDDY/ VEMULAP/

95

500

GUDIPATI LAXMAREEDY

17.05.38.3 79.31.8.7

575

CHERKUPA KETHEPALI

SOURCE	DISTB NO	soil type	Area ha	S.NO	NAME OF FARMER	N kg ha-1
M ,OW	1	black soils	0.8	1	ADAGUDI MALLIAH	205
M	1	red soils	0.8	2	SUNKARI YELLAIAH	205
M	2	red soils	0.2	3	SUNKARI KEASIAH	205
M	3	black soils	0.4	4	CHAKALI SATTIAH	82.5
M,OW	D-3	black soils	0.8	5	V.CHINA VEKNATAYA	95
M	4	red soils	0.4	6	KANDULA NARASAIH	60
M	4	red soils	0.4	7	M.SUDARSHAN REDDY	60
M	5	red soils	0.4	8	BURGI .JITHENDER REDDY	60
M	5	red soils	0.4	9	CHITALURI.SAIDULU	60
M,BW	6	red soils	1.6	10	RACHAKOND SAVAIAH	205
M,OW	8	red soils	5	11	YADAV REDDY	82.5
M,BW	10	red soils	2	12	K.VENAKATA NARASIAH	60
M	10	black soils	0.8	13	CHINATAM RAMSUSEALA	90
M,OW	12	medium black soils	3.2	14	CH.NAGIAH	35
M	13	light soils	2.4	15	NANDAYLA APPA REDDY	90
M,OW	15	light soils	4.8	16	NANDAYLA SOMI REDDY	160
M,OW	R-6	red soils	0.4	17	KOPPALA NARASIAH	165
M,OW	R-8	black soils	0.8	18	JETTANGI VENKANNA	25
M,BW	23	medium black soils	0.4	19	GADDAM MALLIAH	110
M,BW	19	medium black soils	0.6	20	SADACHARI.SALIKOLIMI	102.5
M,BW	22	light soils	2	21	KONTHAM JAGAN REDDY	160
M	29	brownish red soils	0.4	22	PALAVAI CHANDRAIAH	45
M,OW	32	red soils	2	23	RAO NURSI REDDY	95
M,BW	28	medium black soils	1.8	24	GOLI MARA REDDY	160
M,BW	16	red soils	0.4	25,26	N.JANAKI RAMIREDDY	77.5
M,BW,OW	20	light soils	3.5	27	MUNTA LINGAREDDY	160
M,OW	29	red soils	1.2	28	KORADALA LINGAYA	160
M	28	medium black soils	3.5	29	PADURU RAGAVA REDDY	67.5
ID	25	red soils	1.2	30	NANDYALA SUDAKAR REDDY	90
M,OW	28,26	red soils	8	31	BHARATH REDDY	160
M,OW	SEEPAGE	black soils	2	32	VENKAT REDDY	85
M	1	light red soils	0.6	33	MEDA LAXMAYA	160
M,OW	2	light black soils	1.2	34	MALA KRISHNA REDDY	165
M,OW	3	light black soils	1.4	35	BATTI NARAYANA	160
BW CHECK	5	red soils	4	36	DHARWATMANGTHA	160
M,BW	7	red soils	0.8	37	PULSA DEVAIAH	150
M,OW	9	red soils	1.6	38	JALA UPENDAER	160
M,OW	10	red soils	2	39	MADAGONDLA LAXAMIAH	160
M,OW	12	red soils	0.6	40	GUNDAPALLI SAMALU	180
M	14 CH-75	red soils	1.8	41	CHANDUPATLA VENKANA	160
M,OW	14	red soils	1.4	42	VATTU VEERASWAMY	45
M,BW	14	red soils	0.8	43	JAKKALI BUCHAYYA	160
M,OW	14	black soils	0.4	44	HANUMANTHARAO	160
	14	medium black soils	0.8	45	UNKNWN	160
M,OW	14	light soils	1.2	46	KOLLA SHEKAR REDDY	125

M,OW	14	light soils	0.8	47	NAGARA TEJA	125
M,OW	4	red soils	1.2	48	BANOTH SAKKU	217.5
M,OW	9	black soils	1.2	49	SYOTHULA THOTAIAH	67.5
M,OW	9	medium black soils	0.4	50	NAKKA LINGAIAH	217.5
M,OW	10	medium black soils	0.4	51	RACHAKONDA SATTAIAH	160
M,OW	14	light soils	0.4	52	PABBU SAIDULU	215
M,BW	14	brownish red soils	2	53	MALU INDRA REDDY	160
M,OW	14	red soils	5	55	MALA RUKMA REDDY	160
M,OW	18	medium black soils	2.4	56	M.RANGA REDDY	160
M,OW,BW	16	red soils	1.2	57	GONAGANTI VENKANNA	160
M,OW	17	light soils	0.8	58	MAHOBBOB VALI	160
M,OW	20	red soils	1.6	59	KAKKIRENI PICHYA GOUD	240
M,BW	20	medium black soils	2.4	60	CHINTAM RMSH RAMULU	240
M,OW	OUT SIDE	red soils	3.6	61	CH.MALLAIAH	160
M,OW	29 A,B	red soils	1.2	62	VEDA SANKAR	160
M	30	black soils	1.2	63	VADLA UPENDAR	195
M,OW	29B	light red soils	2.4	64	BEZZAM SRINU	160
M,OW	29	red soils	5	65	NAGIRDY MOHAN REDDY	177.5
M,OW	28	red soils	0.6	66	JAMLA DHARAWAT	160
M,BW	29	red soils	2.8	67	JANUGI PICHYA	217.5
M,BW	Tank	red soils	0.4	68	METIBOINA VENKANNA	275
LA RDY CHR	Tank	red soils	0.4	69	BUDIGA RAMULU	275
ACHERVU T	Tank	red soils	0.4	70	SANKARAMADDI RAM REDDY	50
ACHERVU TANK		black soils	0.8	71	CHAKALI VENKANNA	160
EYOND STD	29	medium black soils	1.2	72	JAKIR	80
M	Tank	light soils	0.4	73	DHARAWAT HUSSAIAN	275
NDLA CHER	29	light soils	0.4	74	GURAKA VENKATRAMULU	275
M	35	red soils	0.8	75	CHITTALURI SAIDULU	160
M,BW,OW	32	black soils	2	76	BOLKA LINGAIAH	165
M	CHECK	medium black soils	2	77	RAVULAPENTA SAIDULU	160
BW CHECK	TAIL END	medium black soils	1.2	78	LAKA PAKA JANKI RAMULU	160
M ID CROP	RAINFED	light soils	1.6	79	KALIVEMULA SAIDULU	127.5
ID CROP	Tail END	brownish red soils	1.2	80	UTKUR NARSI REDDY	120
M,BW	NSP,OW	red soils	0.8	81	UNKNOWN	102.5
UTSIDE AREA		medium black soils	6	82	DONGARI SAMPATAIAH	210
M,OW	4	red soils	2	83	URA RAMANARAYANA	222.5
M	15	light soils	1.6	84	URA YADAIAH	165
M,OW	5 RIDGE CNI	red soils	0.6	85	NARRA VENKAT REDDY	160
M	7 RIDGE CNI	medium black soils	5	86	MANDADI RAMESH REDDY	165
M	7 RIDGE CNI	red soils	2.4	87	BADUGULA ANAND	240
M	29	medium black soils	1.1	88	BOUNTHU SRIRAMULU	215
M,OW	33	red soils	0.8	89	GOORA VENKATAIAH	215
M,BW	29	light soils	0.8	90	PONNNAM NARASIAH	275
M,OW	BW CHECK	red soils	1.2	91	GOLIVENKAT REDDY	192.5
BW CHECK	26	medium black soils	1.4	92	GADDAMEDDI MALLAIH	157.5
TANK,OW	24,25	red soils	0.8	93	HANUMALA SUDHAKAR REDD	275
M,OW	21	red soils	0.6	94	POREDDY PRATAP REDDY	165

M,OW

29

light soils

5

95

GUDIPATI LAXMAREEDY

115

P2o5 kg ha-1		kharif crops grown			kharif yeild uptained			kharif y
		2011-12	2010-11	2009-10	2011-12	2010-11	2009-10	2011-12
230 Nil		Rice	Rice	Rice	2800	2800	2800	7000
230 Nil		Rice	Rice	Rice	2800	2800	2800	7000
230 Nil		Rice	Rice	Rice	1700	1680	1800	4250
152.5 Nil		Rice	Rice	Rice	2100	2100	2800	5250
165	32.5	Rice	Rice	Rice	1680	1680	1960	4200
115 Nil		Rice	Rice	Rice	2240	2240	2500	5600
115 Nil		Rice	Rice	Rice	2100	2100	2100	5250
115 Nil		Rice	Rice	Rice	2240	2240	2240	5600
115 Nil		Rice	Rice	Rice	1680	1680	1680	4200
230 Nil		Rice	Rice	Rice	2100	2100	2100	5250
152.5 Nil		Rice	Rice	Rice	2240	2240	2240	5600
115 Nil		Rice	Rice	Rice	2800	2800	2800	7000
230 Nil		Rice	Rice	Rice	2100	2240	2100	5250
87.5	35	Rice	Rice	Rice	2400	2400	2800	6000
230 Nil		Rice	Rice	Rice	2400	2400	2800	6000
115 Nil		Rice	Rice	Rice	2200	2200	2450	5500
50 Nil		grren gram	cotton	Rice	1680	1680	1960	4200
25 Nil		Rice	Rice	Rice	2000	2240	2240	5000
115 Nil		Rice	cotton	cotton	2000	2240	2240	5000
115 Nil		Rice	Rice	Rice	2000	1680	1680	5000
115	75	Rice	Rice	Rice	2000	2450	2450	5000
120 Nil		cotton	cotton	cotton	2000	6 Q	2450	5000
165 Nil		green graa	Rice	rice	4000	2240	4000	10000
115 Nil		Rice	Rice	Rice	2240	2240	2450	5600
130	77.5	Rice	Rice	Rice	2200	2500	2500	5500
115 Nil		Rice	rice	rice	2200	2500	2500	5500
115 Nil		rice	redgram	castor	2200	3-4 q	2500	5500
172.5	145	rice	cotton	turmeric	2200	50 q	114 q	5500
230 Nil		cotton	cotton	redgram	5 q	4 00	800	5 q
115 Nil		Rice	rice	rice	2450	2800	2450	6125
187.5	35	rice	rice	rice	2240	2240	2240	5600
115 Nil		rice	rice	rice	1020	1400	1400	2550
50 Nil		rice	rice	rice	1120	1400	1400	2800
115 Nil		rice	rice	rice	1680	1800	1800	4200
115 Nil		rice	rice	rice	1680	1680	1680	4200
87.5	25	rice	rice	rice	2000	2100	2100	5000
115 Nil		rice	rice	green gran	2100	2240	400	5250
115 Nil		rice	rice	rice	2000	2140	2140	5000
120 Nil		rice	rice	rice	1680	1680	1680	4200
42.5	12.5	rice	rice	rice	1120	1120	1120	2800
115 Nil		rice	rice	rice	2800	2800	2800	7000
115 Nil		rice	rice	rice	2240	2240	2240	5600
115 Nil		rice	rice	rice	2240	2240	2240	5600
115 Nil		rice	rice	rice	2800	2800	2800	7000
172.5 Nil		rice	rice	rice	3150	2100	2100	7875

150 Nil	rice	rice	rice	2500	2500	2500	6250
115	75 Rice	Rice	Rice	2800	2800	2800	7000
72.5	50 Rice	Rice	Rice	2100	2100	2100	5250
115 Nil	gren gram	gren gram	gren gram	100	100	100	250
115 Nil	Rice	Rice	Rice	2100	2100	2100	5250
42.5 Nil	Rice	Rice	Rice	1960	1960	1960	4900
115 Nil	Rice	Rice	Rice	1960	2240	2240	4900
115 Nil	Rice	Rice	Rice	2240	2240	2240	5600
115	145 Rice	Rice	Rice	1680	1680	1680	4200
115 Nil	Rice	Rice	Rice	1680	1680	1680	4200
115 Nil	Rice	Rice	Rice	2800	2800	2800	7000
172.5 Nil	Rice	Rice	Rice	2520	2520	2520	6300
72.5 Nil	Rice	Rice	Rice	2520	2520	2520	6300
115 Nil	Rice	Rice	Rice	2440	2440	2440	6100
115	107.5 Rice	Rice	Rice	2210	2440	2240	5525
57.5 Nil	Rice	Rice	Rice	2100	2520	2440	5250
115 Nil	G.gram	G.gram	G.gram	2100	2520	2440	5250
85 Nil	Rice	G.gram	G.gram	2100	2240	2450	5250
115 Nil	Rice	Rice	Rice	2800	2450	100	7000
115 Nil	Rice	Rice	Rice	1750	2440	2100	4375
115	72.5 Rice	Rice	Rice	1680		1960	4200
115	72.5 Rice	Rice	Rice	2800	2440	2240	7000
50 Nil	Rice	Rice	Rice	2520	1680	2240	6300
115 Nil	Rice	Rice	Rice	2520	1680	1680	6300
57.5 Nil	Rice	Rice	Rice	2440	2440	1680	6100
115 Nil	G.gram	G.gram	G.gram	2210	2440	2440	5525
115 Nil	Rice	Rice	Rice	2100	1680	1680	5250
115	72.5 Rice	Rice	Rice	2100	2440	2440	5250
50	72.5 Rice	Rice	Rice	1020	2440	1020	2550
115 Nil	G+Rice	Rice	G+Rice	1020	2440	2100	2550
115	72.5	Rice	Rice	1020	2100	2500	2550
140	72.5			2520	700	2800	6300
157.5 Nil	Cotton	Redgram	Cotton	2520	2440	2100	6300
115 Nil				2440	2100	100	6100
165 Nil	Rice	Rice	Rice	2440	2100	2100	6100
50	72.5 Rice	Rice	Rice	2800	1680	1960	7000
50 Nil	Rice	Rice	Rice	1750	1680	2240	4375
115 Nil	Rice	Rice	Rice	1680	2800	2240	4200
50 Nil	Rice	Rice	Rice	2800	2240	1680	7000
172.5	217.5 G.gram	Rice	Rice	2520	10	1680	6300
42.5	115 Cotton,R.g	Rice	rice	2520	40	2800	6300
42.5	42.5 Rice	Rice	Rice	2440	2100	2520	6100
115 Nil	Rice	Rice	Rice	2440	2440	2240	6100
130	25 Rice	Rice	Rice	2440	2440	2240	6100
42.5 Nil	Rice	Rice	Rice	1020	2440	1680	2550
115 Nil	Rice	Rice	Rice	2100	1020	2450	5250
50	72.5 Rice	Rice	Rice	2100	2100	2450	5250

42.5

72.5 Rice

Rice

Rice

2100

2100

4000

5250

ield uptained (ha)		S.NO	NAME OF FARMER	Kharif manaures applied			khar 2011-12
2010-11	2009-10			2011-12	2010-11	2009-10	
7000	7000	1	ADAGUDI MALLIAH	3 trucks	3 trucks	nil	2800
7000	7000	2	SUNKARI YELLAIAH	nil	25 cart load	30 cart load	2800
4200	4500	3	SUNKARI KEASIAH	nil	4-5 tractors		1700
5250	7000	4	CHAKALI SATTIAH	nil	nil		2100
4200	4900	5	V.CHINA VEKNATAYA	nil	4 trucks	4 trucks	1680
5600	6250	6	KANDULA NARASAIH	nil	nil	nil	2240
5250	5250	7	M.SUDARSHAN REDDY	nil	nil	nil	2100
5600	5600	8	BURGI .JITHENDER REDDY	nil	nil	nil	2240
4200	4200	9	CHITALURI.SAIDULU	nil	nil	nil	1680
5250	5250	10	RACHAKOND SAVAIAH	nil	nil	nil	2100
5600	5600	11	YADAV REDDY	nil	nil	nil	2240
7000	7000	12	K.VENAKATA NARASIAH	nil	3 trucks	nil	2800
5600	5250	13	CHINATAM RAMSUSEALA	4 trucks	4 trucks	4 trucks	2100
6000	7000	14	CH.NAGIAH	Nil	Nil	4 trucks	2400
6000	7000	15	NANDAYLA APPA REDDY	Nil	Nil	nil	2400
5500	6125	16	NANDAYLA SOMI REDDY	1 trucks/acr	trucks/acr	trucks/acr	2200
4200	4900	17	KOPPALA NARASIAH	sheep pen 4 days			1680
5600	5600	18	JETTANGI VENKANNA		3 tractors	Nil	2000
5600	5600	19	GADDAM MALLIAH	Nil	Nil	Nil	2000
4200	4200	20	SADACHARI.SALIKOLIMI	Nil	Nil	Nil	2000
6125	6125	21	KONTHAM JAGAN REDDY	Nil	Nil	Nil	2000
6q	6125	22	PALAVAI CHANDRAIAH	3 trucks	2 trucks	Nil	2000
5600	10000	23	RAO NURSI REDDY	Nil	3 trucks	Nil	4000
5600	6125	24	GOLI MARA REDDY	Nil	Nil	Nil	2240
6250	6250	25,26	N.JANAKI RAMIREDDY	1 truck	Nil		2200
6250	6250	27	MUNTA LINGAREDDY	Nil	4 trucks	4trucks	2200
3-4 q	6250	28	KORADALA LINGAYA	Nil			2200
50 q	114 q	29	PADURU RAGAVA REDDY	Nil	4trucks	4 trucks	2200
4 00	2000	30	NANDYALA SUDAKAR REDDY	Nil	2 trucks		5 q
7000	6125	31	BHARATH REDDY	Nil	Nil	Nil	2450
5600	5600	32	VENKAT REDDY	Nil	2 tractor	Nil	2240
3500	3500	33	MEDA LAXMAYA	Nil	Nil	Nil	1020
3500	3500	34	MALA KRISHNA REDDY	Nil	Nil	Nil	1120
4500	4500	35	BATTI NARAYANA	Nil	Nil	Nil	1680
4200	4200	36	DHARWATMANGTHA	4 t	4trucks	4trucks	1680
5250	5250	37	PULSA DEVAIAH	5 tractor	5tractor	5 tractor	2000
5600	1000	38	JALA UPENDAER	Nil	Nil	Nil	2100
5350	5350	39	MADAGONDLA LAXAMIAH	5 tractor	5tractor	5 tractor	2000
4200	4200	40	GUNDAPALLI SAMALU	3 tractor	3 tractor	3 tractor	1680
2800	2800	41	CHANDUPATLA VENKANA	Nil	Nil	Nil	1120
7000	7000	42	VATTU VEERASWAMY	4 tratctor	4 tratcor	4 tractor	2800
5600	5600	43	JAKKALI BUCHAYYA	Nil	3 tractor	Nil	2240
5600	5600	44	HANUMANTHARAO	Nil	Nil	Nil	2240
7000	7000	45	UNKNWN	Nil	Nil	Nil	2800
5250	5250	46	KOLLA SHEKAR REDDY	Nil	Nil	Nil	3150

6250	6250	47	NAGARA TEJA	Nil	4 tratctor	Nil	2500
7000	7000	48	BANOTH SAKKU	5 tractor	5 tractor	Nil	2800
5250	5250	49	SYOTHULA THOTAIAH	Nil	Nil	5 tracotr	2100
250	250	50	NAKKA LINGAIAH	4 tratctor	4 tratcor	4 tractor	100
5250	5250	51	RACHAKONDA SATTAIAH	Nil	Nil	5 tractor	2100
4900	4900	52	PABBU SAIDULU	4 tratctor	4 tratcor	4 tractor	1960
5600	5600	53	MALU INDRA REDDY	2 tratctor	52tratcor	2tractor	1960
5600	5600	55	MALA RUKMA REDDY	4 tratctor	4 tratcor	4 tractor	2240
4200	4200	56	M.RANGA REDDY	1 tractor	Nil	Nil	1680
4200	4200	57	GONAGANTI VENKANNA	Nil	Nil	Nil	1680
7000	7000	58	MAHOBBOB VALI	4 tratctor	4 tratcor	4 tractor	2800
6300	6300	59	KAKKIRENI PICHYA GOUD	5 tractor	5 tractor	5 tractor	2520
6300	6300	60	CHINTAM RMSH RAMULU	Nil	Nil	Nil	2520
6100	6100	61	CH.MALLAIAH	Nil	Nil	Nil	2440
6100	5600	62	VEDA SANKAR	Nil	Nil	Nil	2210
6300	6100	63	VADLA UPENDAR	Nil	Nil	Nil	2100
6300	6100	64	BEZZAM SRINU	5 tractor	5 tractor	5 tractor	2100
5600	6125	65	NAGIRDY MOHAN REDDY	2 tractor	2 tractor	2 tractor	2100
6125	250	66	JAMLA DHARAWAT	6 tractor	6 tractor	6 tractor	2800
6100	5250	67	JANUGI PICHYA	4 tractor	4 tractor	4 tractor	1750
0	4900	68	METIBOINA VENKANNA	Nil	Nil	Nil	1680
6100	5600	69	BUDIGA RAMULU	6 tractor	6 tractor	6 tractor	2800
4200	5600	70	SANKARAMADDI RAM REDDY	4 tractor	4 tractor	4 tractor	2520
4200	4200	71	CHAKALI VENKANNA	2 tractor	2 tractor	2 tractor	2520
6100	4200	72	JAKIR	Nil	Nil	Nil	2440
6100	6100	73	DHARAWAT HUSSAIAN	Nil	Nil	Nil	2210
4200	4200	74	GURAKA VENKATRAMULU	Nil	Nil	Nil	2100
6100	6100	75	CHITTALURI SAIDULU	Nil	Nil	Nil	2100
6100	2550	76	BOLKA LINGAIAH	2 tractor	2 tractor	2 tractor	1020
6100	5250	77	RAVULAPENTA SAIDULU	Nil	Nil	Nil	1020
5250	6250	78	LAKA PAKA JANKI RAMULU	2 tractor	2 tractor	2 tractor	1020
1750	7000	79	KALIVEMULA SAIDULU		6-7 tractor		2520
6100	5250	80	UTKUR NARSI REDDY			4 tractor	2520
5250	250	81	UNKNOWN	Nil	Nil	Nil	2440
5250	5250	82	DONGARI SAMPATAIAH	Nil	Nil	Nil	2440
4200	4900	83	URA RAMANARAYANA		3tractor		2800
4200	5600	84	URA YADAIAH	2 tractor	2 tractor	2 tractor	1750
7000	5600	85	NARRA VENKAT REDDY		5-6 tractor		1680
5600	4200	86	MANDADI RAMESH REDDY	Nil	Nil	Nil	2800
25	4200	87	BADUGULA ANAND	Nil	Nil	Nil	2520
100	7000	88	BOUNTHU SRIRAMULU	Nil	Nil	Nil	2520
5250	6300	89	GOORA VENKATAIAH	Nil	Nil	Nil	2440
6100	5600	90	PONNNAM NARASIAH		2 tractor		2440
6100	5600	91	GOLIVENKAT REDDY	Nil	Nil	Nil	2440
6100	4200	92	GADDAMEDDI MALLAIH		2 -3tractor		1020
2550	6125	93	HANUMALA SUDHAKAR REDD	Nil	Nil	Nil	2100
5250	6125	94	POREDDY PRATAP REDDY	Nil	Nil	Nil	2100

5250	10000	95	GUDIPATI LAXMAREEDY	Nil	Nil	Nil	2100
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if yeild uptained		kharif yeild uptained (ha)		
2010-11	2009-10	2011-12	2010-11	2009-10
2800	2800	7000	7000	7000
2800	2800	7000	7000	7000
1680	1800	4250	4200	4500
2100	2800	5250	5250	7000
1680	1960	4200	4200	4900
2240	2500	5600	5600	6250
2100	2100	5250	5250	5250
2240	2240	5600	5600	5600
1680	1680	4200	4200	4200
2100	2100	5250	5250	5250
2240	2240	5600	5600	5600
2800	2800	7000	7000	7000
2240	2100	5250	5600	5250
2400	2800	6000	6000	7000
2400	2800	6000	6000	7000
2200	2450	5500	5500	6125
1680	1960	4200	4200	4900
2240	2240	5000	5600	5600
2240	2240	5000	5600	5600
1680	1680	5000	4200	4200
2450	2450	5000	6125	6125
6 Q	2450	5000	#VALUE!	6125
2240	4000	10000	5600	10000
2240	2450	5600	5600	6125
2500	2500	5500	6250	6250
2500	2500	5500	6250	6250
3-4 q	2500	5500	3-4 q	6250
50 q	114 q	5500	50 q	114 q
4 00	800	5 q	4 00	2000
2800	2450	6125	7000	6125
2240	2240	5600	5600	5600
1400	1400	2550	3500	3500
1400	1400	2800	3500	3500
1800	1800	4200	4500	4500
1680	1680	4200	4200	4200
2100	2100	5000	5250	5250
2240	400	5250	5600	1000
2140	2140	5000	5350	5350
1680	1680	4200	4200	4200
1120	1120	2800	2800	2800
2800	2800	7000	7000	7000
2240	2240	5600	5600	5600
2240	2240	5600	5600	5600
2800	2800	7000	7000	7000
2100	2100	7875	5250	5250

2500	2500	6250	6250	6250
2800	2800	7000	7000	7000
2100	2100	5250	5250	5250
100	100	250	250	250
2100	2100	5250	5250	5250
1960	1960	4900	4900	4900
2240	2240	4900	5600	5600
2240	2240	5600	5600	5600
1680	1680	4200	4200	4200
1680	1680	4200	4200	4200
2800	2800	7000	7000	7000
2520	2520	6300	6300	6300
2520	2520	6300	6300	6300
2440	2440	6100	6100	6100
2440		5525	6100	5600
2520	2440	5250	6300	6100
2520	2440	5250	6300	6100
2240	2450	5250	5600	6125
2450	100	7000	6125	250
2440	2100	4375	6100	5250
	1960	4200	0	4900
2440	2240	7000	6100	5600
1680	2240	6300	4200	5600
1680	1680	6300	4200	4200
2440	1680	6100	6100	4200
2440		5525	6100	6100
1680	1680	5250	4200	4200
2440		5250	6100	6100
2440	1020	2550	6100	2550
2440	2100	2550	6100	5250
2100	2500	2550	5250	6250
700	2800	6300	1750	7000
2440	2100	6300	6100	5250
2100	100	6100	5250	250
2100	2100	6100	5250	5250
1680	1960	7000	4200	4900
1680	2240	4375	4200	5600
2800	2240	4200	7000	5600
2240	1680	7000	5600	4200
10	1680	6300	25	4200
40	2800	6300	100	7000
2100	2520	6100	5250	6300
2440	2240	6100	6100	5600
2440	2240	6100	6100	5600
2440	1680	2550	6100	4200
1020	2450	5250	2550	6125
2100	2450	5250	5250	6125

2100

4000

5250

5250

10000

Appendix: 1.b.Salient features of the distributaries under Musi project in Left flank canal

Sl. No	Distributor No.	Distance from Main Canal starting point (km)	Length of distributor (km)	Catchment area (ha)	Cumulative catchment area (ha)	Cumulative catchment area (Acres)
1	D1 A	0.08 km	1.25 km	33.6	33.6	84
2	D 1	0.41	0.36	17.41	51.01	127.525
	Gopi Samudram Tank			36.03		
3	D1 B			142.5	193.51	483.775
4	D 2	2.78	0.91	69.33	262.84	657.1
5	D 4	4.14	0.85	97.53	360.37	900.925
6	D 5	5.82	7.36	419.67	780.04	1950.1
Cated duck bill 5.833 to 7.65 km, length 1.26 km, width 4.875, FSD 1.83, Q = 5.465 cumecs						
7	D 7		0.67	26.86	806.9	2017.25
8	D 8		1.22	76.16	883.06	2207.65
9	D 9		1.52	258.81	1141.87	2854.675
10	D 10		0.79	14.88	1156.75	2891.875
Cated duck bill weir 12.07 to 14.051 km, length 1.98 km, width 4.265, FSD 1.525, Q = 5.46 cumecs						
	Nalla Cheruvu			30.77		
11	D 11	-	-	32.41	1189.16	2972.9
12	D 12	12.08	0.61	66.96	1256.12	3140.3
13	D 13	12.63	0.49	24.34	1280.46	3201.15
	Subba Samudram Tank			89.88		
14	D 14	Sub dist- 12 No	12	1955.75	3236.21	8090.525
Cross Regulator 14.05 to 16.88 km, L = 2.85 km, W = 4.265 km, FSD = 1.525, Q = 5.46 cumecs						
15	D 15	14.08	-			
16	D 16	15.2	0.55	105.61	3341.82	8354.55
17	D 18	16.21	1	165.17	3506.99	8767.475
18	D 19	17.07	0.03	57.96	3564.95	8912.375
Cated duck bill weir 16.886 to 17.343 km, length 0.45 km, width 3.81, FSD 1.525, Q = 4.64 cumecs						
19	D 20	17.45	0.33	13.52	3578.47	8946.175
20	D 21	17.97	0.19	11.95	3590.42	8976.05
Cated duck bill weir 17.343 to 26.213 km, length 3.83 km, width 3.05, FSD 1.525, Q = 3.99 cumecs						
21	D 22	19.81	1.22	141.13	3731.55	9328.875
Cated duck bill weir						
22	D 23	20.39	0.36	10.78	3742.33	9355.825
23	D 24	21.11	0.67	57.15	3799.48	9498.7
24	D 25 A	22.07	0.49	12.54	3812.02	9530.05

Khammam Road						
25	D 25 B	24.08	0.76	118.43	3930.45	9826.125
Cated duck bill weir						
26	D 26	24.6	1.28	6.74	3937.19	9842.975
27	D 27	25.88	4.81	78.87	4016.06	10040.15
National High Way – Hyderabad To Vijayawada						
28	D 28A ,B	26.18	4.21	218.82	4234.88	10587.2
Km 26.213 to 27.798, L = 1.525 km, W = 3.05 km, FSD = 1.37, Q = 3.31 cumecs						
Km 27.798 to 32.552, L = 4.75 km, W = 2.74 km, FSD = 1.22, Q = 2.40 cumecs						
Km 32.552 to 33.985, L = 1.80 km, W = 2.44 km, FSD = 1.145, Q = 2.26 cumecs						
29	D 28 C	26.97	0.27	12.05	4246.93	10617.33
30	D 29	27.48	5.94	682.59	4929.52	12323.8
31	D 29 A	30.5	0.33	13.004	4942.524	12356.31
Cross Regulator						
32	D 29 B	31.4	1.04	18.78	4961.304	12403.26
33	D 29 C		0.06	39.22	5000.524	12501.31
34	D 29 D		0.12	39.22	5039.744	12599.36
35	D 29 E		0	8.44	5048.184	12620.46
Km 33.985 to 38.10, L = 4.85 km, W = 2.285 km, FSD = 1.145, Q = 2.265 cumecs						
Immapet Road						
36	DD 30	33	0.48	30.61	5078.794	12696.99
37	D 31	33.01	0.42	41.18	5119.974	12799.94
38	D 32	34.03	2.9	257.63	5377.604	13444.01
Km 38.10 to 40.233, L = 2.4139 km, W = 1.525 km, FSD = 0.685, Q = 0.96 cumecs						
39	D 33 A	34.14	0.24	69.25	5446.854	13617.14
40	D 33 B	34.96	0.38	13.09	5459.944	13649.86
41	D 34	35.03	1.1	103.7	5563.644	13909.11
42	D 35	36.09	1.13	92.8	5656.444	14141.11
43	D 36	36.31	1.16	99.01	5755.454	14388.64
44	D 37		1.152	67.04	5822.494	14556.24
45	D 38		0.73	35.21	5857.704	14644.26
46	D 39	38.23	0.33	296.76	6154.464	15386.16
47	D 40 A, B		1.07	100.95	6255.414	15638.54

Appendix.1.a Salient features of the distributaries under Musi project in Right flank canal

Sl. No.	Distributor No.	Distance from Main Canal starting point (km)	Length of distributor (km)	Catchment area (ha)	Cumulative catchment area (ha)	Cumulative catchment area (Acres)
1	D1	0.73	0.6	53.44	53.44	133.6
2	D2			54.13	107.57	268.925
3	D2A	1.64	0.76	53.16	160.73	401.825
4	D3	2.46	0.46	131.98	292.71	731.775
5	D4	4.4	2.44	189.56	482.27	1205.675
6	D4A	5.5	0.31	12.49	494.76	1236.9
7	D5	6.58	0.61	24.25	519.01	1297.525
8	D6	7.85	0.46	34.96	553.97	1384.925
9	D7	8.68	0.61	51.28	605.25	1513.125
10	D8	10.7	1.52	210.74	815.99	2039.975
National High Way Frm Hyd To Suryapet						
11	D9	12.07	0.46	47.84	863.83	2159.575
12	D10	12.9	1.52	163.33	1027.16	2567.9
13	D11	13.87	0.67	25.99	1053.15	2632.875
14	D12	14.48	1.52	205.91	1259.06	3147.65
Cross Regulator 15.10 Km						
15	D13	15.51	1.83	230.45	1489.51	3723.775
16	D14	15.94	0.46	90.28	1579.79	3949.475
17	D15	16.55	2.29	238.46	1818.25	4545.625
Ridge Canal Right Side						
18	D1		0.76	32.83	1851.08	4627.7
19	D2		0.46	26.1	1877.18	4692.95
20	D3		0.3	21.53	1898.71	4746.775
21	D4		1.22	107.21	2005.92	5014.8
22	D5		0.97	86.81	2092.73	5231.825
23	D6		1.46	113.39	2206.12	5515.3
24	D7		0.76	159.57	2365.69	5914.225
25	D8		2.44	184.09	2549.78	6374.45
26	D9		0.61	50.74	2600.52	6501.3
27	D10		0.61	75.28	2675.8	6689.5
28	D11		0.76	70.54	2746.34	6865.85
29	D12		0.76	81.6	2827.94	7069.85
30	D13		2.13	210.93	3038.87	7597.175
31	D14		0.61	81.66	3120.53	7801.325
32	D15		1.22	130	3250.53	8126.325
33	D.16	16.59	0.76	16.93	3267.46	8168.65

34	D17	16.64	0.61	12.35	3279.81	8199.525
35	D18	17.22	0.61	4.07	3283.88	8209.7
36	D19	17.74	2.13	140.82	3424.7	8561.75
37	D20	20.78	0.61	23.08	3447.78	8619.45
38	D21	22.08	1.37	101.9	3549.68	8874.2
39	D22	23.38	1.83	140.59	3690.27	9225.675
40	D23	23.83	2.44	233.1	3923.37	9808.425
41	D23A			7.26	3930.63	9826.575
Tail End Ridge Canal Right Side						
42	D24	0.18	3.96	319.01	4249.64	10624.1
43	D25	0.38	0.76	31.94	8499.28	21248.2
44	D26	0.95	1.22	99.51	8598.79	21496.975
45	D27	1.06	1.37	71.89	8670.68	21676.7
46	D28	2.25	2.13	202.65	8873.33	22183.325
47	D29	2.43	2.43	108.43	8981.76	22454.4
48	D30	3.1	4.11	205.89	9187.65	22969.125
49	D31	3.9	0.61	29.01	9216.66	23041.65
50	D32	4.57	0.76	69.08	9285.74	23214.35
51	D33	5.03	1.22	30.48	9316.22	23290.55
52	D34			79.34	9395.56	23488.9
53	D36			180.18	9575.74	23939.35
Tail End Ridge Canal Left side						
54	D24	23.36	0.46	29	9604.74	24011.85
55	D25	26.3	2.136	194	9798.74	24496.85
56	D26	27.22	0.91	113.97	9718.71	24296.775
57	D27	28.13	0.61	7.16	9805.9	24514.75
58	D28	29.29	0.61	9.73	9728.44	24321.1
59	D29	30.73	2.44	181.69	9987.59	24968.975

