CHARACTERIZATION AND SPATIAL FERTILITY STATUS OF BLACK SOILS OF BILAGI AND BAGALKOT TALUKAS

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By
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CERTIFICATE

This is to certify that, the thesis entitled "**CHARACTERIZATION AND SPATIAL FERTILITY STATUS OF BLACK SOILS OF BILAGI AND BAGALKOT TALUKAS**" submitted by **Mr. Sharanagouda, S. Mushtoor ID.NO. UHS15PGM629** for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE) in SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** of the University of Horticultural Sciences, Bagalkot, is a record of research work carried out by him during the period of his study in this university under my guidance and supervision. The data of this thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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DATE: July 2018

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BAGALKOT

JULY 2018 ***(SHARANAGOUDA, S. M.)***

Affectionately Dedicated to

My Beloved Parents

Shri. Shankaragouda and Smt. Boramma

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1. INTRODUCTION

Soil is one of the most important natural resource without which terrestrial life cannot sustain. Soil can be termed Soul of Infinite Life as it supports all life-forms directly or indirectly. Soil serves as media for plant growth to feed humans and animals and hence, it is one of the major sources of livelihood to most of the human population on earth.

In recent years, its importance is also recognized in maintaining human and animal health. It is very much evident that the soil's native ability to supply nutrients in sufficient quantity has declined over years due to intensive crop production. One of the greatest challenges to scientists and policy makers is to develop and implement soil, crop and nutrient management technologies that enhance not only the quality of soil, but also water and air. It is necessary to sustain the productive capacity of our fragile soils to support the food and fibre demand of our growing population.

Soil and land resources, in recent years are under tremendous pressure with highly competing and conflicting demands of rising population. In India, the burgeoning population is increasing at the rate of 2.1 per cent per annum. A large proportion of the land area in our country show clear evidence of soil degradation, which in turn is affecting the country's productive resource base. Over 50 per cent of the total geographical area is suffering from various forms of soil degradation. Salinisation and alkalization are the two processes of chemical deterioration by which saline and alkali soils produced.

Bagalkot district is categorized under arid and semi-arid agro-ecological regions. The geology of the district indicates the presence of lime in north-western parts while, sandstone dominates in the south eastern parts. The soils derived from easily weatherable lime based parent material associated with aridity, are likely to possess more salts. The groundwater in the deep layers accumulated over years is also likely to be saline and restricts its utilization for irrigation. Thus, both soils and groundwater exhibit salinity in Bagalkot district. The salts present in soil are likely to get redistributed with irrigation as the salts move from one region to other region (Bajwa, 2002).

Black soils are the important soils in semi-arid dry land agriculture as they are the most productive soils. The major contributing factor for the productivity of black soils in semi-arid environment is their high water holding capacity. These black soils have a capacity to store sufficient water for crop production. In arid and semi-arid areas, besides the concern over water and nutrient management, the growing land degradation process due to chemical soil degradation (salinization and/or sodification) also contributes to aggravate the unsustainable and variable declining crop yields. The land degradation process increases the dependence on agricultural inputs for crop production.

Most of the productive agricultural land occurs in the arid and semi arid regions of the world. Irrigation has brought mixed blessings to mankind. On one hand, it has transformed parched lands of arid and semi arid regions into highly productive lands. On the other hand, considerable areas of irrigated lands have become salt affected and barren. With the increase in irrigation potential more and more lands are becoming salt affected.

Salt affected black soils have inherent constraints due to their typical physical and chemical characteristic features which lower the crop productivity. Thus, the present study in Bilagi and Bagalkot talukas helps to find out the potential and the chemical constraints of these salt affected black soils through soil survey.

Soils chemical properties such as pH, EC, plant nutrient availability *etc.* are the indications of soil quality. These chemical properties of soils play an important role in determining the retention and availability of nutrients in soil. The nutrient supply in the soil depends on the level of organic matter, $CaCO_3$ and pH of the soil (Deshmukh, 2012).

The anthropogenic activities such as irrigation may occur by improper management of irrigation. Estimates of the area of salt-affected soils vary widely, ranging from 6 per cent to 10 per cent of earth's land area, and 77 million hectares (M ha) of irrigated lands. Crop yields are drastically affected due to lack of availability of water, nutrients, and oxygen in the root zone. The magnitude of yield reduction depends on the crop, soil type, and management. Crop yields can be enhanced by nutrient management (especially N), water management (irrigation with good quality water and appropriate drainage), use of soil amendments (manures and gypsum, *etc.*) and use of salt tolerant varieties. Nutrients leaching will occur under saturated soil conditions with water percolating downward through the soil profile. Therefore, the challenge under arid and semi-arid conditions is the proper management of crop fertilization and soil-water relations to enhance maximum and sustainable crop production.

Bagalkot district has been given the special status as hub of horticulture for the expansion of horticultural crops by considering the export potentiality. Incidentally, the soils in the district possess different magnitudes of salinity and nutrient availability. The available information above aspects is scattered. Hence, a detailed study of black soils in Bilagi and Bagalkot talukas would help to identify the degree of salinity, nutrient availability and their suitability for growing different horticultural crops.

Crop production in these soils is not satisfactory because of some soil related constraints. An attempt has been made in the present investigation to study the soils for nutrient availability in saline black soils of Bilagi and Bagalkot talukas with following well defined objectives.

1. Characterization of soils for electro chemical properties and free $CaCO_3$
2. Quantification of soils to assess major (primary and secondary) and micro nutrients
3. Correlation of available nutrients with soil chemical properties (pH, EC and free $CaCO_3$)

2. REVIEW OF LITERATURE

Soil salinity and alkalinity are two major threats of irrigated agriculture. Although the problems of salt-affected soils are known for quite some time, they deserve immediate attention as their magnitude and intensity have been increasing along with expansion of area under irrigation. In india out of 7 m ha of total salt-affected soils, 1.42 m ha area have deep black and medium black soils occurring mostly in the central peninsula India (Abrol and Bhumbla, 1981).

Salt affected soils usually occur in association with their normal counterparts, but distinguish themselves in having higher concentration of electrolytes and poor to extremely poor fertility status, resulting in restricted availability and uptake of nutrients by plants (Szabolcs, 1989). Extensive research work has been carried out both within and outside India on characteristics classification, reclamation and management of salt affected soils.

The build up of salt in any affected soil may influence crop production in several ways; through changes in the proportion of exchange and water soluble cations, soil reaction, physical properties of the soil and osmotic and specific ions and its effect on plant roots and soil microbes. Diagnosis and classification of salt affected soils is generally based on pH, electrical conductivity and carbonate content (Richards, 1954)

Essential nutrient availability and uptake is highly influenced by soil conditions. In black soils, nitrogen loss through volatilization process and phosphorus fixation through its reaction with free calcium decreases the availability. Further, high pH and presence of $CaCO_3$ reduces the availability of micronutrients through sorption and precipitation process (Sehgal, 1991). Thus, understanding the basic chemical properties of black soils is essential to overcome these constraints and come out with proper management of these soils for their sustainable and efficient utilization (Richards, 1954).

Black soils have inherent constraints due to their typical physical and chemical characteristics which can affect the crop productivity. Thus, the present study in Bilagi and Bagalkot talukas helps to find out the potentials and chemical properties of these salt affected black soils through soil survey. The review of the work done on the black soils is briefly presented below.

2.1 Soil-site characteristics

Murthy and Landey (1967) studied saline-alkali soils of Bellary district in Karnataka locally called as ‘Chuolu’, ‘Karl’ and ‘Jougu’. Chuolu and Karl soils were found in low-lands and depressions where rain water stands for long time due to restricted drainage. The soil ‘Juogu’ was found in depressions where water table was high and where soil remained wet due to impervious sub-soil horizon.

Mishra *et al.* (1975) studied the physiography and soils of Dewas district of Madhya Pradesh and reported that hill slopes and undulating plateau were dominantly under dry deciduous forest and had shallow and coarse textured soils with swell-shrink potential and mostly cultivated to rainfed crops like soybean and sorghum followed by wheat and bengal gram. Soils of gently to moderately sloping plain were moderately deep to deep, calcareous with vertic properties and cultivated with cotton and pigeon pea.

In a study on the effect of seepage and waterlogging on the development of saline and sodic soils in Bhadra project area of Karnataka, Bhadrapur and Rao (1977) observed that all low land soils were saline-sodic due to seepage from uplands. Minahas and Bora (1982) reported the effect of altitude on the soil properties and observed an increase in organic carbon and decrease in pH and calcium carbonate with increasing altitude.

Sharma *et al.* (1996) reported that the soils at elevated topography were shallow to moderately shallow, clayey to loamy-skeletal, yellowish brown while, the soils at lower topography were deep to very deep, fine to fine-loamy and grayish. The influence of topography was marked on soil properties such as pH, $CaCO_3$, clay content, vertic properties CEC and exchangeable cations.

Vadivelu *et al.* (1983) and Bhattacharyya *et al.* (1989) reported that soil site and climatic characteristics change with geographic units which in turn influence the land use pattern. They observed that hill ridges with shallow soils were mostly under forest with patches of rainfed crops. The pediment surface has shallow to deep soils while the soils occurring on plain and the flood plains were very deep soils.

Mruthunjaya and Gowda (1993) reported that the salt-affected soils from the Vanivilas command area of Karnataka are Inceptisols. They were medium deep, pale red to brownish yellow, and varied from sandy clay loam to sandy clay. The Vertisols were medium deep to very deep in depth and light grey to very dark grey in colour.

Padole and Deshmukh (1998) while studying the salt-affected soils of Purna valley of Vidarbha, Maharashtra used different approach for soil site suitability for alternative uses and concluded that all the interpretative system indicated that the soils *viz.* sodic Haplusterts and sodic Calciusterts are marginal for cotton. These soils have main constraints of high ESP with imperfect to poor drainage, very low hydraulic conductivity, AWC and $CaCO_3$. The soils *viz.* Aridic Haplusterts and Aridic Calciusterts are moderately suitable for cotton due to moderate limitation of drainage, AWC and $CaCO_3$. These soils have high potential and can be used to its optimum potential with some management corrections such as improvement of internal drainage, timely tillage operations, use of organics, use of gypsum in sodic conditions, provision of mulch, soil and water conservation method, appropriate selection of crops, proper crop rotation, selection of salt tolerant crops *etc.*

2.2 Electro chemical properties

2.2.1 Soil Reaction (pH)

Soil reaction indicates whether the soils are acidic, neutral or alkaline in nature. It plays an important role in determining the nutrient availability and biological activity. Soils with high pH values have shown positive influence on NH_3 losses (Fenn and Kissel, 1973). Losses of ammonia were higher at the field moisture range and in unreclaimed soils and generally ranged between 30 and 65 per cent depending upon the level of N applied and prevailing soil moisture conditions (Bharadwaj and Abrol, 1978; Rao and Batra, 1983).

According to Singh *et al.* (1980) the saline soils occurring in semi arid parts of the Indo-Gangetic plains had pH values ranging from neutral to alkaline. A tendency of gradual decrease of pH with depth in these soils was reported by Bhargava and Abrol (1978).

Virmani*et al.* (1982) reported that the factors such as the presence of $CaCO_3$, high content of bases, especially calcium and magnesium in the profile, were responsible for high pH and its variation with climatic change.

Gupta and Khosla (1982) ascribe the high pH observed in sodic soils due to low CO_2 in environments. A theoretical expression based on low salt Na- (Ca+Mg) exchange equilibrium in sodic soils is developed to quantitatively relate exchangeable sodium ratio with CO_2, pH, sodium concentration and ionic strength for calcareous sodic soils containing sodium carbonate. The pH of the system adequately describes the ESR and therefore, the exchangeable sodium percentage (ESP) of the soil.

Tiwari *et al.* (1983) reported that the soils in Kanpur region of Uttar Pradesh have higher pH. The pH of the soils varied from 8.5 to 10.3. Such high pH of soils was attributed to the presence of soluble sodium carbonate and bicarbonate.

The pH of the soils varied from 8.5 to 10.3. Such high pH of black soils was due to presence of high exchangeable cations on the exchange complex and due to calcareousness (Kaushal *et al.,* 1986). Further, it was observed that black soils had relatively higher pH value than sandy soils because imperfect drainage of black soils and also might be due to effective recycling of basic cations in black soils.

Prasad *et al.* (2001) reported that the black soils in Nagpur district showed the pH values ranging from 7.9 to 8.2 and the pH gradually increased down the depth. The black soils of Wardha district of Maharashtra were moderately alkaline and pH ranged from 7.9 to 8.4 (Kadao *et al.,* 2002).

In a similar study, Chalwade *et al.* (2006) studied the physico-chemical and macronutrient status of black soils (Vertisols of Parbhani and Nanded districts of Maharashtra) and reported pH values from 7.8 to 8.5 with a mean of 8.12. The pH varied from 7.1 to 8.2 with an average of 7.6 in sandy clay loam to clay textured soils of Jaunpur district, Uttar Pradesh (Raghubanshi and Singh, 2008).

2.2.2 Electric Conductivity (EC)

The upward movement of salts was also observed by Agarwal and Ramamoorthy (1970) and Bhadrapur and Rao (1979) in different irrigation areas by capillary movement.

The saline soils which are formed under the influence of continental and anthropogenic cycles, semi-arid parts of Indo-Gangetic alluvial plains had high EC values throughout the profile or in ilie profile substratum. (Poonia and Bhumbla, 1973; Bhargava *et al.* 1972; Abrol and Bhumbla,1972).

In alkali soils, the soluble salts decrease with increasing sodicity. Bhargava *et al.* (1976) reported that the presence of calcium carbonate prevents soils from sodification upon leaching when the soils are dominant with sodium chloride and sodium sulphate and high SAR values. Soils with sodium carbonate as predominant salt should be classified as alkali rather than saline alkali even if ECe is higher than 4.0 dS m^{-1}.

Krishnamoorthy and Govindarajan (1977) observed that in black soils electrical conductivity values ranged from 0.15 to 0.80 dSm^{-1} and showed increasing trend with depth.

Bhadrapur and Rao (1979) reported from a study of saline and sodic soils of the Tungabhadra project area that EC values for all the soil profiles throughout the depth were more than 4 dSm^{-1} indicating that they were saline. The EC values were highest in the surface layer which decreased with depth. They also opined that the large difference in EC values between the surface and subsurface layers 5 suggested the rapid upward movement of ions due to capillary rise of water.

Kharche (1990) reported a slight variation in EC with increasing depth due to leaching of salts from the surface through percolating water followed by evapo-transpiration resulting in the accumulation of salts in the surface horizon. The conditions facilitating accumulation of salts on the surface horizons and the absence of leaching from surface to lower depths, have been found to be responsible for increasing trend of the EC values in profile stratum upwards, while leaching of salts by irrigation water to the deeper layers and absence of rapid capillary rise were responsible for lower EC value in the surface layer (Sharma *et al.*, 2008).

In another study high electrical conductivity in lower depths was mainly due to leaching of salts from the upper layers and accumulation in the lower depths on account of irrigation (Balphande *et al.*, 1996).

Sharma *et al.* (1997) reported that the soil properties such as pH, $CaCO_3$, clay content, CEC and exchangeable cations were markedly influenced by the topography of the landscape.

2.2.3 Calcium carbonates

It is estimated that the calcareous soils cover more than 30 per cent of the earth surface, and $CaCO_3$ content varies from a few per cent to 95 per cent (Marschner, 1995). Calcareous soils occur naturally in arid and semi-arid regions because of relatively little leaching (Brady and Weil, 1999). Soils containing measurable quantities of native calcium carbonate are classified as calcareous soil. Calcareous soils are sometimes referred to as alkaline soils, but they are distinguishable with their high pH and carbonate contents of the alkaline earth metals *viz.*, calcium and magnesium (Talibudeen, 1981).

Calcareous soil affects the soil properties like physical and chemical properties such as fertility and the availability of plant nutrients (FAO, 1973).Calcareous soils are alkaline because of the presence of $CaCO_3$. The carbonates are sparingly soluble, moderately reactive and alkaline in nature; their dissolution results in high solution HCO_3^- concentration which buffers the soil in the pH range of 7.5 to 8.5, regulating the availability of essential nutrients (Lindsay, 1979).

The accumulation of $CaCO_3$ in soils might be due to semi-arid climatic conditions and drainage problems of the Rajasthan area. This may have facilitated the accumulation of $CaCO_3$ in these soils (Dhir *et al.,* 1979).

Sharma and Raychoudhari (1988) reported a gradual increase in $CaCO_3$ content with decrease in topographic level. Sharma *et al.* (1988) reported a gradual increase in $CaCO_3$ content with decrease in topographic level. Sehgal (1991) observed nodular $CaCO_3$ up to 20 per cent in black cotton soils. Solid phase calcium carbonate governed the phosphorus reactions and related to carbonate particle-size distribution.

Murthy (1988) reported the presence of calcium carbonate in Indian Vertisols either as concretion or in a finely powdered form which varied from 5 to 200 g kg^{-1}.Virmani *et al.* (1982) reported that the factors such as presence of $CaCO_3$, high content of bases, especially calcium and magnesium in the profile, were responsible for high pH and its variation with climatic change.

Subbaiah and Manickam (1992) studied the genesis and morphology of vertisols and noticed that the size and abundance of $CaCO_3$ concentration increased with soil depth. Murthy (1988) reported the presence of calcium carbonate in Indian vertisols either as concretion or in a finely powdered form which varied from 5 to 200 g kg^{-1}.

Vertisols of Vanivilas command area had lime content ranged from 1.00 to 7.87 per cent. The increase in the carbonate and bicarbonate concentration in the soil solution might have increased the lime content (Mruthunjaya and Gowda, 1993).

The calcium carbonate content of black soils of Wardha district varied between 2.00 and 19.80 per cent in different horizons and in general the content increased with depth (Kadao *et al.,* 2003). The CaCO3 ranged from 3.0 to 18.0 per cent with an average 7.38 per cent in black soils of Parbhani and Nanded districts of Maharashtra (Chalwade *et al.,* 2006).

The $CaCO_3$ content of coastal sandy soils of Guntur district, Andhra Pradesh ranged from 3.13 to 4.13 (Mydhili, 2006), while in sandy soils of Amritsar district, Punjab it varied from nil to 4.4 per cent with an average value of 1.1 per cent (Sharma *et al.* 2008).

The $CaCO_3$ content of black soils of Marh area of Jammu & Kashmir varied from 0.40 to 0.74 per cent (Pardeep Wali *et al.,* 2009), while in black soils of Katoltahasil in Nagpur district it ranged from 3.84 to 9.69 per cent with a mean value of 6.94 per cent (Jibhakate *et al.,* 2009) and in Ghataprabha left canal command area of north Karnataka ranged from 5.13 to 11.55 per cent and in Ausatahsil of Latur district were varied from 0.18 to 12.6 per cent (Waghmare *et al.,* 2009).

Binita *et al.* (2009) reported the calcium carbonate content of the black soils of GLBC command ranged from 5.13 to 11.55 per cent. Vertisols of India have calcium carbonate content generally ranging from 7.0 to 10.0 per cent (Dudal, 1965).

The $CaCO_3$ content of sandy loam soils of Ganapavaram pilot area of Nalgonda district of Andhra Pradesh ranged from 0.2 to 20.7 per cent (Rajeshwar *et al.,* 2009). In sandy soils of Degana district of Rajasthan $CaCO_3$ values varied from 0.50 to 4.00 per cent with mean value of 2.13 per cent (Yadav *et al.,* 2005).

Calcium carbonate content in the soil varied from 5.2-20.2 per cent, higher concretion of $CaCO_3$ was observed in majority of the samples it is attributed to alkaline pH. Soil indicated a tendency of precipitation of $CaCO_3$ during irrigation. Semi-arid climatic condition, characterized by low RF and high rate of evaporation favouring more accumulation and precipitation of $CaCO_3$ (Deshmukh, 2012).

2.2.4 Organic carbon

Organic matter content varied from 0.5 – 2.0 per cent in black soils more or less equally distributed in first meter of profile. High temperature in arid region, organic matter decomposition rate is very high and hence, the soil organic matter content is very low. Since, OM content is an indicator of available N, if soil low in OM its supplies low N to plants (More *et al.,* 1988).

Kharche (1990) studied the organic carbon status in black soils of Nagpur district and revealed that, it varied from 0.11 to 0.76 per cent. He further reported that as soil depth increases, organic carbon content decreases.

The surface soils recorded higher organic carbon values than sub-surface layers. High amount of organic carbon in surface soils could be attributed to dispersion of organic matter along with dispersed clay particles that comes to the soil surface during summer on account of capillary rise and gets deposited in isolated patches on soil surface. The decreased organic carbon content down the profile could also be attributed to the *in situ* incorporation of crop residues and addition of FYM and other organic manures to the soil surface every year (Balpande *et al.,* 1996).

Rao *et al.* (1995) reported low organic matter content in the black soils of Telugu Ganga project area in Nellore District and they attributed to high alkaline soil reaction (pH 8.2-9.4).

The organic carbon content in black soils of Wardha district of Maharashtra ranged from 1.4 to 8.7 g kg^{-1} (Kadao *et al.,* 2002). The organic carbon content in black soils of Ausatahsil of Latur district ranged from 0.18 to 0.87 per cent with a mean value of 0.52 per cent (Waghmare *et al.,* 2009). The organic carbon content of black soils of Ghataprabha left canal command area of north Karnataka ranged from 0.34 to 1.33 per cent (Binita *et al.,* 2009).

Laxminarayana and Rajagopal (2009) reported an organic carbon content which varied from 0.46 to 1.17 per cent in black soils of Andhra Pradesh. The soil organic carbon content varied from 1.0 to 16.0 g kg^{-1} in clayey soils of Lendi watershed, Chandrapur district of Maharashtra (Girish *et al.,* 2010). The organic carbon content of the black soils of Krishna western Delta, Andhra Pradesh varied from 0.27 to 0.62 per cent with an average per cent of0.49 (Srinivas *et al.,* 2011).

Patil (2011) reported that organic carbon content of soil ranged from 0.12 per cent Rastapur soil series of Vertisols to 1.18 per cent in Shirawali series of Alfisols. It ranged from very low to very high organic carbon content status in Kolhapur district of Maharashtra.

2.3 Primary nutrients

2.3.1 Nitrogen

Simultaneous and contrary-wise capillary movement of water in wet soils helps transport ammonical-N to the soil surface where it can be lost to the atmosphere (Fenn and Kissel, 1973). A direct relationship between NH_3 loss and evaporation of water has been shown by Fenn and Escarzaga (1977).

Nitant and Dargan (1974) reported that complete hydrolysis of N fertilizer at a pH of 10.4 was delayed by four days when compared with normal soils. This causes a gradual supply of NH_4^+ ions to the solution phase and consequently more volatilization losses.

In calcareous soils, ammonia loss can occur in the vicinity of hydrolyzing urea applied on the surface. Ammonium carbonate is produced upon urea hydrolysis, which dissociates to form NH_4^+, OH^- and CO_2.NH_4^+ forms NH_3 that may be lost by volatilization (Mortvedt *et al.,* 1999).

Hagin and Tucker (1982) reported that, application of ammonium fertilizers to calcareous soil does not helps in acidifying soil, due to presence of high carbonate content, that provides large buffer capacity where in the H^+ ions produced do not alter the soil pH to an appreciable extent.

Losses of ammonia were higher at the field moisture range and in unreclaimed soils of Karnal, Haryana. It generally ranged between 30 and 65 per cent depending upon the level of N applied and prevailing soil moisture conditions in alkali soils (Rao and Batra, 1983).

Yeresheemi *et al.* (1999) studied on macro and micro nutrient status of some salt affected Vertisols of Upper Krishna command area. They indicated that the study area had very low amounts of alkaline mineralisable N (46.0 to 162 kg/ha) which decreased with the profile depth. The low levels may be ascribed to several factors such as lower organic carbon, resulting from sub-optimal plant growth, high pH and high $CaCO_3$ content in the soil series under investigation, favouring higher ammonia volatilization losses and reduced nitrification and subsided activity of N-fixing microbes.

In a study of distribution of available N in semi-arid region of Rajastan, Kumawat (2000) observed that soils mostly low in clay content and low to very low in organic carbon, showed a decreasing trend of available N with depth. There was a linear relationship between organic carbon and available N. Lower clay content, with pH 7.8 to 8.5 was responsible for low CEC and retention of ammonium ions on exchange complex, leading to lower N availability.

Najar *et al.* (2005) assessed the status of some salt affected soils of Jammu and Kashmir at different locations for macro and micronutrients and recorded that the contents of available N ranged from 82 to 144 kg/ha in the surface layers and decreased with depth.

Prasad *et al.* (2008) reported the nutrient status of soils in Ramachandrapuram Mandal of Chittoor district in Andhra Pradesh. The available nitrogen content of surface soil samples varied from 54 to 103 kg ha^{-1}. Low nitrogen status of soil could be attributed to low amount of organic carbon in these soils. The available phosphorus and potassium contents varied from 9.29 to 23.96 kg ha^{-1} and 135-320 kg ha^{-1} respectively.

Pulakeshi *et al.* (2012) studied on nutrients status of Mantagani village under northern transition zone of Karnataka. They reported that the available nitrogen content was low in major portion of the study area (605 ha) which might be due to low organic matter content in soils. The total nitrogen content in the soils was dependent on temperatures rainfall and altitude. Low organic matter content in these areas due to low rainfall and low vegetation facilitate faster degradation and removal of organic matter leading to nitrogen deficiency.

Singh *et al.* (2013) analysed the fertility status of alluvial and medium black soil and ravinous, Chambal region of Madhya Pradesh. The range of available N were 126 to 361 kg ha^{-1} in alluvial soil; 178 to 408 kg ha^{-1} in medium black soil and 125 to 301 kg ha^{-1} in ravinous land, respectively.

2.3.2 Phosphorus

Studying the availability of P in salt affected soils of Uttar Pradesh, Bina Devi and Varshney (1979) noticed that available P was positively and significantly associated with soil pH and moisture. High pH of salt affected soils which might have contributed to enhanced mineralization of organic P was attributed to be the cause. The reduction in available P subsequent to rainy season was attributed to the interference caused by enhanced concentration of various ionic species in the soils and decreased moisture status due to rapid evaporation.

Ahmad *et al.* (1992) reported that when super phosphate is applied to alkaline calcareous soils, about 49-59 per cent and 14-19 per cent is converted into insoluble calcium phosphate and aluminum phosphate respectively, while water soluble fractions ranged from 5-9 per cent only.

Availability of P in air dry and waterlogged conditions was compared in salt affected soils by Srivastava and Srivastava (1993). It was noticed that in air dry soils, with the increase in pH from 7.3 to 10.8, availability of P increased linearly. The increased availability of P in soils saturated with sodium was attributed to accelerated dissolution of Ca-P compounds or complexes this is due to the creation of sink for calcium. They recorded an increase of 6.1 ppm in available P in air dried soils with each unit increases in soil pH, whereas the increase in P per unit pH increase in waterlogged soils was 7.5 ppm.

In calcareous soils, precipitation of insoluble Ca-P formation is considered to be the major factor for P unavailability (Bramley *et al.,* 1992). Fixation of P is a serious problem in alkaline and calcareous soils (Sharif *et al.,* 2000).

Phosphorus availability is very much limited in calcareous soils around the globe hampering most of the crop yield. At higher pH values, phosphate anions react with Ca and Mg to form phosphate compounds of limited solubility (Rahmatullah, 1994; Mortvedt *et al.,* 1999).

Studies of Westermann and Leytem (2003) indicated that in alkaline and calcareous soils, precipitation of P to insoluble Ca-P is generally the most controlling process for tying up of P and reducing its availability for the crops. More specifically, as lime content (Ca concentration) increased in the soil, P availability to plants decreased.

Viswasarao *et al.* (2005) observed that the available P_2O_5 content of the black soils of Krishna western delta region of Andhra Pradesh varied from 8.7 to 44.9 kg P_2O_5 ha^{-1} with a mean of 20.1 kg P_2O_5 ha^{-1} (Venumadhav and Prasadrao, 2003) and in Krishna district of Andhra Pradesh, it was low to medium. The black soils of Krishna district of Andhra Pradesh reported low to medium available phosphorus (Viswasa Rao *et al.,* 2005).

Fuleky (2006) studied the P supply of thirty six Hungarian soils, collected from the soil bank, by determining the inorganic phosphate fractions. The P fractions analysed were absorbed phosphates, easily soluble Ca phosphates, Al bound phosphates, Fe phosphates and hardly soluble Ca phosphates. The observations showed that the accumulation of P in the form of sparingly soluble Ca phosphates were predominant and easily soluble Ca-P and Fe-P were present in lesser degrees and served as main phosphorus source for the plants in calcareous soils.

The available phosphorus content varied from 10 to 25 ppm in the black soils of Guntur district, Andhra Pradesh (Satish *et al.,* 2008). The black cotton soils of

Ghataprabha left canal command area of north Karnataka had medium to high available phosphorus content and it ranged from 12.0 to 38.0 kg ha^{-1} with mean value of 22.3 kg ha^{-1} (Binita *et al.,* 2009). Waghmare *et al.* (2009) reported that available phosphorus content varied from 4.22 to 24.98 kg ha^{-1} with mean value of 14.29 kg ha^{-1} in black soils of Ausatahsil of Latur district, Maharashtra.

2.3.3 Potassium

The availability of K in alkali soils generally been reported to be adequate, the main reason being the predominance of K rich micaceous minerals in soils of arid and semi-arid regions (Kapoor *et al.* 1981). Dissolution of muscovite saturated units released large amount of K in sodic soil environments (Pal, 1985).

The available potassium was medium to high in most of the soils of the Karnataka state except in lateritic soils of coastal plain and Western Ghats and in shallow red and black soils (Prasad *et al.,* 1976).

Available potassium and magnesium are usually adequate supply in calcareous soils due to native high levels of exchangeable K and Mg, which are hardly leached in low rainfall regions (Brady and Weil, 1999).

Relatively higher levels of available K found in the soils of Upper Krishna command area. It could be attributed to predominance of K-rich micaceous minerals in arid region soils and their dissolution under salt-affected conditions (Yeresheemi *et al.,* 1999).

The low potassium content in these black sandy soils might be due to high crop removal of potassium from soils and very low use of potassic-fertilizers by farmers. Similarly low to medium content of potassium in coastal soils of Guntur district was observed by Babu *et al.* (2010).

Pulakeshi *et al.* (2012) conducted a survey to assess available nutrient status of soils of Mantagani village in North Karnataka by GIS technique in black and red soil, the available nitrogen, phosphorus and potassium content ranged from 179-303 kg ha^{-1}, 21-35 kg ha^{-1} and 202-417 kg ha^{-1} respectively.

The available K content in Kabeerdham district of soil ranged from 208 to 821 kg ha^{-1} with an average value 446.2 kg ha^{-1}. The 88.89 per cent tested soil samples were in high level of available K and only 11.11 per cent samples were tested under medium range. High K attributed to the prevalence of K-rich clay minerals like illite and kaolinite Kumar *et al.* (2014).

2.4 Secondary nutrients

2.4.1 Calcium and Magnesium

In calcareous soils, the proportion of Ca to other exchangeable cations generally exceeds 80 per cent, and a low proportion of exchangeable Mg (<4%) may lead to Mg deficiency in plants (Hagin and Tucker, 1982).

The available Ca and Mg content in sandy soils of Jaipur district of Rajasthan ranged from 671 to 705 and 262 to 318 mg kg^{-1}, respectively with a mean of 682 and 285 mg kg^{-1} respectively (Gathala *et al.*, 2004).

Kabaria and Polara (2006) reported that the exchangeable Ca and Mg ranged from 5.08 to 33.04 and 2.5 to 20.9 cmol (p+) kg^{-1} with a mean value of 20.6 and 11.66 cmol (p+) kg^{-1} respectively in coastal soils of Amreli district of Gujarat.

Pulakeshi *et al.* (2012) studied on nutrients status of Mantagani village under northern transition zone of Karnataka. They reported that major portion of the study area was sufficient in exchangeable Ca and Mg status. Ananthanarayana *et al.* (1986) reported higher exchangeable Ca and Mg contents in black soils than red soils.

2.4.2 Sulphur

Sulphur as an essential secondary element, is becoming deficient due to continous use of sulphur free fertilizers, growing high yielding varieties and intensive cropping with high sulphur requiring crops. Several factors also influence the availability of sulphur in soil.

Ramesh *et al.* (2003) reported that the surface horizons in black soils of Prakasam district of Andhra Pradesh were rich in available sulphur than subsurface layers. The available sulphur content was found to be sufficient in surface and deficient in subsurface layers in black soils of Guntur district, Andhra Pradesh with values varying from 3.9 to 15.3 ppm (Satish *et al.,* 2008)

Pulakeshi *et al.* (2012) studied on nutrients status of Mantagani village under northern transition zone of Karnataka. They reported that the area under study was medium to low in available sulphur status with 181 and 126 ppm per ha, respectively. Low and medium level of available sulphur in soils of the area may be due to lack of sulphur addition and continuous removal of S by crops (Balanagoudar, 1989).

2.5 Micro nutrients

Out of seventeen essential plant nutrients required for plant growth, seven are required in much smaller quantities hence they are termed as micronutrients, these are iron, manganese, zinc and copper which are equally essential as major nutrients. Deficiency of micronutrient may be due to low total content of elements caused by soil factors reducing their availability to plants.

Arora and Shekon (1981) reported that high pH of calcareous black soils coupled with semi-arid conditions decreased the availability of Mn by conversion of Mn^{2+} to Mn^{3+}. Sufficient content of manganese due to high organic matter content was observed in Upper Krishna Command Area by Vijayshekar *et al.* (2000).

Soil pH is the most important factor regulating Zn and Mn supply in alkaline soils. Both Zn and Mn concentration decreases 100 fold for each unit increase in pH (Lindsay and Norwell, 1978). Copper solubility is pH dependent and it decreases with increase in pH (Obreza *et al.*, 1993). Raghupathi (1989) reported that available copper content in North Karnataka soils ranged from 0.4 to 1.2 ppm. Similar results were also observed by Ravikumar *et al.* (2007).

Singh *et al.* (1993) found that the highest DTPA extractable Zn and Mn in forest and agricultural soils but did not show marked differences with waste lands. Rainfed agricultural lands were poorer in micronutrients than irrigated agricultural lands.

At alkaline pH values, Zn and Mn form compounds of low water solubility to plants. The soil around a plant root tends to be acidic due to root exudates of H^+ ions.

Therefore, soils that are slightly alkaline may not necessarily be deficient in Zn or Mn (Marchner, 1995).

The availability of phosphorus and molybdenum is reduced by the high levels of calcium and magnesium that are associated with carbonates. In addition, iron, boron, zinc and manganese deficiencies are common in soils that have a high $CaCO_3$ due to reduced solubility at alkaline pH values (Marschner, 1995).

Thakur (1996) evaluated the DTPA extractable Zn, Cu, and Fe & Mn of the Middle Narmada Valley of Madhya Pradesh and reported that the amount of available Fe, Mn and Cu was sufficient in all soils where as the available Zn status was in the deficient range.

Visible iron deficiency or iron chlorosis is common in calcareous soils which is known as lime-induced iron chlorosis. The primary factor associated with iron chlorosis under calcareous conditions appears to be the effect of the bicarbonate ion (HCO_3^-) in reducing iron uptake (Bavaresco *et al.*, 1999).

Available Zn status in black soil was deficient in the major portion of the Mantagani study area. Since, the soils are alkaline and rich in $CaCO_3$, zinc may be precipitated as hydroxides and carbonates under alkaline pH range. Therefore, their solubility and mobility may be decreased resulting in reduced availability Pulakeshi *et al.* (2012).

Excess $CaCO_3$ raises the pH of soil to high levels (8.0 -8.4) at which plant nutrients are relatively unavailable. Increased losses of nitrogen ammonia and reduced solubility of P occur in high pH soil. Micronutrients Zn, Fe, Mn and Cu tend to be less available at high pH levels (Mortvedt, 2000).

Pal *et al.* (2002) studied the available zinc, copper, iron and manganese status in rice growing soils by collecting 85 surface soil samples from lateritic zones of Aligarh (Orissa) and found that the DTPA extractable Zn, Cu, Fe and Mn were ranged from 0.98 to 3.78, 1.72 to 3.74, 24 to 290 and 22 to 112 mg kg^{-1} with the mean value of 1.96, 2.43, 139.80 and 69.12 mg kg^{-1} respectively. They all decreased with increasing in pH.

Gupta (2005) reported that 11.2 per cent of Indian soils are deficient in DTPA extractable iron. The low content of DTPA Zn might be due to low organic matter and high $CaCO_3$ content in these soils. Dhange *et al.* (2000) reported that DTPA - Fe of soils of Shevgaon Tahsil of Ahmadnagar district Maharashtra were ranged between 2.22 to 9.06 ppm.

Sharma and Chaudhary (2007) reported that available Mn in the studied profiles varied from 2.7 to 56.7 mg kg^{-1}, respectively. All the soils had amounts of available Mn in lower Shiwaliks of Solan district in North – West Himalayas.

Rajeshwar *et al.* (2009) reported that the DTPA – Extractable iron content varied from 0.4 to 40.2 mg kg^{-1}soil. All the surface soils were sufficient in available iron content. Vertical distribution of iron exhibited little variation with depth in soils of Garikapadu in Krishna District of Andhra Pradesh.

Chouhan *et al.* (2012), reported that the black soil samples of Dewas district of Madhya Pradesh were found high in Mn and B, medium in Cu, Fe, and S, and low in case of Zn. The correlation study indicated that the pH had negative correlation with DTPA-Cu, Fe, Mn and organic Carbon had positive relationship with DTPA-Zn, Cu, Mn, S and B.

Cholarajan and Vijayakumar (2013) reported that the micronutrient status of rhizosphere soils of Thanjavur district, Tamilnadu was made at 9 different locations. The objective of the present study was to analyze the status of micronutrients and their relationship with various physiochemical properties. Soil samples were collected at a depth of 0-30cm and analyzed zinc, copper, iron and manganese. The Zn, Cu, Fe and Mn ranged from 0.56 - 0.96, 0.57 - 0.96, 4.16 - 5.36 and 2.03 - 2.65 $mgkg^{-1}$ respectively.

Hirey and Takankhar (2013) carried out a study to determine the status of secondary and micronutrients of Tuljapur tehsil of Osmanabad District, Maharashtra, India. Based on the analysed data the DTPA-Cu content of soil series of Vertisols and Alfisols of western Maharashtra ranged from 1.30 to 6.30 and 0.4 to 6.7 $mgkg^{-1}$ respectively.

Ghiri *et al.* (2013) studied the relationships between micronutrient availability and calcium carbonate content in soil. Results indicated that DTPA-extractable Fe, Mn, Zn and Cu in the soils ranged 2.2–90.0, 0.6–15.4, 0.2–12.2, and 0.6–5.4 mg kg^{-1}, respectively. Generally, Zn deficiency was more widespread, followed by Fe deficiency, but Cu and Mn contents in nearly all soils were sufficient.

Kumar *et al.* (2014) reported that tested black soils of Kabeerdham area were medium to low in DTPA extractable Zn, Fe and Mn, and Cu found in high quantity in these soils.

Patil *et al.* (2016) conducted a study during the year 2015-2016 to assess the micronutrients status of Agriculture College Farm, Nandurbar (Maharashtra). The available zinc varied from 0.12 to 1.55 mg kg^{-1}. The 16.77 per cent samples were sufficient and 83.23 per cent samples were in deficient in available zinc.

Upadhyay and Sharma (2016) studied soil samples in Lucknow district and stated that deficient levels of zinc were found at all the locations subjected to minimum level at Devricala (0.03 mg/kg). Iron was highest (23.14 mg/kg) at Mahipatpur and lowest at Tilsua (2.95 mg/kg). Maximum and minimum level of Copper was found at Tilsua (0.35 mg/kg) and Bhavanipur (0.200 mg/kg) respectively. Manganese was found maximum at Khalilabad (6.35 mg/kg) and minimum at Gosainganj (1.40 mg/kg).

3. MATERIAL AND METHODS

A Study was conducted to assess the soil fertility status of black soils irrigated under different water sources in Bilagi and Bagalkot talukas. The description of the study area and methods of soil collection and analysis are presented in this chapter under different headings.

3.1 General description of the study area

3.1.1 Location

Bagalkot district, with a total geographical area of around 6.5 lakh ha is situated at 16.12^0 N and 75.45^0 E in northern Karnataka. The district comes under semi-arid region with mean annual rainfall of 517.3 mm and mean temperature of 32.6^0 C. A significant portion of northern district namely large areas of Mudhol and Jamkhandi and parts of Bilagi, Hunugund and Bagalkot talukas are under black soils. Sugarcane is one of the major crops cultivated with canal, lift and tubewell irrigations while onion, maize, groundnut also cultivated in patches with protective irrigations. However, bengalgram, sorghum, onion, pearlmillet *etc.* are grown under rainfed conditions. Though the soils appear same, their fertility status are likely to be different depending on the crops grown and respective nutrient management practices. This study area restricted to black soils of Bilagi and Bagalkot talukas is depicted in Figure 1.

3.1.2 Geology

The pre-cambrian formations include granites, gnesisses and metasediments of Dharwar underlaid mainly by the crystalline formations of different ages. The pre-Cambrian formation including granites, gneisses and metasediments of Dharwar super group, shales, sandstones, quartzites and limestones of Kaladgi series are common. Basalts of Eocene to upper Cretaceous and laterites of Pleistocene ageare also seen in the district while, laterites and river alluvium (Recent) occur as stray patches at insignificant levels. Hence Bagalkot district is considered as live museum of rocks as is underlaid by the crystalline ages.

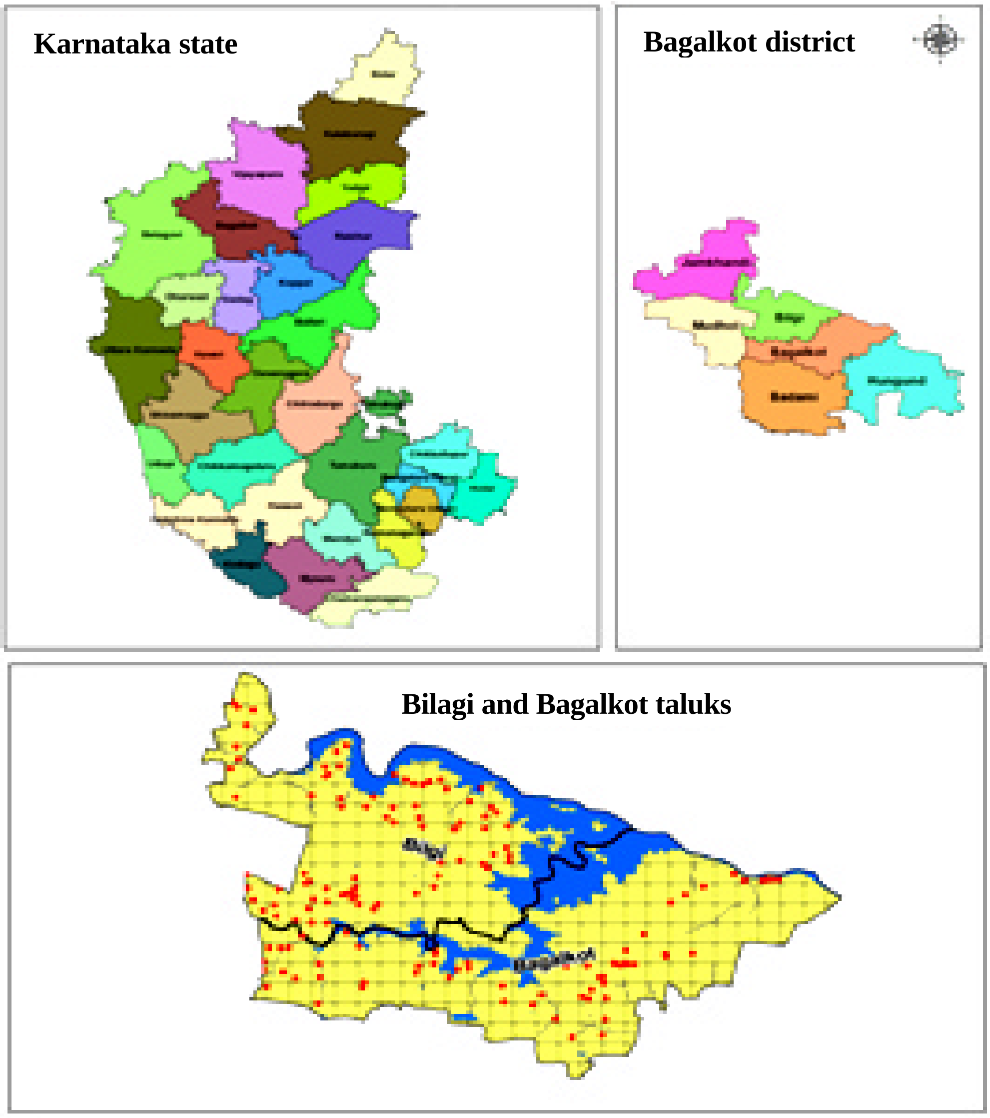


Fig. 1: Location map of the study area

3.1.3 Physiography, relief and drainage

The physiographic feature of the area indicate that they are evolved from the limestone and sandstone under paleoclimatic succession. Physiographically, Bilagiand Bagalkot talukas covers upland as well as lowlands. The general elevation in the area varies from 620-640 m above mean sea level (MSL).

3.1.4 Climate

The climate of the area is sub-tropical with dry semi- arid conditions possess well exposed summer (March to May), rainy (June to October) and winter (November to February) seasons. The mean annual temperature (last 10 year) of the Bilagi and Bagalkot talukas varied from (30.2 to 32.6^{o}C). The average annual precipitation was about (447.3 mm), and nearly 90 per cent of it is received during monsoon season.

3.1.5 Natural vegetation and agricultural land use

A large portion of cultivated land was observed under irrigations with canal water, stream water (lift) or ground water (borewell) sources. Onion, maize, groundnut *etc.* were also seen in patches with irrigation facilities. Under rainfed conditions bengalgram, sorghum, onion, pearlmillet *etc.* during *Kharif–Rabi* were observed. Major cropping systems of Bilagi and Bagalkot talukas are presented in Table 1 and Figure 2.

3.1.6 Source and extent of irrigation

Agriculture is the main occupation in the taluka. Major crops of Bilagi and Bagalkot talukas are sorghum, maize, wheat, sugarcane, Pearl millet, sunflower, pulses and groundnut. The crops are grown under rainfed as well as irrigated conditions. Major sources of water for irrigation are Canals, streams/ rivers (by lift irrigation) and ground water (by borewell water) irrigation and area covered under sources of irrigation are presented in Table 2 and Figure 3.

3.2 Categorization of study area

The study was restricted to black soils of Bilagi and Bagalkot talukas as it most dominant soil type. In terms of irrigation water sources, farmers were found

Table 1. Categorization of sampling units (grid) based on cropping systems in Bilagi and Bagalkot talukas

SI. No.	Major croppingsystem	Major sources of irrigation	No. of grids represented	No. of grids studied	Area represented (In lakh ha)
1	Jowar cropping system	Rainfed (No irrigation)	40	40 (100.0)	15,125
2	Maize / groundnut - onion cropping system	Borewell and / or Canal	10	7 (70.0)	2,831
3	Sugarcane mono cropping system	Borewell, Stream, Canal	117	100 (85.5)	64,419
	Total		**167**	**147 (88.0)**	**82,375**

Note: 1. Each grid is (2.25 x 2.25) ˜ 5.06 Sq km; 2. Value in parenthesis depict per cent area (grids) studied

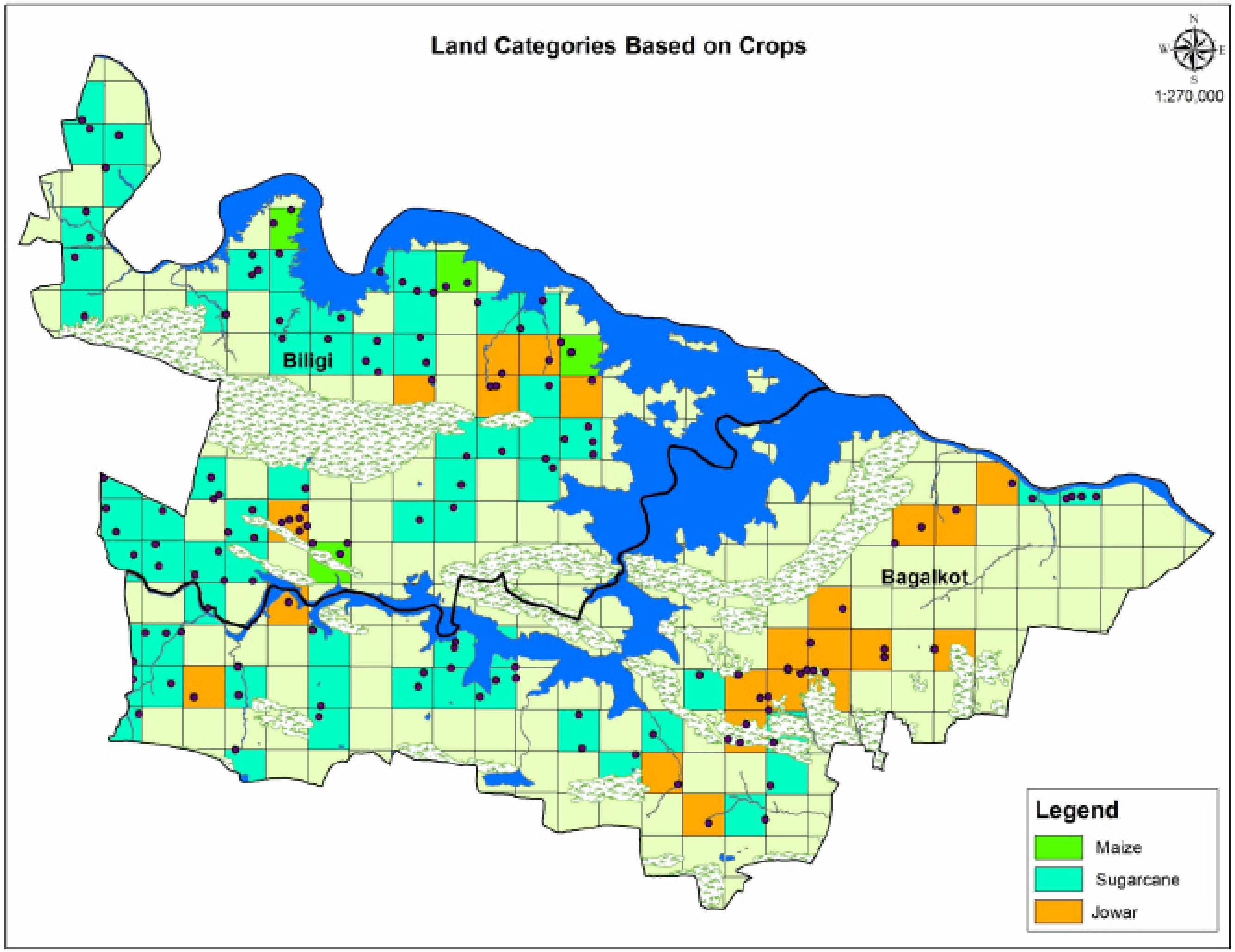


Figure 2: Extent of different cropping systems in Bilagi and Bagalkot talukas

Table 2. Categorization of sampling units (grid) based on source of irrigation water in Bilagi and Bagalkot talukas

SI. No.	Major source of irrigation	Major crops grown	No. of grids represented	No. of grids covered	Area represented (In lakh ha)
1	No irrigation (Dryland / Rainfed)	Sorghum, Pearl millet, Bengalgram, Redgram, Cowpea	40	40 (100.0)	15,125
2	Borewell	Maize, onion, sugarcane	88	78 (88.6)	47,131
3	Lift (Stream)	Sugarcane	23	15 (65.2)	13,618
4	Canal + Borewell	Sugarcane, Maize	7	5 (71.4)	3,066
5	Lift + Borewell	Sugarcane	9	9 (100.0)	3,435
	Total		**167**	**147 (88.0)**	**82,375**

Note: 1. Each grid is (2.25 x 2.25) ˜ 5.06 Sq km; 2. Value in parenthesis depict per cent area (grids) studied

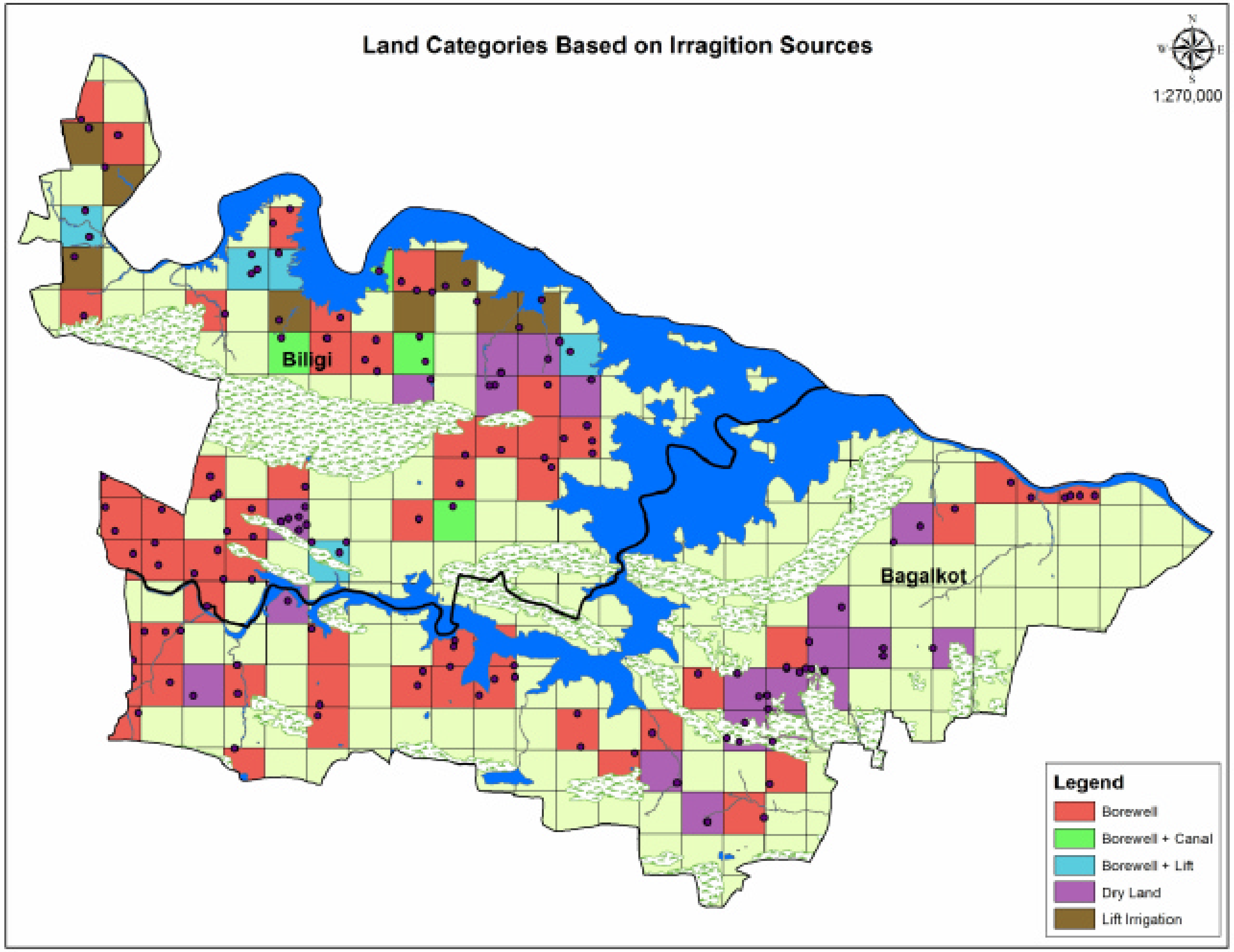


Figure 3: Extent of irrigation from different water sources in Bilagi and Bagalkot talukas

using water from irrigation canals, lift irrigations all along the natural streams /rivers and ground water through borewells. Based on irrigation water sources the soils of Bilagi and Bagalkot were grouped into five categories based on irrigation sources and based on cropping system, the area was grouped into three categories (Table 1 and 2). These criteria were overlaid on 2.25 × 2.25 Sq.km grid maps of Bilagi and Bagalkot talukas. Each grid was identified as a study unit and the prominent cropping system and the source of irrigation in that unit were considered in categorizing them.

3.3 Data sets used

Soil maps of NBSS and LUP (at 1:1,00,000 scale), toposheets of Survey of India (1:50,000) and natural resource maps prepared by KSRSAC for Bilagi and Bagalkot talukas were used for identification of soil sampling points. The details of soil sample collections are presented in this section.

3.4 Collection of soil samples

The toposheets of Bilagi and Bagalkot (1;50,000 scale) with the existing grids of 4.5 x 4.5 km^2 (20.25 Sqkm) were split into to 4 equal units of 2.25 x 2.25 km^2 grids having an area of 5.06 Sq km. Each of these grids were considered as a sampling unit and marked for soil sampling. The dominant cropping systems along with the details on crop, irrigation water source, soil colour *etc.* were recorded for each unit. The exact soil sampling points were determined and marked on the toposheet and the exact sampling locations were recorded using GPS meter (eTrex Garmin model 20) which are depicted in Figure 1. The actual locations from each point 3 surface soil samples (0-15 cm) were collected as replications and made into one representative composite sample of that site. Representative Soil samples for each study unit was collected and brought to laboratory for processing and analysis.

Soil samples collected from the study area were air dried in shade on the day of sampling. Air dried samples were crushed with a wooden pestle and mortar, sieved and the fine earth portions (< 2 mm) were stored in separate containers for further analysis. The details of the standard methods adopted are given below. The processed dry soil samples were analysed for soil fertility parameters.

3.5 Soil analysis

Soil reaction (pH) : The soil pH was determined for 1:2.5 soil and water suspension by potentiometric method using pH meter (Model Systronics 361) with glass electrode (Jackson, 1973).

Electrical conductivity (EC) : Electrical conductivity of soil water suspensions (1:2.5) were measured using EC meter (ElicoCL 180) (Jackson, 1973). The soil suspension EC values ($EC_{2.5}$) were converted to saturation paste (ECe) values by multiplying with a conversion factor of 3.6 given by Dasog (1975) for these black soils.

Soil organic-C: Approximately two grams of 2.0 mm sieved soil sample was fine powdered (0.2 mm) using agate pestle and mortar. A known weight (0.5g) of finely powdered sample was treated with known and excess volume of standard $K_2Cr_2O_7$in presence of concentrated H_2SO_4. The unused $K_2Cr_2O_7$was determined by back titrating with standard ferrous ammonium sulphate in presence of ferroin indicator (Walkley and Black, 1934).

Free $CaCO_3$: Known weight of soil (20 g) was treated with known volume of 1M HCl (100 ml) and heated the contents on waterbath completely. The unused acid was titrated with 0.5M NaOH in presence of phenolphthalein as indicator to quantify free $CaCO_3$ in soil (Richards, 1954).

3.6 Analysis of soil samples for fertility parameters

Available nitrogen (N) : A known weight of soil was distilled along with 0.32% $KMnO_4$ and 2.5% NaOH in a N- distillation unit (Gerhardt model). Ammonia volatalised during distillation is trapped in 2% boric acid and titrated with standard H_2SO_4 solution in presence of mixed indicator for determining available nitrogen content in soil (Subbiah and Asija, 1956). The soils were categorised into low (< 280 kg ha^{-1}), medium (280-560 kg ha^{-1}) and high (> 560 kg ha^{-1}) based on available-N content.

Available phosphorus (P_2O_5) : Available phosphorus in the soil was extracted using Olsen's extractant and estimated its cone after developing blue colour by ascorbic acid method. The intensity of blue colour was read at 660 nm using spectrophotometer (Thermofisher spectronics 200) and calculated using to P-standard curve (Jackson, 1973). Based on the available-P_2O_5 contents the soils were categorised into low (< 22.9 kg P_2O_5 ha^{-1}), medium (22.9-56.3 kg P_2O_5 ha^{-1}) and high (> 56.3 kg P_2O_5 ha^{-1}).

Available potassium (K_2O) : Available potassium content of soil was determined by extracting the soil with neutral normal ammonium acetate (pH 7.0) at 1:5 soil extractant ratio and measured potassium content in the leachate using a flame photometer (systronics) at 766 nm as outlined by Jackson (1973). The soils were categorised into low (144 kg K_2O ha^{-1}), medium (144-336 kg K_2O ha^{-1}) and high (> 336 kg K_2O ha^{-1})

Available calcium and magnesium: The extractant obtained for available potassium was used for the determination of available calcium and magnesium contents. Available Ca was estimated by titrating a known quantity of extract with standard EDTA solution using sodium hydroxide and P & R indicator. Exchangeable calcium + magnesium both together was estimated separately by titrating with standard EDTA solution in presence of ammonia buffer and EBT indicator. Exchangeable magnesium content in soil was calculated by subtracting exchangeable Ca content from exchangeable Ca + Mg content of the respective soil (Jackson, 1973).

Based on the soils available Ca contents the soils were categorised into low (< 24.0 meq 100 g^{-1}), medium (24.0-32.0 meq 100 g^{-1}) and high (> 32.0 meq 100 g^{-1}) by considering 60-80% of CEC as in medium range (CEC of ˜ 40 meq 100 g^{-1}). Similarly, available magnesium contents of (< 6.0 meq 100 g^{-1}), (6.0-8.0 meq 100 g^{-1}) and (> 8.0 meq 100 g^{-1}) were used for categorizing them as low, medium, and high respectively by considering 15-20% of CEC as in medium range (assuming Ca : Mg ratio of 4:1).

Available sulphur (S) : Available sulphur from soil was extracted using 0.15% calcium chloride solution at 1:5 soil to extractant ratio. The concentration of sulphur was determined by turbidimetric method after $BaCl_2$ treatments using spectrophotometer at 420 nm as described by Black (1965). The soils were categorised into low, medium and high sulphur soils with respective S- concentration of <10 ppm, 10-20 ppm and >20 ppm.

DTPA - extractable micronutrients: Estimation of Zn, Fe, Mn and Cu was carried out by adopting DTPA (Diethylene Triamnine Penta Acetic Acid) method (Lindsay and Norwell, 1978) at 1:10 soil to extractant ratio, the concentration of these micronutrients were measured using Micro wave Plasma- Atomic Emmission Spectrometer (MP-AES).

The soil micronutrients were extracted with DTPA buffer in 1:2 soil:extractant ratio and then determined by directly feeding the extractant to MP-AES (Agilent Technologies).

Fertility status of zinc, iron, copper and manganese interpreted as deficient and sufficient by following the criteria given below (Arora, 2002).

Concentration in ppm

Nature	Low	Medium	High
Iron (Fe)	< 2.5	2.5 – 4.5	> 4.5
Manganese (Mn)	< 2.0	2.0 – 4.0	> 4.0
Zinc (Zn)	< 0.6	0.6 – 1.5	> 1.5
Copper (Cu)	< 0.8	0.8 – 1.6	> 1.6

3.7 Statistical analysis

The data obtained were subjected to statistical tests using Anova: single factor and descriptive statistical analysis. Simple correlation studies were also to understand the effect of different soil parameters on available nutrients.

3.8 Spatial distribution of soil fertility parameters

Actual location of each of the study sampling site was recorded in terms of its latitude and longitude position to generate maps of Bilagi and Bagalkot talukas to depict the spatial distribution of soil fertility parameters namely pH, EC, org-C, Major nutrients (Available-N, P_2O_5 and K_2O) secondary nutrients (Available Ca, Mg, and S) and Micronutrients (Fe, Mn, Zn and Cu). The critical limits for each parameter were used to assess their spatial distribution. Finally maps of Bilagi and Bagalkot talukas were generated using Arc-Gissoftware for different soil fertility parameters.

4. EXPERIMENTAL RESULTS

Characterization of soils for chemical and fertility parameters is very important to maintain the productivity. A study was conducted to assess soil fertility in black soils of Bilagi and Bagalkot. The results obtained are presented in this chapter sequentially under different headings.

4.1 Chemical characteristics of soils

4.1.1 Soil reaction

The data on soil pH of black soils of Bilagi and Bagalkot talukas are presented in Table 3. The soil reaction (pH) was found to be in the range of 7.42 to 9.31 indicating moderate to high alkalinity. Nearly half of the soil samples analysed were found in slightly alkaline (7.50 to 8.00) to moderately alkaline (8.00 to 8.50) while, remaining soil samples recorded higher alkalinity with a pH of >8.5 indicating occurrence of sodicity.

Soil pH varied with the source of irrigation water namely, borewell, canal and lift irrigations. The dryland areas with no irrigations (rainfed) recorded higher pH of 8.63± 0.43 while, soils with borewell irrigations showed significantly lower pH (8.32 ± 0.50). Among other irrigated areas, the soils of canal plus borewell irrigated areas were also in higher range value 8.53 ± 0.31. Thus, the soil pH of dry land areas were significantly higher while, lift and /or borewel lirrigated areas recorded lower pH values.

Comparison of soil pH among cropping systems in Bilagi and Bagalkot talukas revealed that the soils under rainfed jowar cropping system recorded significantly higher pH of 8.85 ± 0.30. However, the soils of maize/groundnut- onion cropping system (8.16 ± 0.50) and sugarcane cropping system (8.33 ± 0.47) recorded lower pH. The soil pH was found in the order of jowar > maize / groundnut- onion = sugarcane cropping systems.

4.1.2 Electrical conductivity

Electrical conductivity (ECe) of black soils of Bilagi and Bagalkot talukas, irrigated with different sources of water, is presented in Table 4. The ECe of soils

Table 3: Extent of soil reaction (pH) among different land use categories in Bilagi and Bagalkot talukas

Land Category	Number of samples with pH values of				pH Range	Mean±SD
	7.50 - 8.00 Slightly alkaline	8.00 - 8.50 Alkaline	8.50 - 9.00 Moderately alkaline	> 9.00 Highly alkaline		
Based on different irrigation sources						
Dry land (no irrigation) (n = 32)	1 (0.6)	3 (2.0)	20 (13.5)	8 (5.4)	7.54 to 9.30	8.63 ± 0.43^{a}
Borewell Irrigation (n = 88)	28 (19.0)	23 (15.6)	33 (22.4)	4 (2.8)	7.42 to 9.31	8.32 ± 0.50^{b}
Lift Irrigation (n = 13)	1 (0.7)	8 (5.4)	4 (2.8)	0	8.00 to 8.90	8.41 ± 0.29^{ab}
Canal + Borewell Irrigation (n = 6)	1 (0.7)	1 (0.7)	4 (2.8)	0	7.92 to 8.74	8.53 ± 0.31^{ab}
Lift + Borewell Irrigation (n = 8)	2 (1.4)	2 (1.4)	4 (2.8)	0	7.51 to 8.80	8.31 ± 0.48^{ab}
Total (n=147)	**33 (22.4)**	**37 (25.1)**	**65 (44.3)**	**12 (8.2)**		
Based on Cropping system						
Jowar (n =40)	0	7 (4.7)	23 (15.6)	10 (6.8)	8.20 to 9.21	8.69 ± 0.32^{a}
Maize / groundnut – Onion (n = 7)	3 (2.04)	1 (0.7)	3 (2.0)	0	7.51 to 8.83	8.16 ± 0.50^{b}
Sugarcane (n = 100)	30 (20.4)	29 (19.7)	39 (26.5)	2 (1.4)	7.42 to 9.31	8.33 ± 0.47^{b}
Total (n=147)	**33 (22.4)**	**37 (25.1)**	**65 (44.3)**	**12 (8.2)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005)

Table 4: Electrical conductivity (ECe) and its magnitude in Bilagi and Bagalkot talukas

Land Category	Number of samples withECe (dS m^{-1})			Range	Mean ± SD
	< 2.00 (Safe)	**2.00– 4.00 (Mod.Saline)**	**>4.00 (Saline)**		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	23 (15.6)	9 (6.2)	0	1.04 to 2.92	1.77 ± 0.55^{c}
Borewell Irrigation (n = 88)	40 (27.2)	41 (27.9)	7 (4.7)	1.15 to 5.40	2.29 ± 0.94^{b}
Lift Irrigation (n = 13)	1 (0.7)	5 (3.4)	7 (4.7)	1.91 to 4.75	3.91 ± 0.83^{a}
Canal + Borewell Irrigation (n = 6)	0	4 (2.8)	2 (1.4)	2.59 to 4.68	3.50 ± 0.91^{a}
Lift + Borewell Irrigation (n = 8)	0	7 (4.7)	1 (0.7)	1.04 to 2.92	3.36 ± 0.59^{a}
Total (n =147)	**64 (43.5)**	**66 (45.0)**	**17 (11.5)**		
Based on Cropping system					
Jowar (n = 40)	28 (19.0)	12 (8.1)	0	1.04 to 3.53	1.81 ± 0.63^{c}
Maize / groundnut – Onion (n = 7)	1 (0.7)	4 (2.8)	2 (1.4)	1.87 to 5.22	3.63 ± 1.12^{a}
Sugarcane (n = 100)	35 (23.8)	50 (34.1)	15 (10.2)	1.15 to 5.40	2.60 ± 1.04^{b}
Total (n =147)	**64 (43.5)**	**66 (45.0)**	**17 (11.5)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005)

ranged from 1.04 dS m^{-1} in dryland soils to 5.40 dS m^{-1} in borewell irrigated soils. Out of 147 soil samples studied, nearly half of the soil samples (64 samples; 43.53 per cent) were safe with an ECe of < 2.00 dS m^{-1} while, another 66 samples (44.89 %) were moderately saline (2.00 to 4.00 dS m^{-1}) and only 17 soil samples were saline (> 4.00 dS m^{-1}) in nature.

The ECe of black soils in Bilagi and Bagalkot talukas indicated that dryland areas without irrigation recorded lower soluble salt content (range 1.04 to 5.40 dS m^{-1} with a mean of 1.77 ± 0.55 dS m^{-1}). Soils of lift, canal plus borewell and lift plus borewell irrigated areas recorded significantly higher salinity with ECe of 3.91 ± 0.83, 3.50 ± 0.91 and 3.36 ± 0.59 dS m^{-1} respectively. However, areas receiving borewell water alone recorded significantly lesser salinity (2.29 ± 0.94 dS m^{-1}) than lift irrigated areas.

The ECe of soils of different cropping systems indicated that the soils under jowar recorded lower ECe (1.81± 0.63 dS m^{-1}; range 1.04 to 3.53 dS m^{-1}) followed by sugarcane (2.60 ± 1.04 dS m^{-1} range 1.15 to 5.40 dS m^{-1}). Thus, the ECe of soils of different cropping systems varied significantly in the order: jowar < maize / groundnut-onion < sugarcane.

4.1.3 Free calcium carbonate

Free $CaCO_3$ contents in soils of Bilagi and Bagalkot irrigated by different water sources and for different cropping systems are presented in Table 5. Free $CaCO_3$ of soils ranged from 8.50 to 26.00% and high $CaCO_3$ were observed in dryland soils. Nearly 88 per cent of soil samples of Bilagi and Bagalkot talukas (129 samples) were found to be calcareous in nature with> 10% of $CaCO_3$ contents.

Comparison of $CaCO_3$ values among different land use categories indicated that all the samples from dryland areas with no irrigation were highly calcareous with free $CaCO_3$ content of 18.17 ± 3.66 per cent. The mean $CaCO_3$ value of dryland was significantly higher compared to soils of irrigated areas. However, free $CaCO_3$ in other irrigated areas were significantly lower and they were found on par with each other.

Table 5: Extent of free calcium carbonate (%) and its magnitude in Bilagi and Bagalkot talukas

Land Category	Number of samples with free $CaCO_3$			Range	Mean ± SD
	< 5.00 (Low)	5.00– 10.00 (Medium)	> 10.00 (High)		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	0	0	32 (21.7)	11.50 to 26.00	18.17 ± 3.66^{a}
Borewell Irrigation (n = 88)	0	15 (10.1)	73 (49.6)	8.50 to 25.50	14.49 ± 3.61^{b}
Lift Irrigation (n = 13)	0	0	13 (8.8)	10.50 to 20.50	14.42 ± 3.38^{b}
Canal + Borewell Irrigation (n = 6)	0	2 (1.4)	4 (2.8)	9.20 to 18.40	13.55 ± 4.03^{b}
Lift + Borewell Irrigation (n = 8)	0	1 (0.7)	7 (4.7)	9.00 to 20.50	14.80 ± 3.81^{b}
Total (n =147)	**0**	**18 (12.2)**	**129 (87.8)**		
Based on Cropping system					
Jowar (n = 40)	0	1 (0.7)	39 (26.6)	10.00 to 26.00	17.81 ± 3.71^{a}
Maize / groundnut – Onion (n = 7)	0	1 (0.7)	6 (4.0)	9.00 to 19.00	15.21 ± 3.59^{ab}
Sugarcane (n = 100)	0	16 (10.8)	84 (57.2)	8.50 to 25.50	14.25 ± 3.55^{b}
Total (n =147)	**0**	**18 (12.2)**	**129 (87.8)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005)

Among different cropping systems, $CaCO_3$ content was significantly higher in jowar system (17.81 ± 3.71 %) while, sugarcane cropping systems recorded significantly lower $CaCO_3$ contents (14.25 ± 3.55 %). Maize based cropping system was found on par with the other two systems.

4.1.4 Soil organic carbon

The soil organic carbon (SOC) content in soils of different land use categories based on irrigation sources and cropping systems are presented in Table 6. In terms of its distribution, nearly 2/3rd of the soil samples (90 samples; 61.22%) recorded medium soil organic-C range (0.50 to 0.75%) and nearly 1/4th of the samples (n=35) recorded higher range of soil organic-C > (0.75%).

Among different land use categories, the dryland soils recorded significantly lower amounts of soil organic-C (0.61 ± 0.13 %). Contrastingly, all the irrigated land categories recorded higher soil org-C contents. Among irrigated areas, lift irrigation with or without borewell recorded significantly higher amounts of soil organic-C with values of 0.75 ± 0.11 (in lift+ borewell) and 0.73 ± 0.10 (in Lift) percents.

Among different cropping systems, maize / groundnut - onion system recorded higher amounts of soil org-C (0.76 ± 0.09 %) followed by sugarcane (0.66 ± 0.14%) and jowar (0.62 ± 0.20 %) cropping systems. The soil organic-C varied significantly among different cropping systems and it was in the order:maize / groundnut – onion > sugarcane > jowar.

4.2 Soil available nutrients

The nutrients present in soils were extracted with suitable extractants and analysed for macro and micro nutrients. The observations were arranged for different land categories based on source of irrigation and cropping system and presented under suitable headings.

4.2.1 Available nitrogen

Available nitrogen content in soils of different land use categories are presented in Table 7 and it ranged from 197.5 to 450.0 kg N ha^{-1}. Among 147 samples analyzed, 87 per cent of the samples (n = 127) recorded medium levels of available

Table 6: Extent of soil organic carbon (%) among different land use categories in Bilagi and Bagalkot talukas

Land Category	Number of samples with SOC			Range	Mean ± SD
	<0.50 (Low)	0.50-0.75 (Medium)	>0.75 (High)		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	7 (4.8)	21 (14.2)	4 (2.7)	0.37 to 0.84	0.61 ± 0.13^{b}
Borewell Irrigation (n = 88)	14 (9.5)	52 (35.4)	22 (14.9)	0.39 to 0.98	0.64 ± 0.14^{b}
Lift Irrigation (n = 13)	0	10 (6.8)	3 (2.1)	0.59 to 0.95	0.73 ± 0.10^{a}
Canal + Borewell Irrigation (n = 6)	1 (0.6)	3 (2.1)	2 (1.3)	0.45 to 0.82	0.69 ± 0.13^{ab}
Lift + Borewell Irrigation (n = 8)	0	4 (2.7)	4 (2.7)	0.57 to 0.89	0.75 ± 0.11^{a}
Total (n =147)	**22 (15.0)**	**90 (61.2)**	**35 (23.8)**		
Based on Cropping system					
Jowar (n = 40)	8 (5.5)	27 (18.3)	5 (3.5)	0.37 to 0.84	0.60 ± 0.12^{c}
Maize / groundnut – Onion (n = 7)	0	3 (2.1)	4 (2.7)	0.59 to 0.89	0.76 ± 0.09^{a}
Sugarcane (n =100)	14 (9.5)	60 (40.8)	26 (17.6)	0.39 to 0.98	0.66 ± 0.14^{b}
Total (n =147)	**22 (15.0)**	**90 (61.2)**	**35 (23.8)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005)

Table 7: Extent of available nitrogen (kg -N ha^{-1}) and its magnitude in Bilagi and Bagalkot talukas

Land Category	Number of samples with available – N			Range	Mean ± SD
	< 280 (Low)	280– 560 (Medium)	>560 (High)		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	8 (5.4)	24 (16.4)	0	197.5 to 366.1	304.0 ± 49.8^{b}
Borewell Irrigation (n = 88)	11 (7.5)	77 (52.4)	0	225.0 to 450.0	359.1 ± 54.5^{a}
Lift Irrigation (n = 13)	0	13 (8.9)	0	288.2 to 389.6	347.3 ± 34.9^{a}
Canal + Borewell Irrigation (n = 6)	0	6 (4.0)	0	292.7 to 409.6	345.4 ± 47.1^{a}
Lift + Borewell Irrigation (n = 8)	1 (0.7)	7 (4.7)	0	259.6 to 403.9	355.5 ± 48.7^{a}
Total (n =147)	**20 (13.6)**	**127 (86.4)**	**0**		
Based on Cropping system					
Jowar (n = 40)	10 (6.8)	30 (20.4)	0	197.5 to 450.0	309.9 ± 54.5^{b}
Maize / groundnut – Onion (n = 7)	0	7 (4.7)	0	351.9 to 415.4	375.6 ± 27.6^{a}
Sugarcane (n = 100)	10 (6.8)	90 (61.3)	0	225.0 to 438.5	357.4 ± 51.1^{a}
Total (n =147)	**20 (13.6)**	**127 (86.4)**	**0**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005)

nitrogen (280-560 kg N ha^{-1}) while, the remaining samples had <280 kg of nitrogen ha^{-1}.

Among soils of different land use categories, the dryland areas with no irrigations recorded significantly lower amounts of available nitrogen (304.0 ± 49.8 kg N ha^{-1}) compared to all irrigated land use categories. Soils of borewell irrigated areas recorded very high N-availability (359.1 ± 54.5 kg N ha^{-1}) and it was found on far with all other irrigated land use systems.

Among different cropping systems, soils from maize / groundnut – onion areas recorded significantly higher amounts of available-N contents (375.1 ± 27.64 kg N ha^{-1}) and it was on par with sugarcane cropping system (357.4 ± 52.06 kg N ha^{-1}). However, jowar cropping system recorded least available N values (309.9 ± 54.5 kg N ha^{-1}).

4.2.2 Available phosphorus

Available phosphorus content in black soils of Bilagi and Bagalkot irrigated with different sources of water is presented in Table 8. It ranged from 18.7 to 67.1 kg P_2O_5 ha^{-1} in borewell irrigated soils. Nearly 83 per cent of soil samples (n=121) were observed with medium available phosphorus contents (22.9 to 56.3 kg P_2O_5 ha^{-1}**).** Only 5 per cent soil samples recorded higher availability of phosphorus and all of them were observed in irrigated areas.

The soils of lift irrigation areas recorded significantly higher phosphorus availability (42.5 ± 7.2 kg P_2O_5 ha^{-1}) while, dry land soils recorded least available phosphorus (29.0 ± 7.8 kg P_2O_5 ha^{-1}). The available P_2O_5 in dryland was found on par with borewell irrigation (33.8 ± 10.0 kg P_2O_5 ha^{-1}) and canal + borewell irrigated areas (37.7 ± 5.9 kg P_2O_5 ha^{-1}).

In terms of cropping systems, maize / groundnut – onion cropping system recorded significantly higher availability phosphorus content (40.7 ± 11.7 kg P_2O_5 ha^{-1}) and it was found on par with sugarcane cropping system. Least available phosphorus (29.0 ± 7.4 kg P_2O_5 ha^{-1}) was recorded in jowar cropping system.

Table 8: Extent of available phosphrous (kg P_2O_5 ha^{-1}) and its magnitude in Bilagi and Bagalkot talukas

Land Category	Number of samples with available – P_2O_5			Range	Mean ± SD
	< 22.9 (Low)	22.9 – 56.3 (Medium)	>56.3 (High)		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	10 (6.8)	22 (14.9)	0	19.70 to 45.30	28.9 ± 7.8^{c}
Borewell Irrigation (n = 88)	11 (7.4)	74 (50.3)	3 (2.1)	18.68 to 67.09	33.7 ± 10.0^{b}
Lift Irrigation (n = 13)	0	13 (8.8)	0	31.25 to 54.29	42.4 ± 7.2^{a}
Canal + Borewell Irrigation (n = 6)	0	6 (4.0)	0	32.76 to 48.33	37.7 ± 5.9^{ab}
Lift + Borewell Irrigation (n = 8)	0	6 (4.0)	2 (1.4)	23.60 to 58.15	39.6 ± 12.4^{ab}
Total (n =147)	**21 (14.2)**	**121 (82.3)**	**5 (3.5)**		
Based on Cropping system					
Jowar (n = 40)	12 (8.1)	28 (19.0)	0	19.70 to 45.30	29.0 ± 7.4^{b}
Maize / groundnut – Onion (n = 7)	0	5 (3.4)	2 (1.4)	29.40 to 58.15	40.6 ± 11.7^{a}
Sugarcane (n = 100)	9 (6.1)	88 (59.8)	3 (2.1)	18.68 to 67.09	35.5 ± 10.1^{a}
Total (n =147)	**21 (14.2)**	**121 (82.3)**	**5 (3.5)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005

4.2.3 Available potassium

The data on available potassium in black soils of Bilagi and Bagalkot talukas are presented in Table 9. The available potassium was found in the range of 263.9 to 480.4 kg K_2O ha^{-1}. More than 2/3rd of the analyzed samples (n=103) recorded higher potassium availability (>336 kg K_2O ha^{-1}) while, 1/3rd of the samples recorded medium range of available potassium. None of the soil samples were observed in lower range of available potassium (<144 kg K_2O ha^{-1}).

Available potassium in soils varied among land categories based on irrigation sources. The dryland areas with no irrigations (rainfed) recorded significantly higher amounts of available potassium (401.2± 42.3 kg K_2O ha^{-1}) while, all other irrigated land use categories recorded lower potassium availability. Least potassium availability (346.8 ± 41.0 kg K_2O ha^{-1}) was recorded in lift plus borewell irrigated soils.

Comparison among different cropping systems recorded significant differences. Jowar based cropping system recorded significantly higher available potassium contents (395.1 ± 43.1 kg K_2O ha^{-1}) followed by maize / groundnut - onion (376.0 ± 49.3 kg K_2O ha^{-1}) and sugarcane (361.5 ± 55.4 kg K_2O ha^{-1}) systems.

4.2.4 Available calcium

The available-Ca contents in soils of different cropping systems, irrigated with different water sources, are presented in Table 10. The available-Ca contents ranged from 28.58 meq 100 g^{-1} in borewell irrigated soils to 46.83 meq 100 g^{-1} in lift irrigated soils. It was observed that all the soil samples of Bilagi and Bagalkot talukas showed medium (24-32 meq 100 g^{-1}) to higher (>32 meq 100 g^{-1}) available calcium (ammonium acetate extractable-Ca).It was interesting to note that there was no significant difference among different land use categories based on irrigation sources and/or cropping systems.

4.2.5 Available magnesium

The data on available-Mg of black soils of Bilagi and Bagalkot talukas are presented in Table 11. The available-Mg content ranged from 7.40 to 18.78 meq

Table 9: Extent of available potassium (kg K_2O ha^{-1}) and its magnitude in Bilagi and Bagalkot talukas

Land Category	Number of samples with available – K_2O			Range	Mean ± SD
	< 144 (Low)	144 - 336 (Medium)	>336 (High)		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	0	3 (2.1)	29 (19.7)	329.6 to 480.8	401.2 ± 42.3^{b}
Borewell Irrigation (n = 88)	0	34 (22.9)	54 (36.7)	263.9to 480.4	359.9 ± 54.8^{a}
Lift Irrigation (n = 13)	0	1 (0.7)	12 (8.2)	331.0 to 460.8	394.5 ± 47.7^{b}
Canal + Borewell Irrigation (n = 6)	0	3 (2.1)	3 (2.1)	303.6 to 393.5	357.8 ± 40.1^{a}
Lift + Borewell Irrigation (n = 8)	0	3 (2.1)	5 (3.4)	310.7 to 425.2	346.8 ± 41.0^{a}
Total (n =147)	**0**	**44 (29.9)**	**103 (70.1)**		
Based on Cropping system					
Jowar (n = 40)	0	4 (2.7)	36 (24.5)	298.1 to 480.8	395.1 ± 43.1^{a}
Maize / groundnut – Onion (n = 7)	0	1 (0.7)	6 (4.1)	329.2 to 459.5	376.0 ± 49.3^{ab}
Sugarcane (n = 100)	0	39 (26.5)	61 (41.5)	236.5 to 486.1	361.47 ± 55.0^{b}
Total (n =147)	**0**	**44 (29.9)**	**103 (70.1)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005)

Table 10: Extent of available calcium (in meq 100 g^{-1}) among different land use categories in Bilagi and Bagalkot talukas

Land Category	Number of samples with Ca			Range	Mean ± SD
	< 24 (Low)	24 – 32 (Medium)	>32 (High)		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	0	11 (7.4)	21 (14.2)	29.28 to 44.58	35.21 ± 4.41[a]
Borewell Irrigation (n = 88)	0	19 (12.9)	69 (46.9)	28.58 to 45.50	35.15 ± 3.91[a]
Lift Irrigation (n = 13)	0	2 (1.3)	11 (7.4)	31.08 to 46.83	37.06 ± 4.55[a]
Canal + Borewell Irrigation (n = 6)	0	1 (0.7)	5 (3.4)	30.30 to 45.78	38.31 ± 5.89[a]
Lift + Borewell Irrigation (n = 8)	0	2 (1.3)	6 (4.0)	26.15 to 42.45	35.43 ± 5.58[a]
Total (n =147)	**0**	**35 (23.9)**	**112 (76.1)**		
Based on Cropping system					
Jowar (n = 40)	0	13 (8.8)	27 (18.3)	29.28 to 44.58	35.12 ± 4.07[a]
Maize / groundnut – Onion (n = 7)	0	1 (0.7)	6 (4.0)	31.08 to 45.50	37.48 ± 5.21[a]
Sugarcane (n = 100)	0	21 (14.2)	79 (53.7)	26.15 to 46.83	35.47 ± 4.29[a]
Total (n =147)	**0**	**35 (23.9)**	**112 (76.1)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005)

Table 11: Extent of available magnesium (in meq 100 g^{-1}) among different land use categories in Bilagi and Bagalkot talukas

Land Category	Number of samples with Mg			Range	Mean ± SD
	< 6.0 (Low)	6.0 – 8.0 (Medium)	>8.0 (High)		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	2 (1.4)	0	30 (21.7)	8.10 to 16.68	11.68 ± 2.46[a]
Borewell Irrigation (n = 88)	0	3 (2.1)	84 (57.1)	7.40 to 16.93	11.70 ± 2.72 [a]
Lift Irrigation (n = 13)	0	0	13 (8.8)	8.48 to 18.20	13.34 ± 2.82 [a]
Canal + Borewell Irrigation (n = 6)	0	0	6 (4.0)	8.98 to 18.78	13.12 ± 3.59 [a]
Lift + Borewell Irrigation (n = 8)	0	0	8 (5.4)	9.73 to 15.53	12.20 ± 1.77 [a]
Total (n =147)	**2 (1.4)**	**3 (2.1)**	**142 (96.5)**		
Based on Cropping system					
Jowar (n = 38)	2 (1.4)	0	40 (27.2)	8.10to16.68	11.55± 2.28 [a]
Maize / groundnut – Onion (n = 7)	0	0	7 (4.7)	10.93to 16.13	13.93± 1.97 [a]
Sugarcane (n = 102)	0	3 (2.1)	99 (67.3)	7.40 to 18.78	11.93± 2.46 [a]
Total (n =147)	**2 (1.4)**	**3 (2.1)**	**142 (96.5)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005)

100 g^{-1}.More than 2/3rd of the soil samples (99 %; n=146) were in higher (> 8.0 meq 100 g^{-1}) available-Mg while, only 2 samples were observed with <6.0 meq of Mg 100 g^{-1} soil.

Available-Mg content was found slightly lower in lift and borewell soils (12.20± 1.77 meq 100 g^{-1}) compared to all other irrigated soils. No significant difference was recorded with available-Mg contents among soils irrigated with different water sources. Similarly, no significant differences were observed among cropping systems also.

4.2.6 Available sulphur

Available sulphur content in black soils of Bilagi and Bagalkot talukas, irrigated with different sources of water, is presented in Table 12. The amount of available sulphur in soils ranged from 8.01 to 34.56 ppm. In terms of its availability, nearly 2/3rd of soil samples recorded medium range of available S (10- 20 ppm-S). Interestingly 1/3rd of the soil samples showed >20 ppm-S (high range) and mostly reported from dryland and borewell irrigation areas.

Among different sources of irrigations, lift irrigation areas were observed with significantly higher amounts of available sulphur (24.01± 5.66 ppm) followed by lift plus borewell irrigations (19.08 ± 4.53 ppm). The soils of dryland (no irrigation) areas recorded least available sulphur (13.98 ± 3.11 ppm).

Among different cropping systems, soils of sugarcane system and maize / groundnut – onion system recorded significantly higher amounts of available-S with respective values of 19.37 ± 6.09 and 19.38 ± 5.11 ppm. Jowar cropping system areas recorded significantly lower amounts of available sulphur (14.76 ± 3.76 ppm).

4.2.7 DTPA-extractable iron

The amounts of DTPA-Fe in black soils of Bilagi and Bagalkot talukas are presented in Table 13 and its concentration ranged from 1.10 to 10.92 ppm. In terms of distribution of available - Fe, nearly 2/3rd of samples (68.70 %) were found in higher range (>4.5 ppm) while, 28 per cent (n= 40) of the samples recorded medium amounts of available Fe (2.5 - 4.5 ppm).

Table 12: Extent of available sulphur (S in ppm) among different land use categories in Bilagi and Bagalkot talukas

Land Category	Number of samples with S			Range	Mean ± SD
	< 10.0 (Low)	10.0 – 20.0 (Medium)	> 20.0 (High)		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	4 (2.7)	27 (18.3)	1 (0.7)	8.01 to 21.45	13.98 ± 3.11^{c}
Borewell Irrigation (n = 88)	5 (3.4)	49 (33.4)	34 (23.2)	9.11 to 34.56	18.75 ± 5.93^{b}
Lift Irrigation (n = 13)	0	4 (2.7)	9 (6.1)	15.23 to 33.71	24.01 ± 5.66^{a}
Canal + Borewell Irrigation (n = 6)	0	5 (3.4)	1 (0.7)	12.74 to 20.83	16.80 ± 3.20^{bc}
Lift + Borewell Irrigation (n = 8)	0	4 (2.7)	4 (2.7)	12.66 to 25.06	19.08 ± 4.53^{ab}
Total (n =147)	**9 (6.1)**	**89 (60.5)**	**49 (33.4)**		
Based on Cropping system					
Jowar (n = 40)	4 (2.7)	32 (21.7)	4 (2.7)	8.01 to 24.58	14.76 ± 3.76^{b}
Maize / groundnut – Onion (n = 7)	0	4 (2.7)	3 (2.1)	12.66 to 26.30	19.38 ± 5.11^{a}
Sugarcane (n = 100)	5 (3.4)	53 (36.1)	42 (28.6)	9.11 to 34.56	19.37 ± 6.09^{a}
Total (n =147)	**9 (6.1)**	**89 (60.5)**	**49 (33.4)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005)

Table 13: Extent of DTPA- extractable iron (Fe in ppm) among different land use categories in Bilagi and Bagalkot talukas

Land Category	Number of samples with Fe			Range	Mean ± SD
	< 2.5 (Low)	2.5 – 4.5 (Medium)	>4.5 (High)		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	2 (1.4)	11 (7.4)	19 (13.0)	1.10 to 10.92	4.73 ± 1.72^{b}
Borewell Irrigation (n = 88)	4 (2.7)	25 (17.0)	59 (40.2)	1.91 to 10.08	5.15 ± 1.66^{b}
Lift Irrigation (n = 13)	0	0	13 (8.8)	5.01 to 9.52	6.98 ± 1.51^{a}
Canal + Borewell Irrigation (n = 6)	0	2 (1.4)	4 (2.7)	3.71 to 8.35	5.68 ± 1.60^{ab}
Lift + Borewell Irrigation (n = 8)	0	2 (1.4)	6 (4.0)	3.28 to 7.85	5.30 ± 1.61^{b}
Total (n =147)	**6 (4.1)**	**40 (27.2)**	**101 (68.7)**		
Based on Cropping system					
Jowar (n = 40)	2 (1.4)	12 (8.2)	26 (17.6)	1.10 to 10.92	4.88 ± 1.64^{b}
Maize / groundnut – Onion (n = 7)	0	2 (1.4)	5 (3.4)	3.28 to 8.24	5.63 ± 1.84^{a}
Sugarcane (n = 100)	4 (2.7)	26 (17.6)	70 (47.7)	1.91 to 10.08	5.38 ± 1.76^{a}
Total (n =147)	**6 (4.1)**	**40 (27.2)**	**101 (68.7)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005)

Among different sources of irrigations, soils of dryland areas (with no irrigation) and borewell irrigated systems recorded least DTPA-Fe with respective values of 4.73 ± 1.72 ppm and 5.15 ± 1.66 ppm. These values were found on par with lift plus borewell (5.30 ± 1.61 ppm) and canal plus borewell (5.68 ± 1.60 ppm). Soils from lift irrigated areas showed significantly higher amounts of iron (6.98 ± 1.51 ppm).

Among different cropping systems, maize / groundnut-onion cropping system had significantly higher amount of DTPA-Fe with mean value of 5.63 ± 1.84 ppm. However, jowar cropping system recorded lower DTPA-Fe contents (4.88 ± 1.64 ppm).

4.2.8 DTPA-extractable manganese

DTPA-extractable manganese (DTPA-Mn) in soils irrigated with different sources of water is presented in Table 14 and it ranged from 2.31 to 18.51 ppm in borewell irrigated soils. Nearly 90 per cent of the soil samples (n=132) were observed in high range of DTPA- Mn (>4.00 ppm) while, 10.20 per cent of samples (n=15) were found to be in medium range (2.0-4.0 ppm).

DTPA-Mn in soils varied with the source of irrigation. The borewell irrigated soils recorded highest DTPA-Mn of 9.13± 3.87 ppm and it was found on par with soils of lift irrigation (8.62 ± 2.08 ppm). The dryland soils without irrigation recorded significantly lower DTPA-Mn (6.14 ± 2.57 ppm). However, DTPA-Mn values of soils of canal plus borewell and lift plus borewell irrigation system were on par with the above dryland cropping systems.

Comparison of DTPA-Mn in soils among different cropping systems revealed that the sugarcane cropping system recorded significantly higher DTPA-Mn (9.06 ± 3.68 ppm) while, jowar based cropping system in dryland area recorded least DTPA-Mn (6.59 ± 2.58 ppm). The maize / groundnut – onion cropping system had DTPA-Mn of 7.94 ± 1.71 ppm and it was found on par with other cropping systems.

Table 14: Extent of DTPA- extractable Manganese (Mn in ppm) among different land use categories in Bilagi and Bagalkot talukas

Land Category	Number of samples with Mn			Range	Mean ± SD
	< 2.0 (Low)	2.0 – 4.0 (Medium)	> 4.0 (High)		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	0	7 (4.7)	25 (17.0)	2.31 to 12.43	6.14 ± 2.57^{b}
Borewell Irrigation (n = 88)	0	8 (5.5)	80 (54.5)	2.92 to 18.51	9.13 ± 3.87^{a}
Lift Irrigation (n = 13)	0	0	13 (8.8)	4.91 to 11.87	8.62 ± 2.08^{a}
Canal + Borewell Irrigation (n = 6)	0	0	6 (4.0)	5.98 to 10.59	8.21 ± 1.68^{ab}
Lift + Borewell Irrigation (n = 8)	0	0	8 (5.5)	5.64 to 10.19	7.98 ± 1.41^{ab}
Total (n =147)	**0**	**15 (10.2)**	**132 (89.8)**		
Based on Cropping system					
Jowar (n = 40)	0	7 (4.7)	33 (22.5)	2.31 to 12.43	6.59 ± 2.58^{b}
Maize / groundnut – Onion (n = 7)	0	0	7 (4.7)	4.91 to 10.01	7.94 ± 1.71^{ab}
Sugarcane (n = 100)	0	8 (5.5)	92 (62.6)	2.92 to 18.51	9.06 ± 3.68^{a}
Total (n =147)	**0**	**15 (10.2)**	**132 (89.8)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005)

4.2.9 DTPA-extractable zinc

The DTPA-extractable zinc in soils (DTPA-Zn) of different land use categories ranged from 0.39 to 3.56 ppm and the data is presented in Table 15. It was observed that majority of the soils samples (n= 121) were observed with medium (0.60 -1.50 ppm) to higher (> 1.5 ppm) level of DTPA-Zn. Only 18 per cent of samples (n=16) were observed with low DTPA- Zn (<0.6 ppm).

Comparison of DTPA-Zn contents of different irrigated land categories indicated that lift plus borewell irrigated areas had higher DTPA-Zn (2.53 ± 0.64 ppm). Contrastingly dryland areas recorded significantly low values (0.54 ± 0.16 ppm). Thus, availability of Zn (DTPA-Zn) was found in the order: (lift plus borewell) =lift > borewell= canal > dry land areas.

In terms of cropping systems, DTPA-Zn content was significantly higher in maize / groundnut – onion cropping system (0.79 ± 1.00 ppm) while, jowar cropping system recorded significantly lower DTPA-Zn contents (0.61 ± 0.19 ppm).

4.2.10 DTPA-extractable copper

The amount of DTPA-extractable copper in black soils of Bilagi and Bagalkot talukas are presented in Table 16 and it ranged from 0.43 to 5.12 ppm. Among 147 soil samples analyzed, nearly eighty two per cent of the soil samples (n=122) were observed with higher ranges of DTPA-Cu (>1.6 ppm) while, 15 per cent of samples (n=22) were found in medium range (0.8-1.6 ppm).

Dryland areas recorded least concentration (1.63 ± 0.65 ppm). However, borewell irrigated areas with or without canal water had 3.37 ± 0.86 ppm and 3.20 ± 1.11 ppm respectively. Among different sources of irrigation water, significantly higher amounts of DTPA-Cu were observed in soils of lift plus borewell irrigated soils.

Among different cropping systems, soils from maize / groundnut –onion system recorded highest DTPA-Cu (3.27 ± 1.39 ppm) followed by sugarcane system (2.67± 0.88 ppm). Jowar cropping system areas recorded significantly lower amounts of DTPA-Cu (1.76 ± 0.65 ppm). Thus, the availability of copper among different

Table 15: Extent of DTPA- extractable Zinc (Zn in ppm) among different land use categories in Bilagi and Bagalkot talukas

Land Category	Number of samples with Zn			Range	Mean ± SD
	< 0.6 (Low)	0.6 – 1.5 (Medium)	> 1.5 (High)		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	21 (14.2)	11 (7.4)	0	0.39 to 0.99	0.58 ± 0.16^{c}
Borewell Irrigation (n = 88)	4 (2.8)	68 (46.3)	16 (10.9)	0.49 to 3.55	1.25 ± 0.39^{b}
Lift Irrigation (n = 13)	0	1 (0.7)	12 (8.1)	0.71 to 3.31	2.26 ± 0.63^{a}
Canal + Borewell Irrigation (n = 6)	1 (0.7)	5 (3.4)	0	0.56 to 1.46	1.10 ± 0.32^{b}
Lift + Borewell Irrigation (n = 8)	0	0	8 (5.4)	1.80 to 3.56	2.53 ± 0.64^{a}
Total (n =147)	**26 (17.7)**	**85 (57.8)**	**36 (24.5)**		
Based on Cropping system					
Jowar (n = 40)	25 (17.1)	15 (10.2)	0	0.39 to 1.22	0.61 ± 0.19^{b}
Maize / groundnut – Onion (n = 7)	0	3 (2.1)	4 (2.7)	0.71 to 3.41	1.79 ± 1.00^{a}
Sugarcane (n = 100)	1 (0.7)	67 (45.5)	32 (21.8)	0.56 to 3.56	1.47 ± 0.57^{a}
Total (n =147)	**26 (17.7)**	**85 (57.8)**	**36 (24.5)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at $P = 0.005$)

Table 16: Extent of DTPA- extractable copper (Cu in ppm) among different land use categories in Bilagi and Bagalkot talukas

Land Category	Number of samples with Cu			Range	Mean ± SD
	< 0.8 (Low)	**0.8 – 1.6 (Medium)**	**> 1.6 (High)**		
Based on different irrigation sources					
Dry land (no irrigation) (n = 32)	3 (2.0)	16 (10.8)	13 (8.8)	0.43 to 3.26	1.63 ± 0.65[c]
Borewell Irrigation (n = 88)	0	3 (2.1)	85 (57.8)	0.99 to 4.85	2.57 ± 0.83[b]
Lift Irrigation (n = 13)	0	1 (0.7)	12 (8.2)	1.04 to 5.12	3.20 ±1.11[a]
Canal + Borewell Irrigation (n = 6)	0	2 (1.4)	4 (2.7)	1.06 to 3.10	2.37 ± 0.88[b]
Lift + Borewell Irrigation (n = 8)	0	0	8 (5.5)	1.85 to 4.97	3.37 ± 0.86[a]
Total (n =147)	**3 (2.0)**	**22 (15.0)**	**122 (83.0)**		
Based on Cropping system					
Jowar (n = 40)	**3 (2.0)**	16 (10.9)	21 (14.2)	0.43 to 3.26	1.76 ± 0.65 [b]
Maize / groundnut – Onion (n = 7)	0	0	7 (4.8)	1.85 to 5.12	3.27 ± 1.39 [a]
Sugarcane (n = 100)	0	6 (4.1)	94 (64.0)	0.99 to 4.85	2.67 ± 0.88 [a]
Total (n =147)	**3 (2.0)**	**22 (15.0)**	**122 (83.0)**		

Note: 1. Values in parenthesis depict per cent; 2. Different letters mean column implies significant difference (at P = 0.005)

cropping system was found in the order: maize / groundnut- onion = sugarcane >jowar system.

4.3 Correlation studies for soil nutrient availability

Correlation coefficients were calculated for all the soil parameters to understand their relationship and the respective coefficients are presented in Table 17. In general, the observations namely pH, EC, free $CaCO_3$ and Soil Organic-C had influenced the nutrient availability in soils. The magnitude of interactions were tested at 5 per cent and 1 per cent P-levels.

Among major and secondary nutrients, the soil pH had negative relationship with available-N content (r = - 0.203**). However, it did not influence availability of other nutrients significantly. Among micronutrients, higher soil pH significantly reduced available-Zn and copper but, it was non significant on DTPA- Fe and Mn content though there was a negative trend.

In terms of the soil salinity, the EC_e values were found positively and significantly correlated with available-Ca (0.251**), available-Mg (0.158*) and available-S (0.151**). It was observed that even the micronutrients contributed for EC_e values.

The free $CaCO_3$ content in soils reduced the available-N content significantly (-0.153*) where as, other major and secondary nutrients did not show any specific trend. Though soil pH had negative effects on soil micronutrients, significant reduction was observed at higher pH only *w.r.t* DTPA-Mn (-0.234**) and DTPA-Zn (-0.239**).

The soil organic-C showed significantly positive effect on available-N (0.311**), available-S (0.157*) and DTPA-Zn (0.232**) while, its effect on other nutrients non-significant through positive interactions were recorded. In terms of nutrient interactions, they did not show any specific trend in available – phosphorous, potassium and calcium content. Interestingly, the available-S content indicated significantly positive relationship with DTPA- Iron and Copper.

Table 17: Correlation studies for soil nutrient availability

	pH	ECe	$CaCO_3$	SOC	Ava-N	Ava-P	Ava-K	Ava-Ca	Ava-Mg	Ava-S	DTPA-Fe	DTPA-Mn	DTPA-Zn	DTPA-Cu
pH	1.000													
ECe	0.126	1.000												
$CaCO_3$	0.126	-0.129	1.000											
SOC	0.095	0.088	-0.205	1.000										
Ava-N	-0.203*	0.101	-0.153*	0.311**	1.000									
Ava-P	-0.090	0.128	-0.034	0.132*	0.111	1.000								
Ava-K	0.025	-0.006	0.089	0.065	-0.199	0.038	1.000							
Ava-Ca	0.045	0.251**	-0.040	0.017	0.061	0.134	0.087	1.000						
Ava-Mg	-0.043	0.158*	0.004	0.040	0.013	-0.141	0.090	-0.020	1.000					
Ava-S	-0.016	0.151*	-0.124	0.157*	0.135	0.121	-0.004	-0.110	0.030	1.000				
DTPA-Fe	0.096	0.222**	-0.049	0.113	0.107	0.015	-0.064	0.095	-0.041	0.192*	1.000			
DTPA-Mn	-0.115	0.057	-0.234*	0.018	0.184*	-0.103	-0.109	0.032	0.007	0.043	0.189*	1.000		
DTPA-Zn	-0.216**	0.381**	-0.239**	0.232*	0.282**	0.126	-0.063	-0.142	-0.142*	0.389**	0.209**	0.238**	1.000	
DTPA-Cu	-0.278**	0.188*	-0.031	0.100	0.190*	0.141	-0.010	0.138	-0.145*	0.210**	0.133	0.295**	0.443**	1.000

Note: * Correlation is significant at P = 0.05 level and ** Correlation is significant at P = 0.01 level

5. DISCUSSION

A study was carried out to assess the nutrient availability in black soils representing different land use categories in Bilagi and Bagalkot talukas. The cropping system was largely determined by the availability of water. The extent of nutrient availability in soils representing different land use categories based on irrigation water sources and cropping systems are discussed in this chapter.

5.1 Chemical characteristics of soils

5.1.1 Soil reaction

The data on soil reaction of major cropping systems irrigated with different water sources are diagrammatically represented in Figure 4 and the extent variations in soil reaction is projected in Figure 5. The soil reaction of black soils of Bilagi and Bagalkot talukas exhibited moderate to high alkalinity. Nearly half of soil samples indicated moderately alkaline pH of 8.00 to 8.50 and majority of them were recorded in dryland areas. Highly alkaline pH of > 9.00 was observed in 12 soil samples in dryland and borewell irrigated areas. Comparison of cropping systems indicated that the soil reaction decreased in the order of jowar (8.69 ± 0.50) > sugarcane (8.33 ± 0.47) = maize / groundnut – onion (8.16 ± 0.50) cropping system

Significant variations in soil reaction were observed among irrigated soils. Higher alkalinity in soils of dryland areas could be attributed to the presence of higher amounts of carbonates and bicarbonates (Dasog, 1975). Soil pH of more than 8.3 clearly indicate dominance of carbonates and bicarbonates in soil (Tiwari *et al.*, 1983; Chabbra, 1996). Sharma and Jha (1989) also recorded similar high alkaline pH in the Indo-Gangetic plains due to accumulation of HCO_3^- and CO_3^{2-}. This could be the reason for observing higher pH in rainfed jowar cropping system. Higher pH could be due to the dominance sodium as carbonation in soils remove active-Ca from soil solution by $CaCO_3$ precipitation (Gupta and Khosla, 1982).

5.1.2 Electrical conductivity

The electrical conductivity of soils at saturation (ECe) is graphically represented in Figure 6 while, spatial distribution of water soluble salts is depicted in

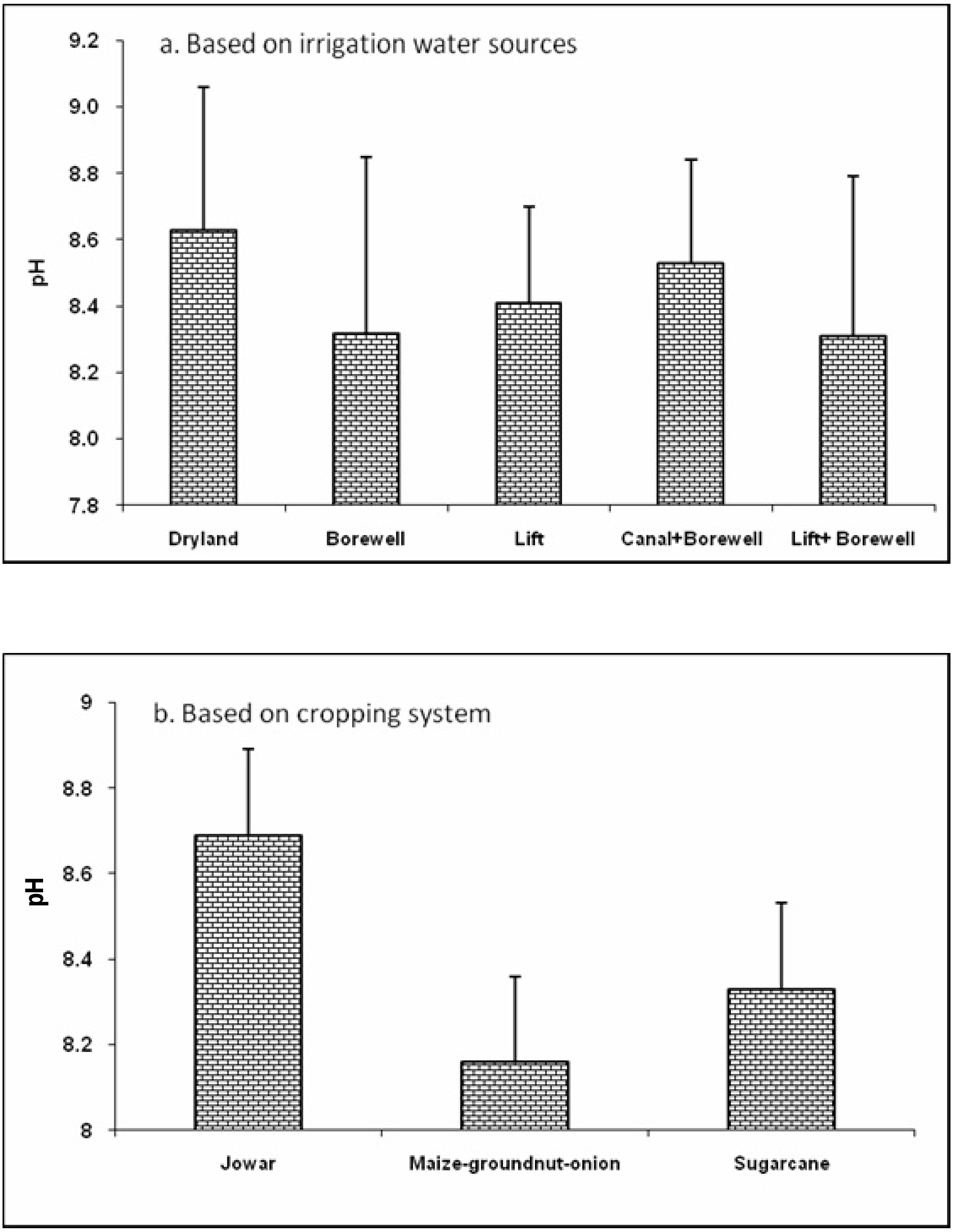
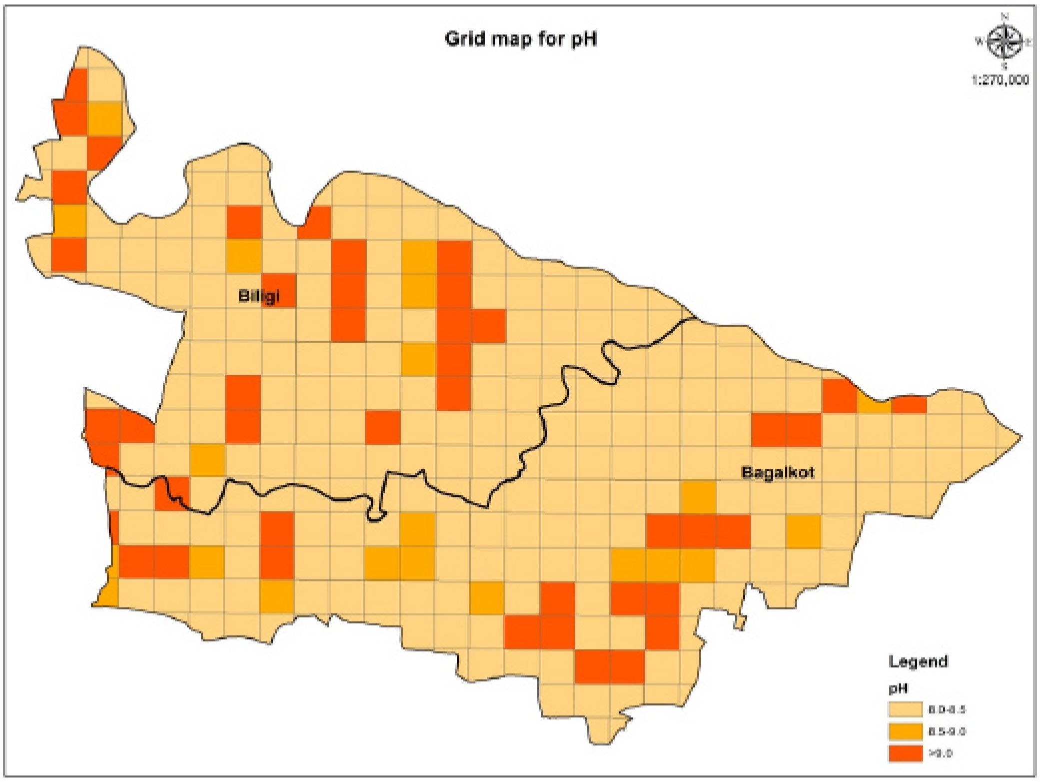


Figure 4: Magnitude of soil reaction (pH) in black soils of Bilagi and Bagalkot talukas



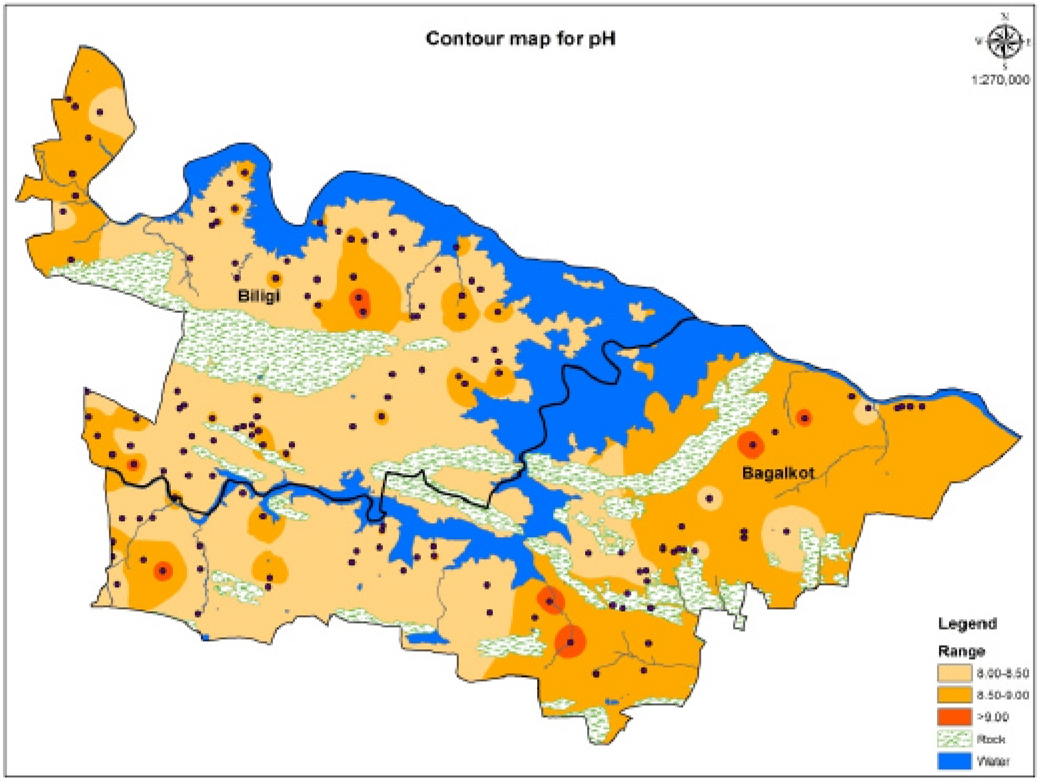


Fig 5: Grid and contour maps of Bilagi Bagalkot and talukas for soil pH

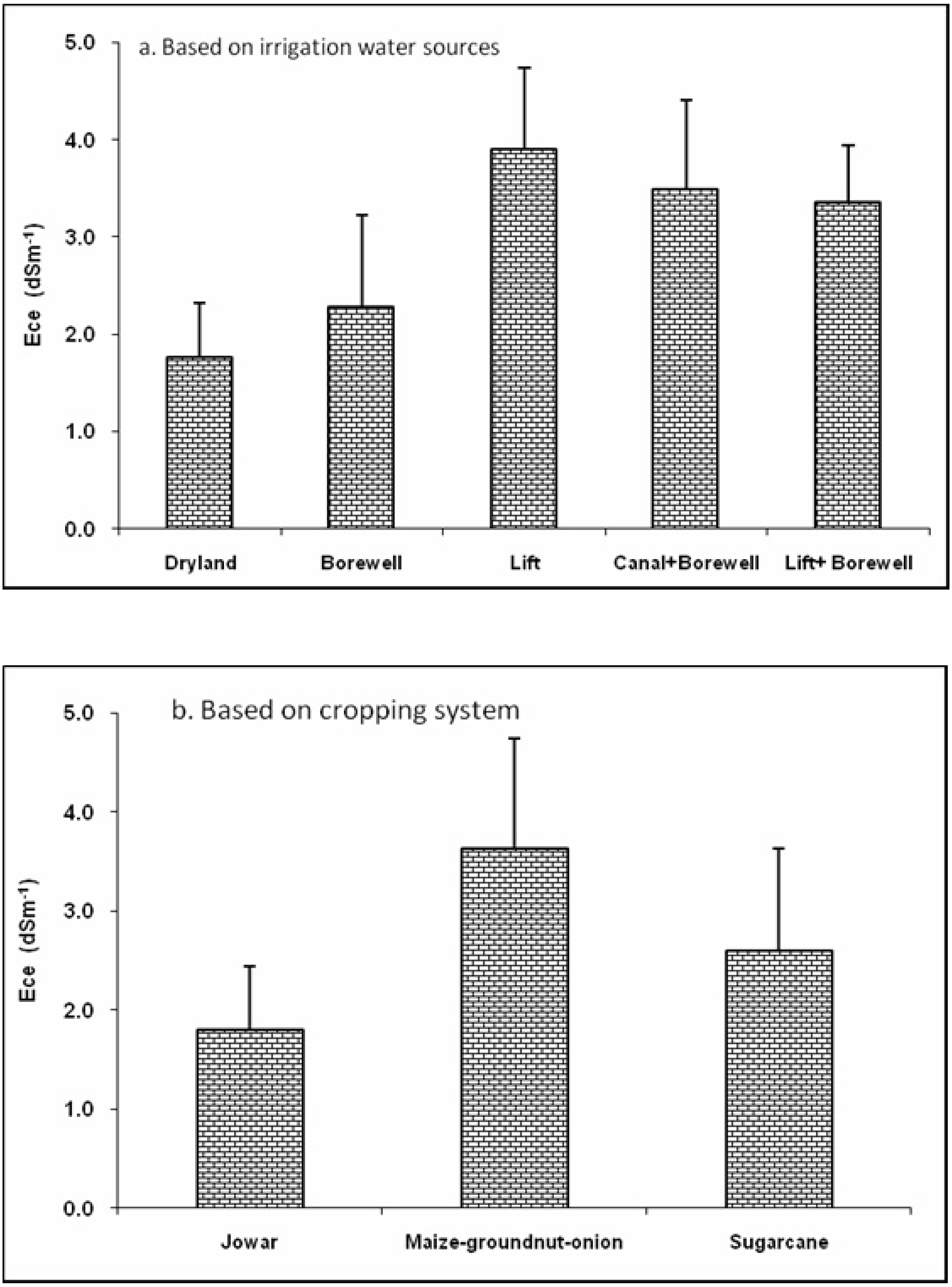


Figure 6: Magnitude of electrical conductivity (ECe) in black soils of Bilagi and Bagalkot talukas

Figure 7. The values of ECe ranged from 1.04 to 2.92dS m^{-1} (mean 1.77 ± 0.55 dS m^{-1}) in dryland areas to 1.15 to 5.40 dS m^{-1} (mean 2.29 ± 0.94 dS m^{-1}) in lift irrigated areas. Nearly 43 per cent of the soil samples were safe in terms of soil salinity while, the remaining samples had > 2.0 dSm^{-1} indicating moderate to high salinity. The magnitude of soil salinity increased with irrigations and varied significantly in the order dryland< borewell< lift plus borewell = canal plus borewell =lift irrigation. In terms of cropping systems, the soil salinity varied significantly among all the categories in the order: maize/groundnut–onion> sugarcane> jowar system. These observations were also evident in spatially represented grid and contour maps for soil salinity (Figure 7).

Conductivity values (ECe) of dryland soils with no irrigation were found moderately higher than other regions as the study area falls under semi-arid conditions with low rainfall and high temperature (Chabbra, 1996). Further additions of salts from easily weatherable parent materials such as limestone, dolomite and gypsum might have enhanced ECe values (Doddamani *et al.,* 1994). The above soil salinity values of this region were similar to some of the soil series of Gujarat and Rajasthan (Sharma and Minhas, 2004). Accumulation of salts is likely to be more severe in clayey soils due to high retention of salts and inherent poor drainage conditions. Moreover, upward movement of salts through capillary water is very common in clayey soils (Agarwal and Ramamoorthy, 1970). Direct additions of salts through irrigation water also aggravate soil salinity and its severity is higher during summer (Bhadrapur and Rao, 1979).

Addition of salts by irrigation water was also recorded. Thus, irrigated areas recorded higher EC_e compared to dryland areas (Paliwal and Maliwal, 1971). Movement of salts within and across soils through percolating water is well explained by Kadu *et al (*2009). Among irrigated soils, higher salinity was observed in lift irrigated areas (both with / without borewell water) existing along major stream lines. Use of stream water was observed even at 6-8 kms away from the main stream. Thus, the seepage water from higher elevation to lower regions might have carried salts. It was very evident that all lift irrigated areas were situated at lower elevations all along the natural drain line. Natural transport of salts from upper to lower regions along with percolating water might have caused soil salinity (Kadu *et al.,* 2009).

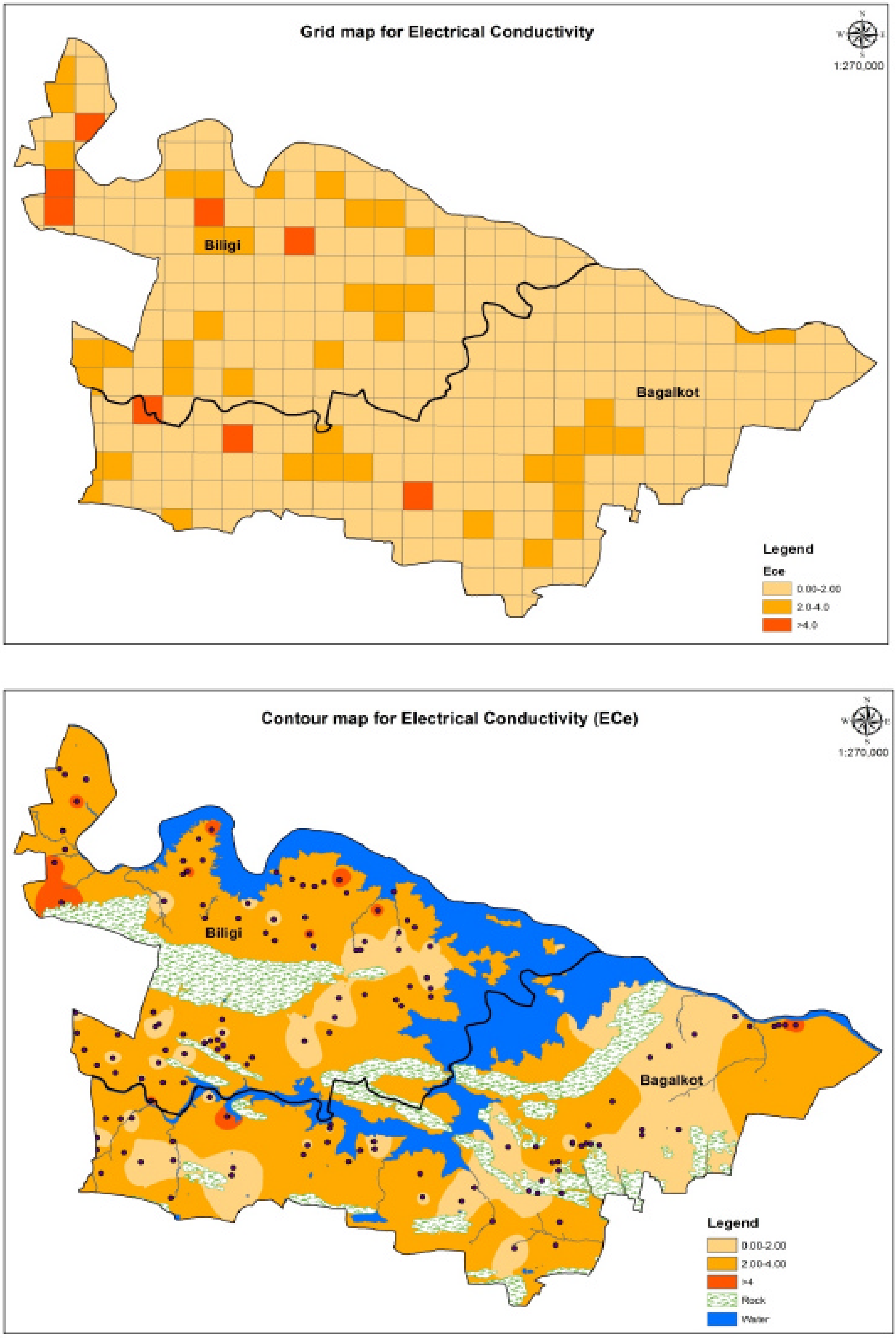


Figure 7: Grid and contour maps of Bilagi and Bagalkot talukas for soil ECe

Excess application of water might have induced salinity in lift irrigated areas. Interestingly, the stream water had higher ECe values during summer (Kirankumar *et al.,* 2016). It is well established that continuous use of marginal and poor quality waters cause soil salinity and sodicity (Chhabra, 1996).Higher water usage in sugarcane systems might have enhanced soil salinity due to salt additions with each irrigations. Moreover, all these soils also belongs to clayey (Vertisols) soils and the problem of salt accumulation is likely to be more severe in black soils (Kijine *et al.,* 1998). This was further evidenced in the spatial map indicating higher EC_e values in sugarcane areas along the stream lines (low elevation area) of Bilagi and Bagalkot.

5.1.3 Free calcium carbonate

The presence of total $CaCO_3$ in soils of Bilagi and Bagalkot talukas are diagrammatically represented in Figure 8 and its distribution over space is depicted in Figure 9. The free $CaCO_3$ content ranged from 8.50 – 26.0 % and large tracts of the study area (n = 129 samples) were found highly calcareous with >10 % of free $CaCO_3$.

The dryland areas with no irrigation facility recorded significantly higher free $CaCO_3$ content compared to irrigated areas. Among cropping systems, the jowar cropping system of dryland areas recorded significantly higher values compared to other two cropping systems. Presence of high total $CaCO_3$ in these soils may be attributed to intensive and frequent alternate wetting and drying of soils (Roy and Barde, 1962; Sharma *et al.,* 1988). Precipitation rate of $CaCO_3$is more severe under saline conditions (Chaabra, 1996). Natural occurrence of calcareous soils in arid and semi-arid regions of the world is well documented (Marschner, 1995; Brady and Weil, 1999). Similar reports on calcareousness soils were reported in Gujarat by Dhir *et al.,* (1979). The calcareousness in the soils of the study area may also be attributed to the fact that these soils are derived from lime based parent material. Geological reports of Bagalkot district also depict the occurrence of calcite and dolomite in these two talukas. These results are in conformity with early findings of Doddamani (1994).

The magnitude of calcareousness was found significantly lesser in irrigated areas compared to drylands. This could be attributed to gradual dissolution of free $CaCO_3$ in soil solution and its removal along with percolating water. The carbonic

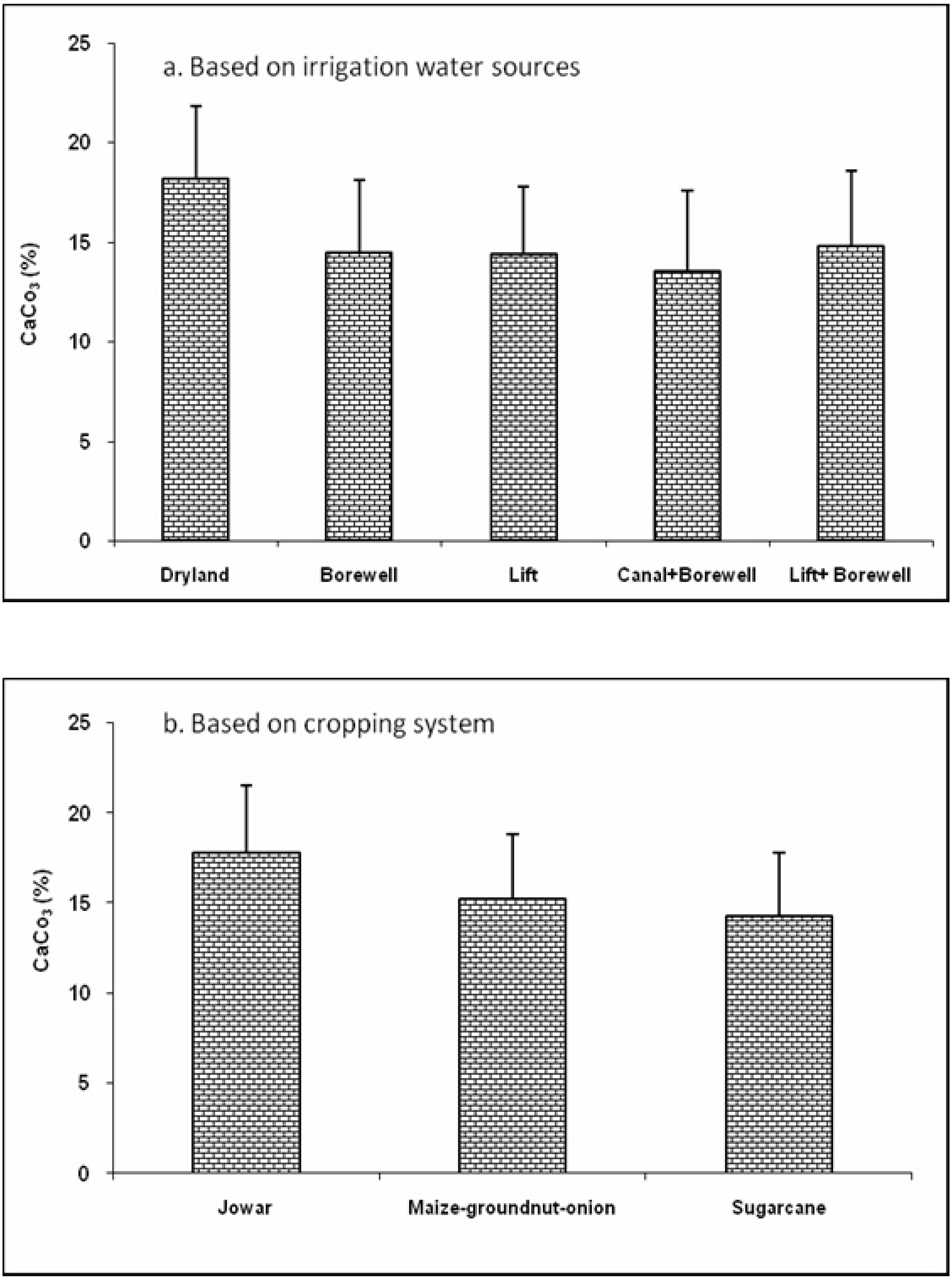
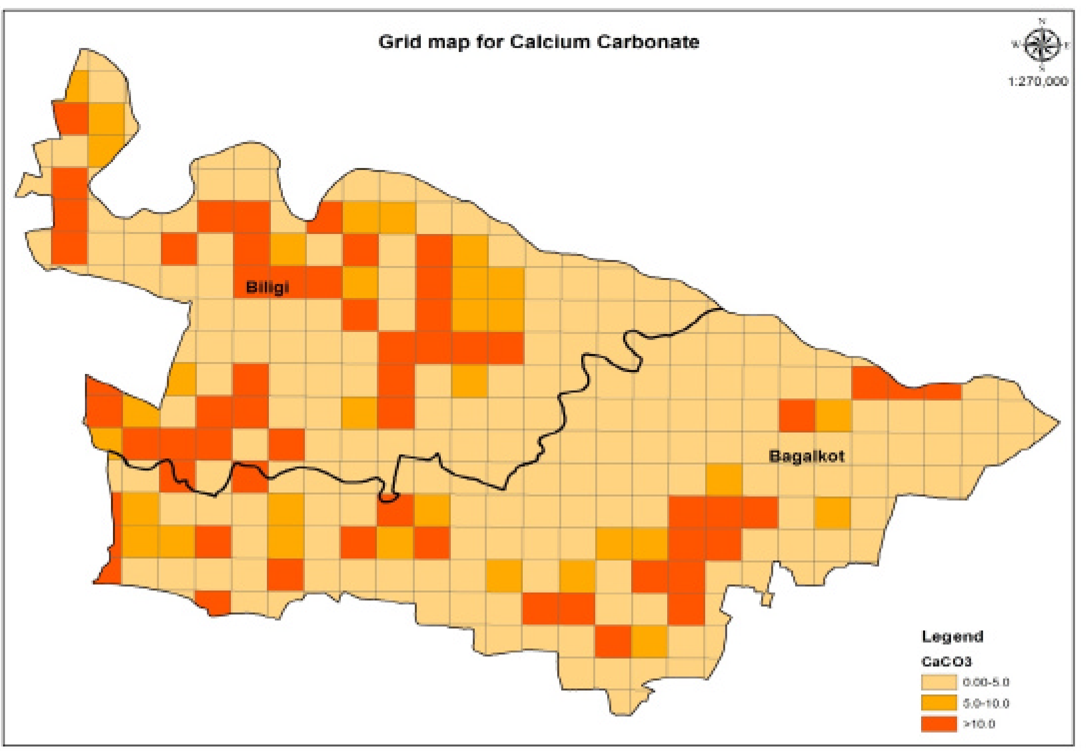


Figure 8: Magnitude of free calcium carbonate in black soils of Bilagi and Bagalkot talukas



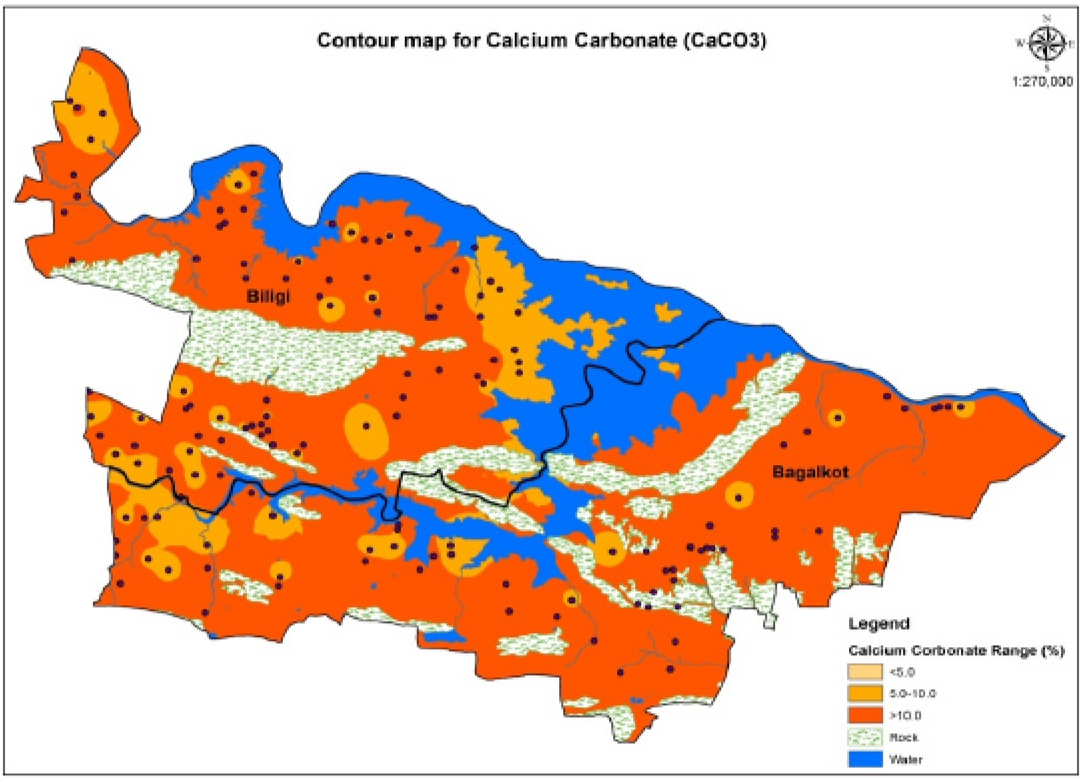


Figure 9: Grid and contour maps of Bagalkot and Bilagi talukas for soil free calcium carbonate

acids produced by dissolution of atmospheric CO_2 in with irrigation water, the production of mineral acids from N and P fertilizers (urea, ammonium sulphate *etc.*) and organic acids generated from decomposition process might have reduced total $CaCO_3$ content. Same reasons may explain for observing varied levels of $CaCO_3$ among different cropping systems (Mruthunjaya and Gowda, 1993).

5.1.4 Soil organic carbon

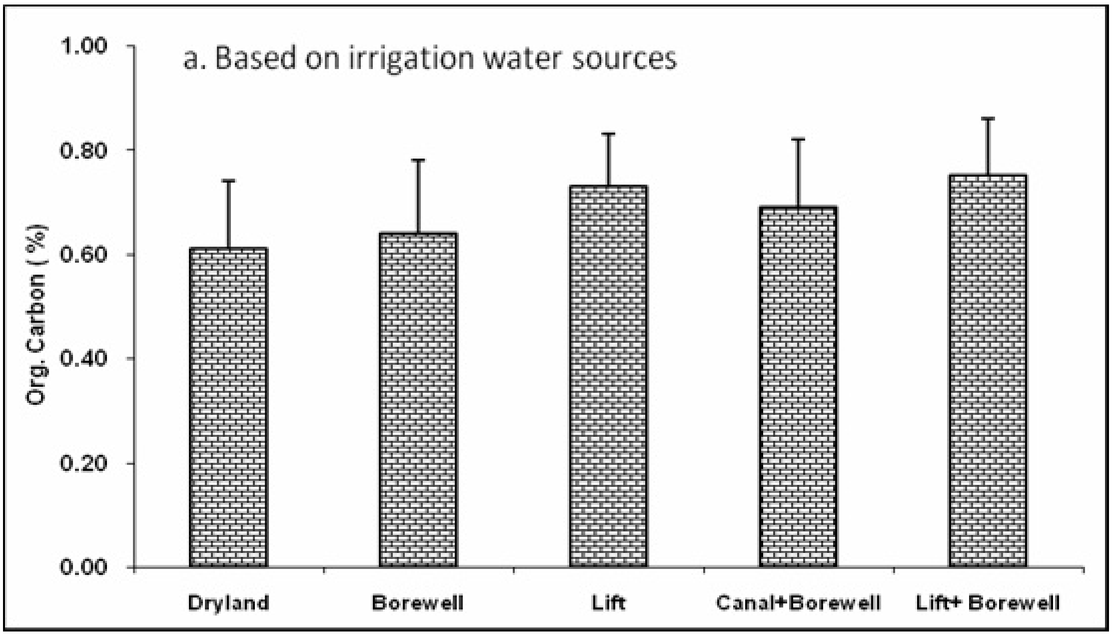
The soil organic-C contents of different land use categories are diagrammatically presented in Figure 10 and its spatial spread over Bilagi and Bagalkot talukas is given in Figure 11. The dryland soils with no irrigations (0.61 ± 0.13%) and borewell irrigated areas (0.64 ± 0.14%) recorded significantly lower amounts of soil organic-C compared to irrigated areas. Among irrigated areas, lift irrigation practice with or without borewell recorded significantly higher amounts of soil organic-C values. Higher amounts of soil organic-C in irrigated soils compared to dryland areas can be attributed to higher biomass turnovers (Nagaraja *et al.,* 2016). It is well-established that the productivity of land increases and hence, the biomass turnover with the introduction of irrigations (FAO, 1982). The soil organic-C content is likely to increase with biomass turnovers (Nagaraja *et al.,* 2016). These observations were further strengthened with observations on cropping systems indicating significant differences among the systems studied (maize/groundnut-onion> sugarcane> jowar).

5.2 Soil available nutrients

5.2.1 Available nitrogen

The extent of available-N in soils of different cropping systems irrigated with different water sources are presented in Figure 12 and the extent of its availability in the study area is depicted in Figure 13. The available-N content was found significantly higher in all irrigated soils compared to dryland soils. However, the available-N contents among different irrigation land categories remained on par with each other.

Higher amounts of available-N in irrigated soils may be attributed to higher soil organic-C contents in these soils (Pulakeshi *et al.,* 2012). Strong positive relationship



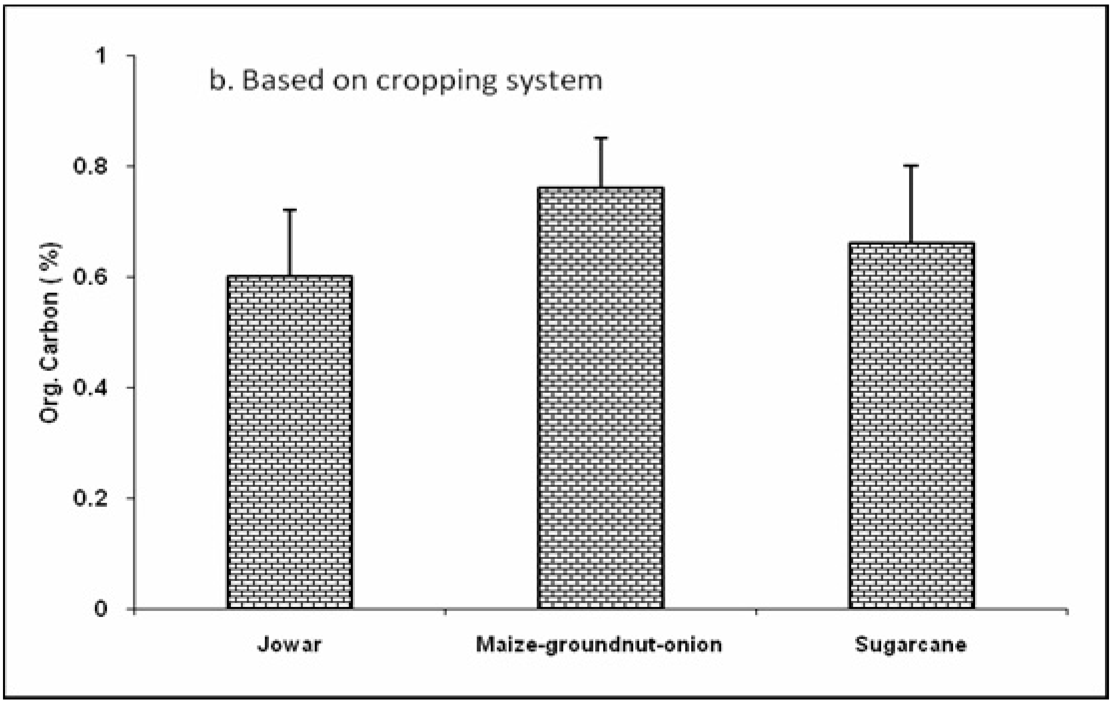


Figure 10: Magnitude of soil organic carbon in black soils of Bilagi and Bagalkot talukas

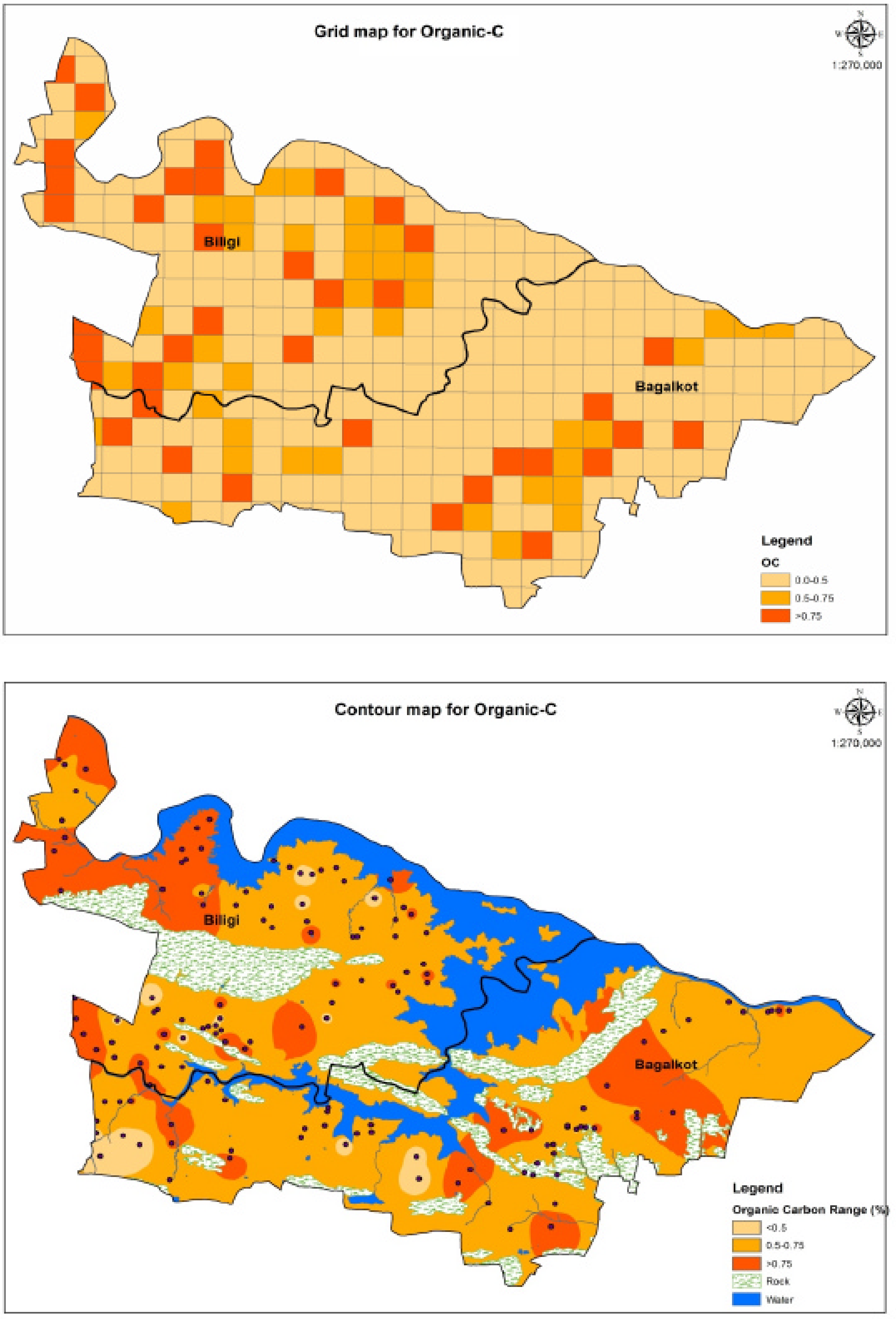


Figure 11: Grid and contour maps of Bilagi and Bagalkot talukas for organic carbon

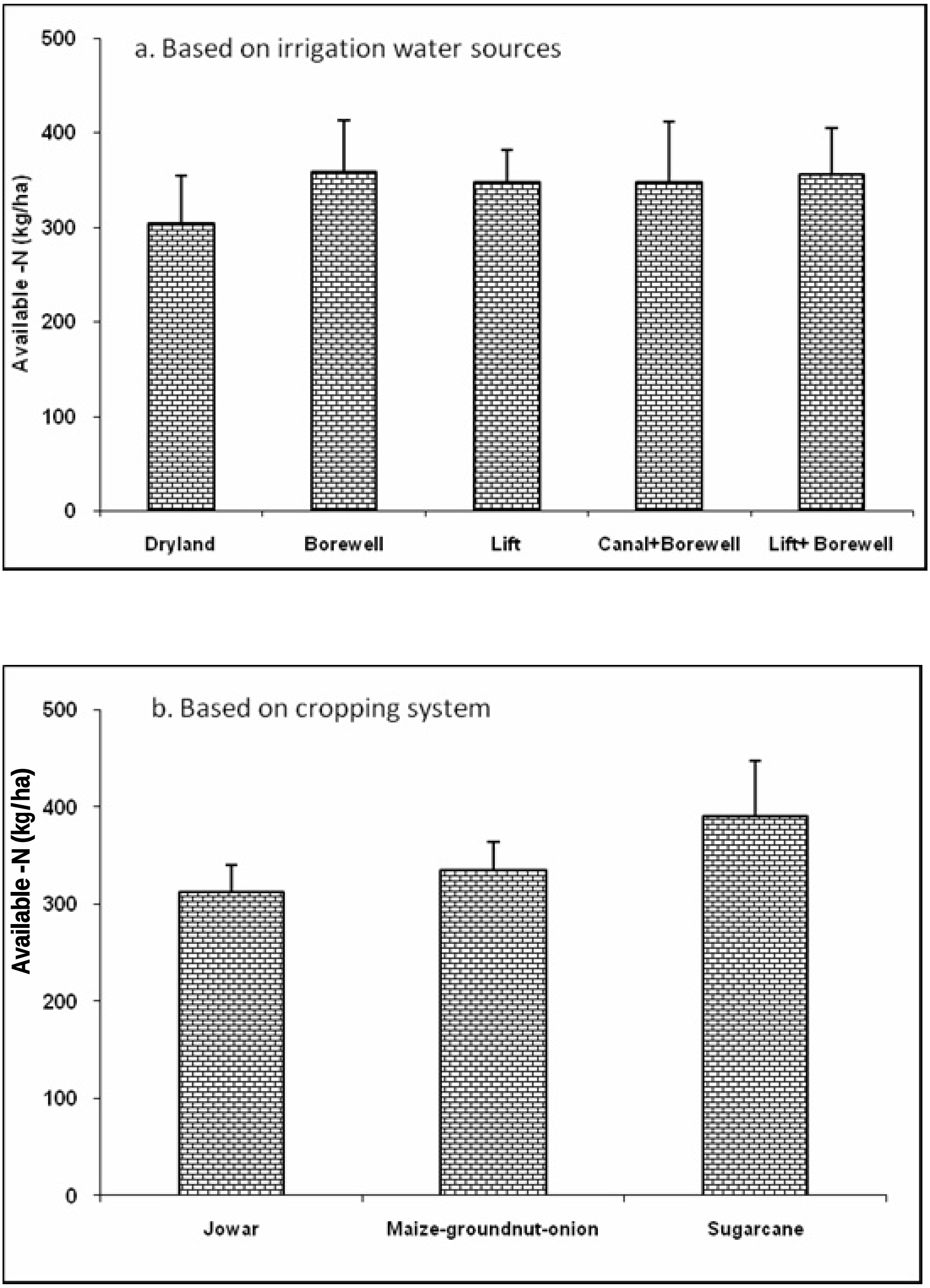


Figure 12: Magnitude of available -N in black soils of Bilagi and Bagalkot talukas

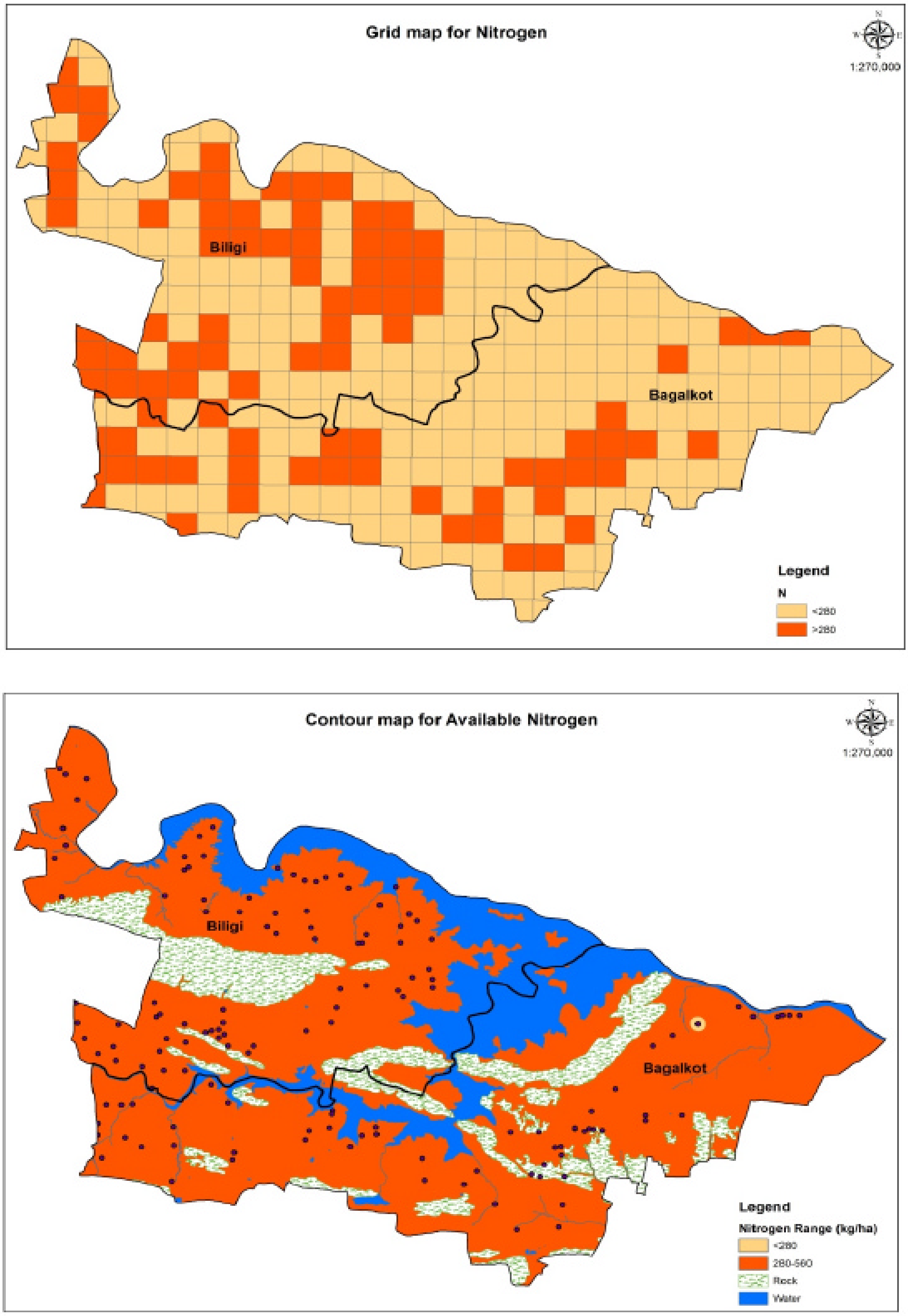


Figure 13: Grid and contour maps of Bagalkot and Bilagi taluka for available nitrogen (N)

between soil organic-C contents and available-N was observed and this relationship well documented by Kumawat (2000). Use of higher amounts of nitrogenous fertilizers in irrigated systems compared to dryland cropping systems (with no irrigation) also might have contributed for available-N (Punithraj *et al.*, 2012). Similar variations in available-N content in the UKP command area were reported by Nandi and Dasog (1992) and Pulakeshi *et al* (2012).

Comparisons of different cropping systems with respect to available-N are in conformity with N-additions. In other words, higher amounts of available-N in sugarcane cropping system may be attributed to both higher soil organic-C contents and high N fertilizers additions (Kumar *et al.,* 2014; Binita *et al.,* 2009).

5.2.2 Available phosphorus

The distribution of available-P_2O_5 content in soils of Bilagi and Bagalkot talukas is diagrammatically depicted in Figures 14 and 15. Large areas (n=121;82.31%) were observed in medium range of available-P_2O_5. The available-phosphorus contents varied significantly with both water sources and cropping systems. Higher amounts of available-P_2O_5 in irrigated soils may be attributed to higher use of P-fertilizers (Punitraj *et al.*, 2012). Unutilised P-fertilizers is likely to get accumulate over time and increase its availability in soil (Freney *et al.*, 1983).

Among plant nutrients, the phosphorous is highly active and its availability is determined by constituents of soil solution especially, carbonates, bicarbonates, iron and calcium contents in their active forms (Vance *et al.,* 2003). Significantly lower amounts of available-P in borewell irrigated soils and dryland soils may be attributed to higher amounts of carbonates and bicarbonates in soil solution (Challa *et al.,* 2000). Occurrence of carbonates, bicarbonates and calcium in these soils were also documented earlier by Kirankumar *et al.* (2016) and Ashwin *et al.,* (2018). At higher pH, the applied-P is likely to get converted to less soluble compounds such as di-calcium phosphate and octa-calcium phosphates (Mortvedt *et al.,* 1999; Rahhmatullah, 1994). Decrease in phosphorous availability with increase in lime content in soil was also reported by Westermann and Leytem (2003).

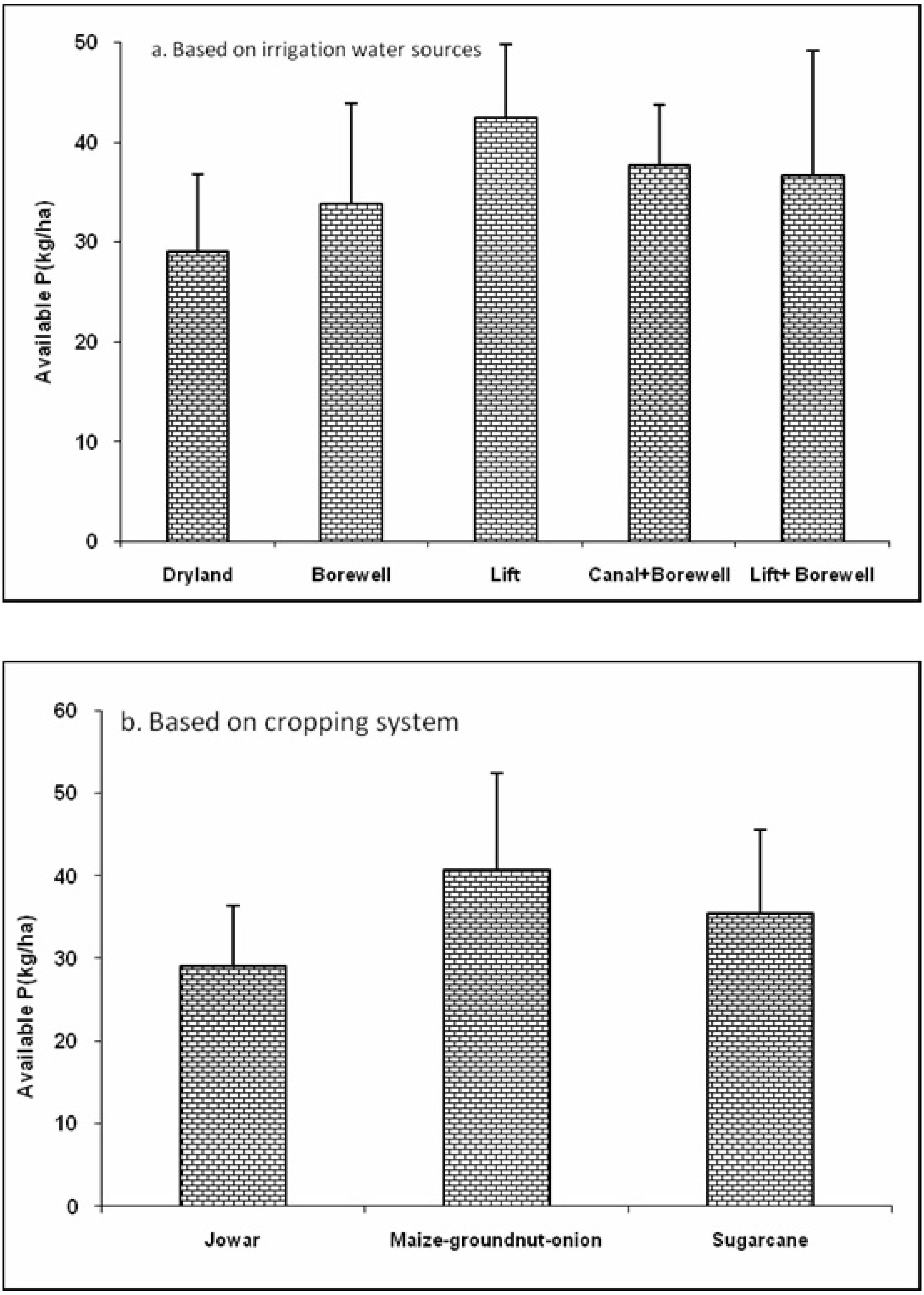


Figure 14: Magnitude of available phosphorus (P2O5)in black soils of Bilagi and Bagalkot talukas

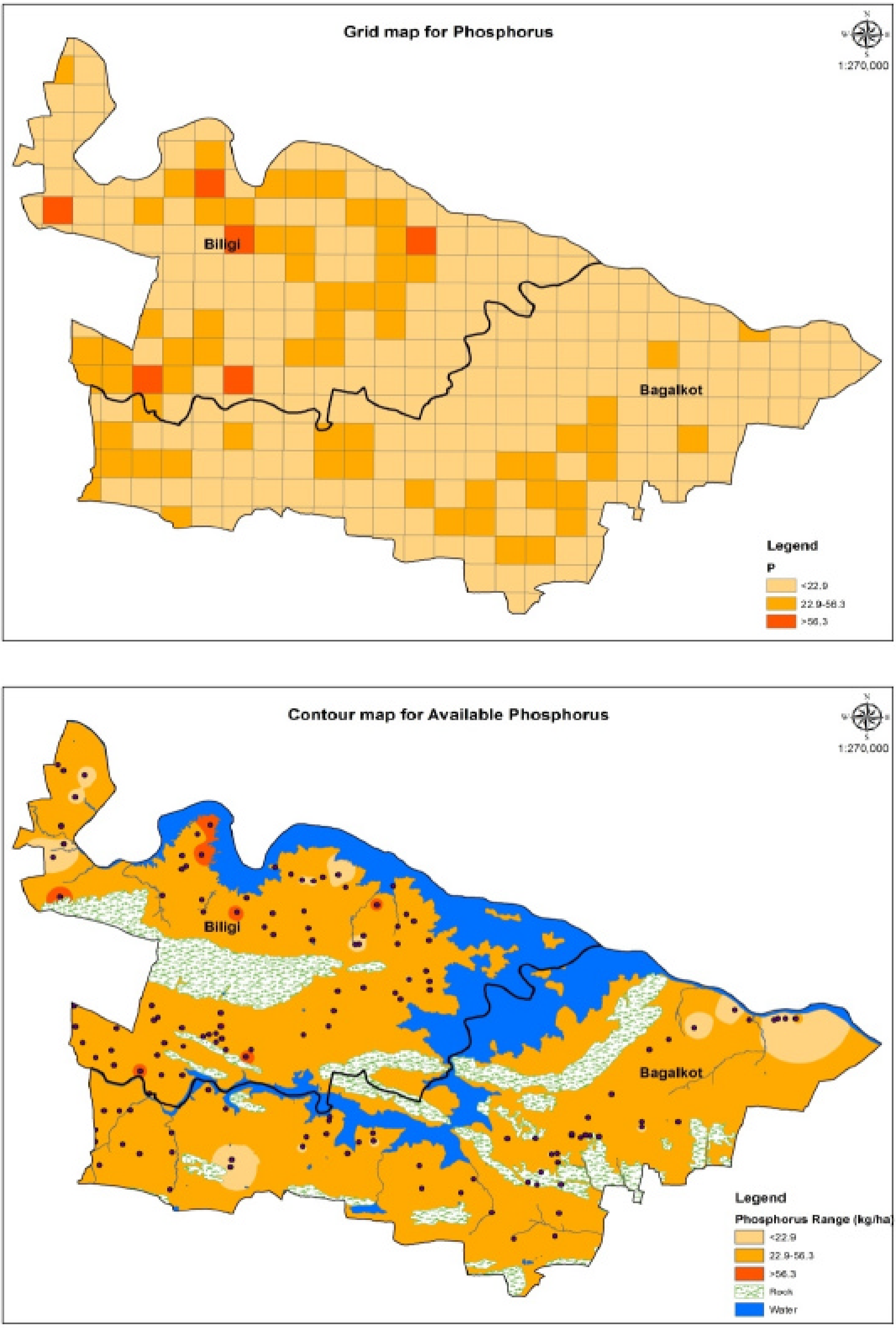


Figure 15: Grid and contour maps of Bilagi and Bagalkot talukas for available phosphorus (P_2O_5)

5.2.3 Available potassium

Information on the available-K_2O status in soils of different land use categories are presented in pictorially in Figure 16 and its spatial distribution over Bilagi and Bagalkot talukas in Figure 17. The available-K_2O was found in the range of 263.9 to 480.4 kg K_2O ha^{-1}. Most of the soils samples (n=103; 70.06%) studied were observed in higher range of potassium availability (>336 kg K_2O ha^{-1}) and none of the soils were in lower range. Soils of dryland areas and lift irrigation areas recorded significantly higher amounts of available-K_2O content with respective values of 401.2 ± 42.3 and 394.5 ± 47.7 kg K_2O ha^{-1}. All other irrigated soils recorded significantly lower amounts except the lift irrigated areas.

Variations in potassium availability may be attributed to intensive agricultural practices in irrigated areas resulting in higher removal of soil potassium by the crop (Shivakumar *et al.,* 2010; Vinod *et al.,* 2017). The black soils are inherently possess high available-K_2O contents (Balanagoudar, 1989; Doddamani, 1994). Many of the farmers have given less importance for the application of potassium through fertilizers. Cultivation of sugarcane continuously with less applications of potassium might have reduced available-K_2O content in soils (Babu *et al.,* 2010). Contrastingly, lower productivity in dryland areas due to scarcity of water might have reduced potassium removal compared to sugarcane cropping system (Raysschaert *et al.,* 2004; Rekha, 2015).

5.2.4 Available calcium

The distribution of available-Ca (ammonium-acetate extractable) in soils of Bilagi and Bagalkot talukas, irrigated with different water sources, are presented in Figures 18 and 19. It was observed that more than 2/3rd of the black soils of the study areas were found in higher ranges >32.0 meq 100 g^{-1} while, the remaining samples were observed in medium range. Interestingly no significant difference were observed among different land use categories both in terms of irrigation sources and cropping systems.

These soils are inherently calcareous in nature and hence, the soils possess more calcium indifferent forms such as free salts, lime and in exchangeable forms (Doddamani, 1994; Dasog *et al.,* 1975). The amount of calcium added by the

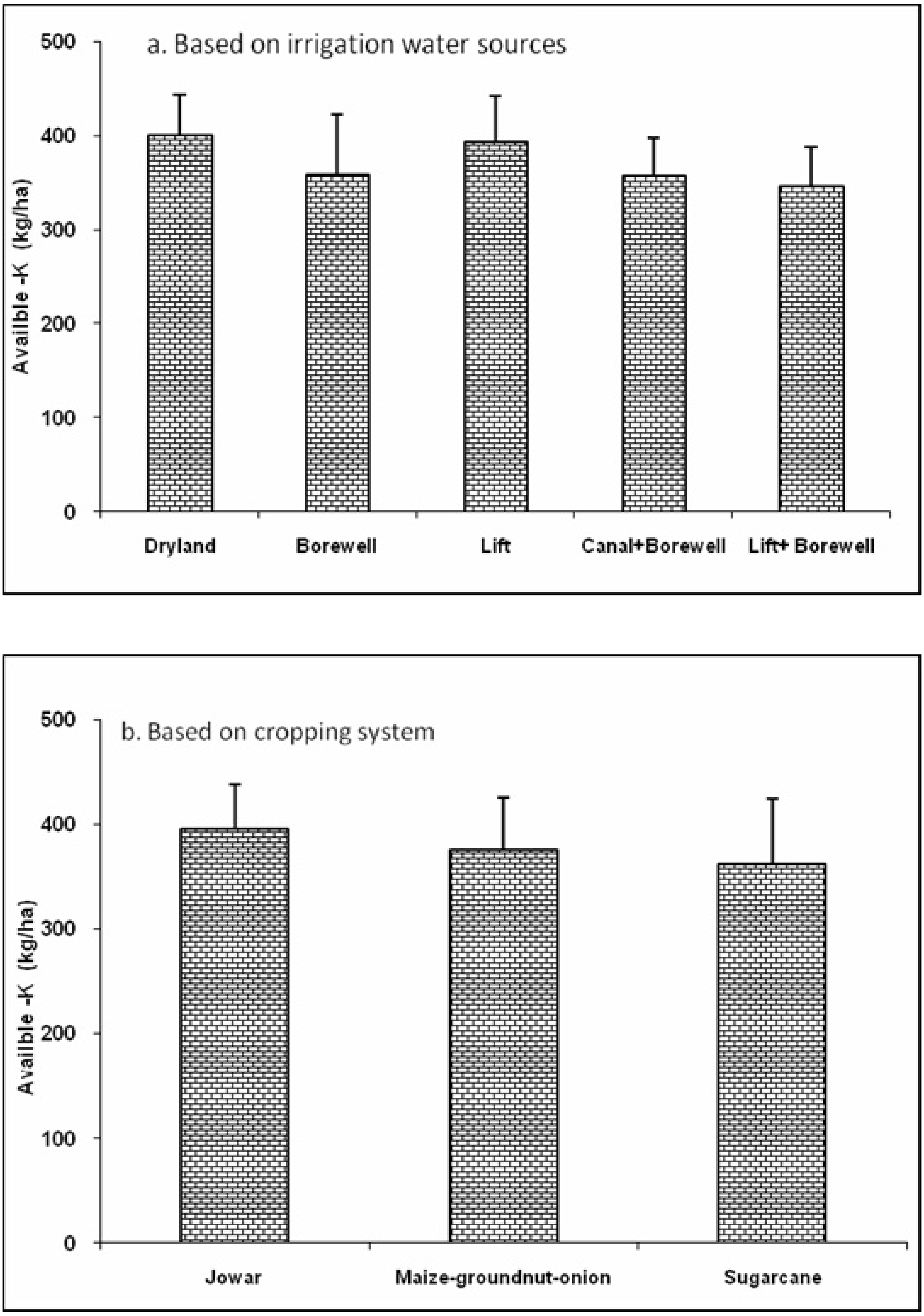
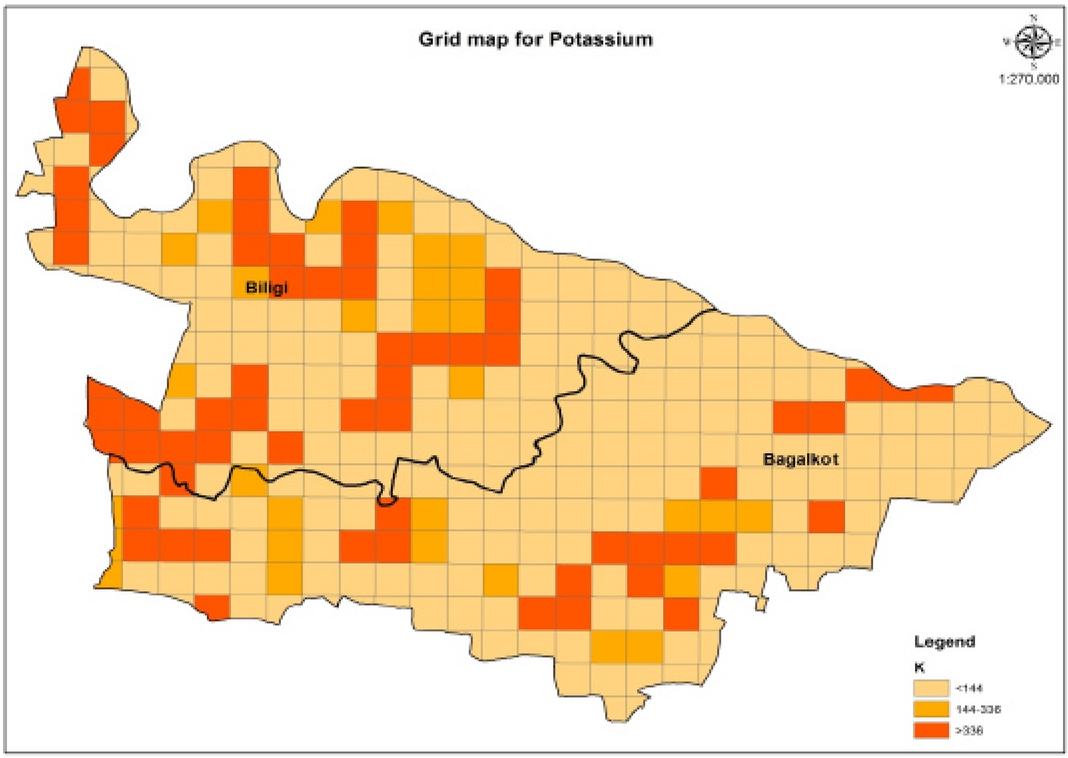


Figure 16: Magnitude of available potassium (K_2O) in black soils of Bilagi and Bagalkot talukas



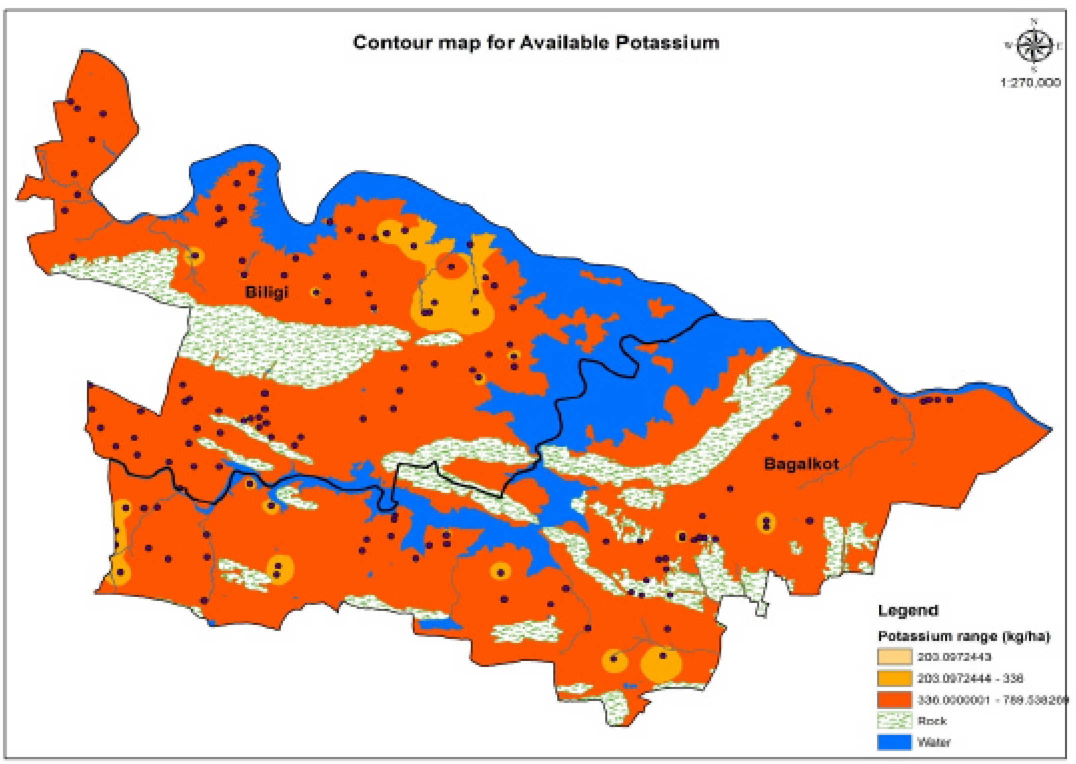
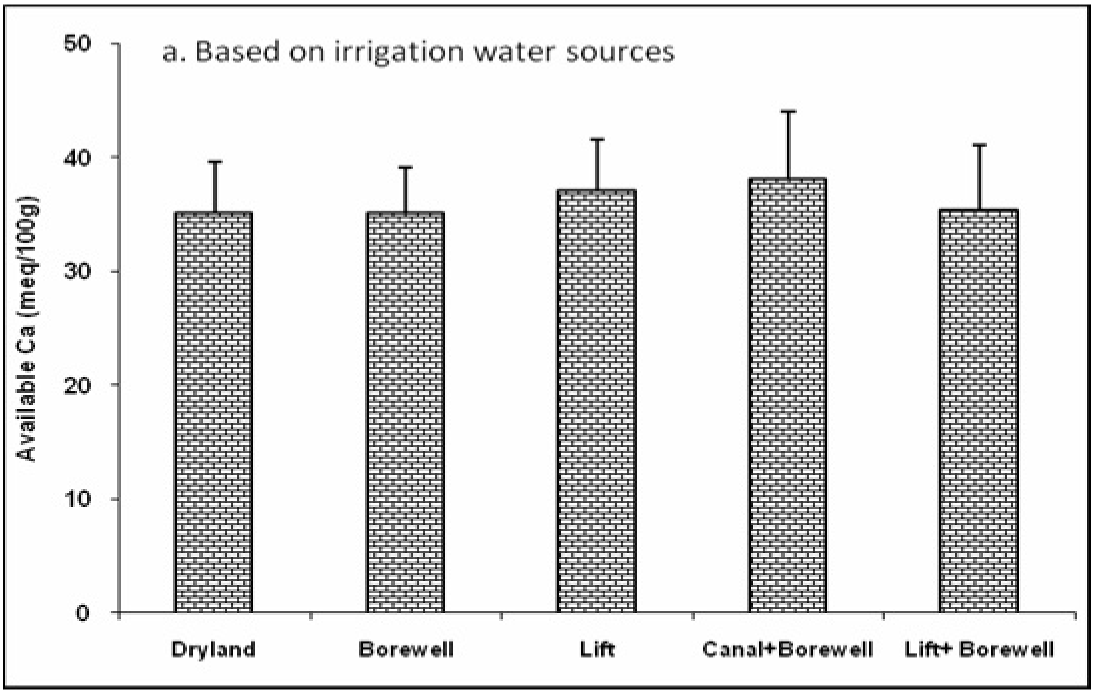


Figure 17: Grid and contour maps of Bagalkot and Bilagi talukas for available potassium (K_2O)



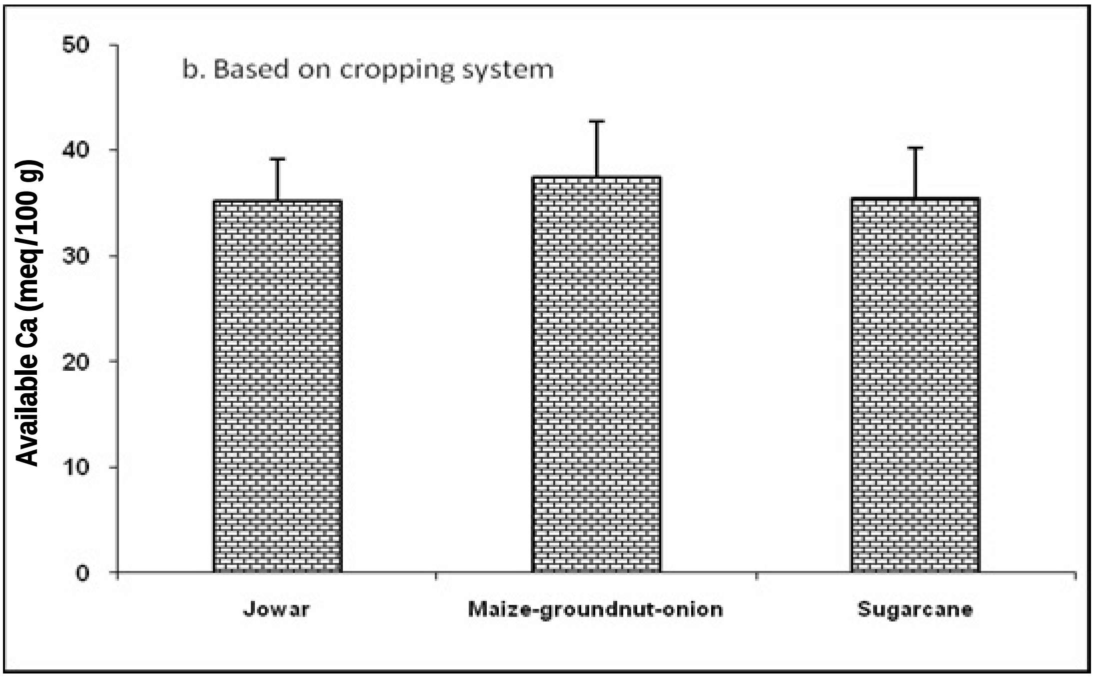


Figure 18: Magnitude of available–Ca in black soils of Bilagi and Bagalkot talukas

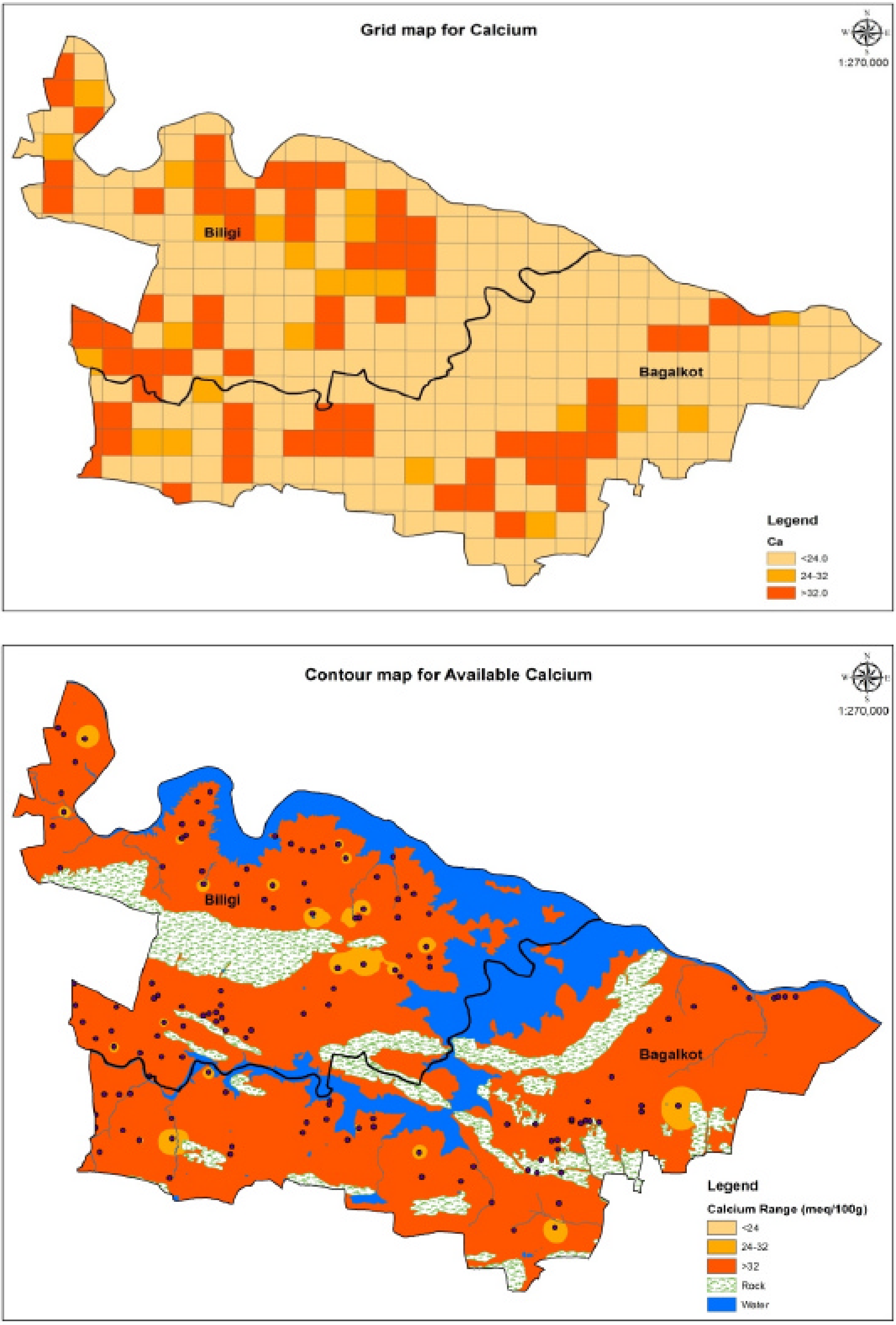


Figure 19: Grid and contour maps of Bilagi and Bagalkot talukas for available calcium

irrigation water, its removal by the crop or percolating water is negligible compared to the amount of calcium present in the soil. Similar observations on high available calcium contents were made in soils of Rajsthan and Gujarath by Dhir *et al* (1979).

5.2.5 Available magnesium

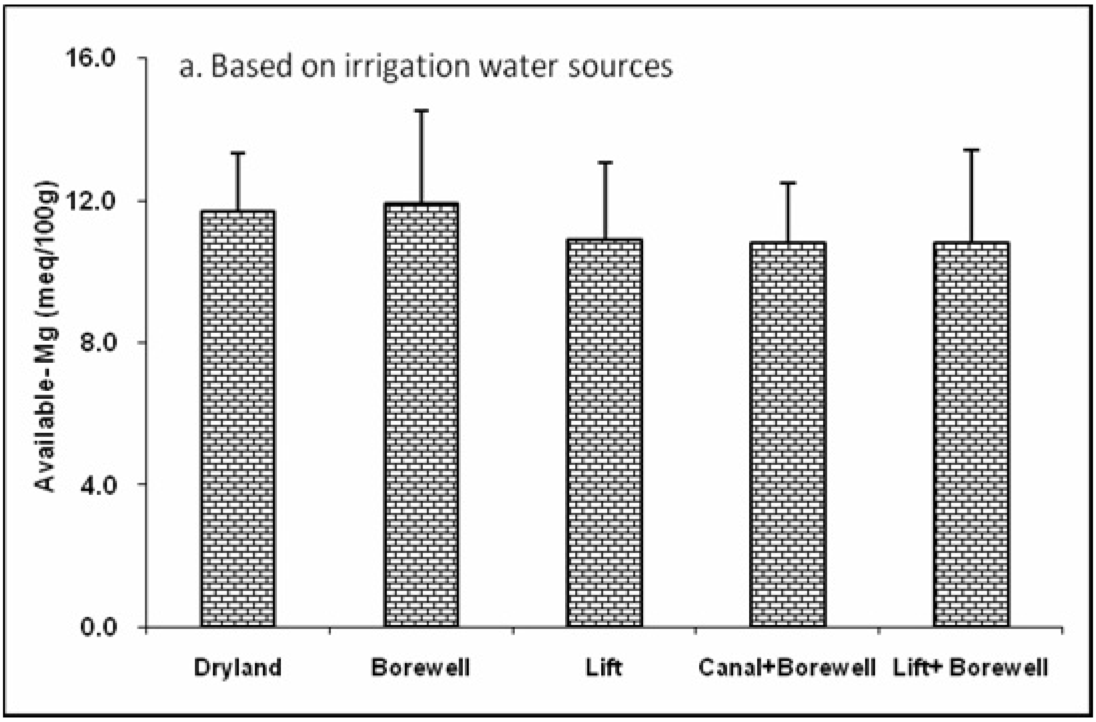
Analysis of soils of Bilagi and Bagalkot talukas for available-Mg indicated that almost all the soil samples recorded higher ranges (>8.0 meq 100 g^{-1}). No significant difference were found *w.r.t* available-Mg contents in different land categories either in terms of land categories or cropping systems.

Slightly lesser values in dryland soils compared to irrigated areas may be attributed to both crop uptake and leaching losses (Punithraj *et al.,* 2012; Sharana Bhoopala Reddy, 2012). Application of magnesium salt is a common practice in these calcareous soils and hence, the crop removal might have been compensated. However, no significant differences were found across land use categories both in terms of irrigation sources and cropping systems (Paliwal and Maliwal, 1971).

5.2.6 Available sulphur

Distribution of available-S in soils of Bilagi and Bagalkot talukas irrigated with different sources of water is presented in Figures 22 and 23. Among irrigated land categories, lift irrigated areas recorded significantly higher amounts of available-S. Contrastingly, it was found significantly lower in dryland soils and the values were found on par with canal + borewell land use system. The soils of Bilagi and Bagalkot talukas are mostly derived from lime based parent material and thus, available-S is likely to be lower as observed in dryland areas (Padole *et al.,* 1998). However, introduction of irrigation in the region have changed the cropping systems and also their nutrient management practices. Application of ammonium sulphateis practiced for sugarcane to overcome the deficiency of sulphur. This might have resulted in observing higher amounts of available-S in irrigated areas (Kapur *et al.,* 2005). Similar reports were added earlier by Rekha *et al.,* (2015).

Higher amounts of sulphur in lift irrigated areas may be attributed to reuse of stream water which is nothing but drained water from irrigated areas (Kirankumar *et al.,* 2013; Ashwin *et al.,* 2018). The salts present in the stream water might have



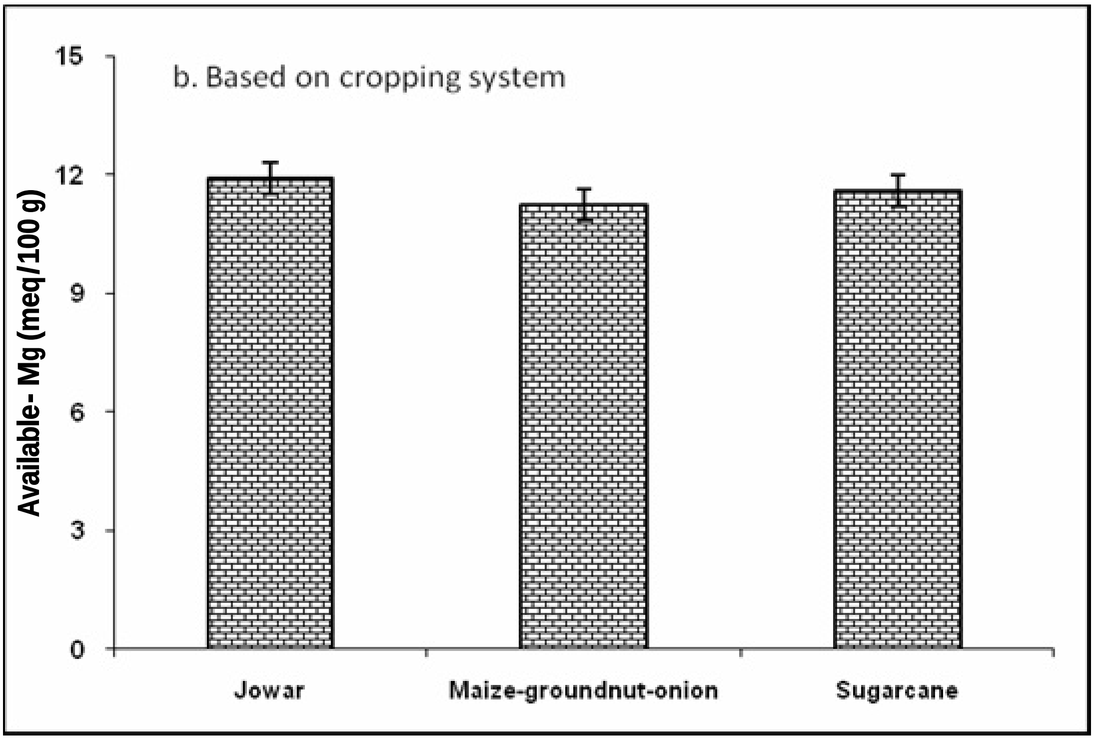
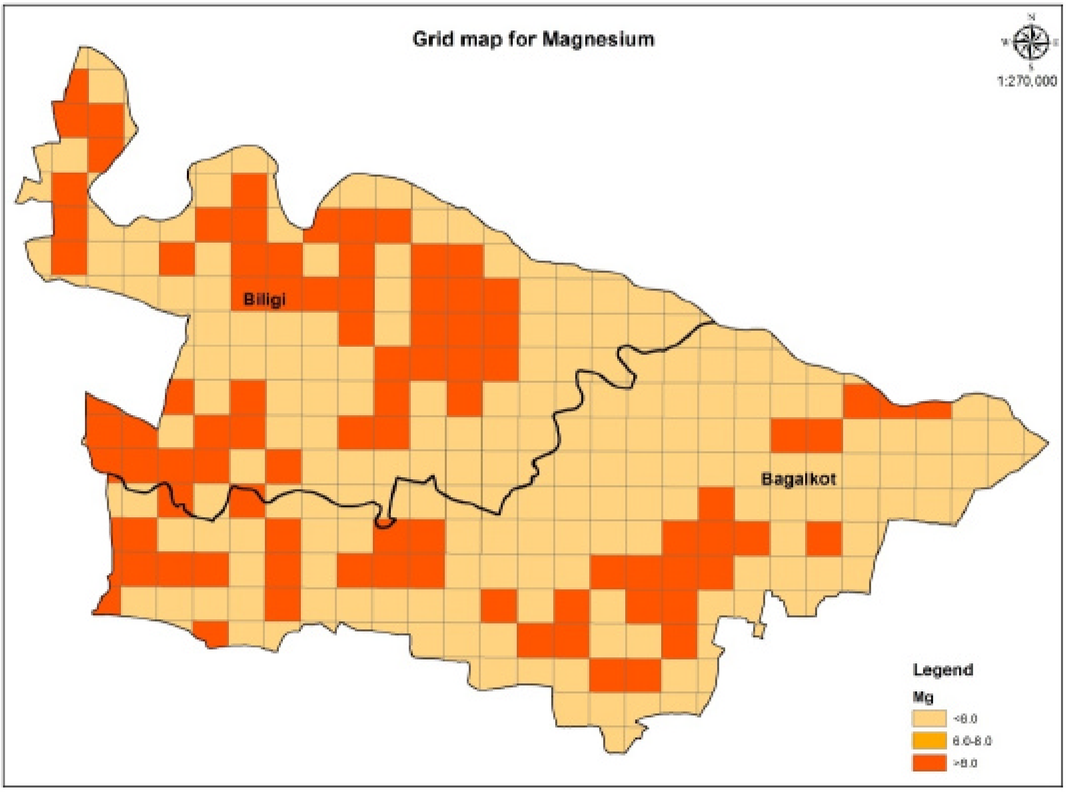


Figure 20: Magnitude of available -Mg in black soils of Bilagi and Bagalkot talukas



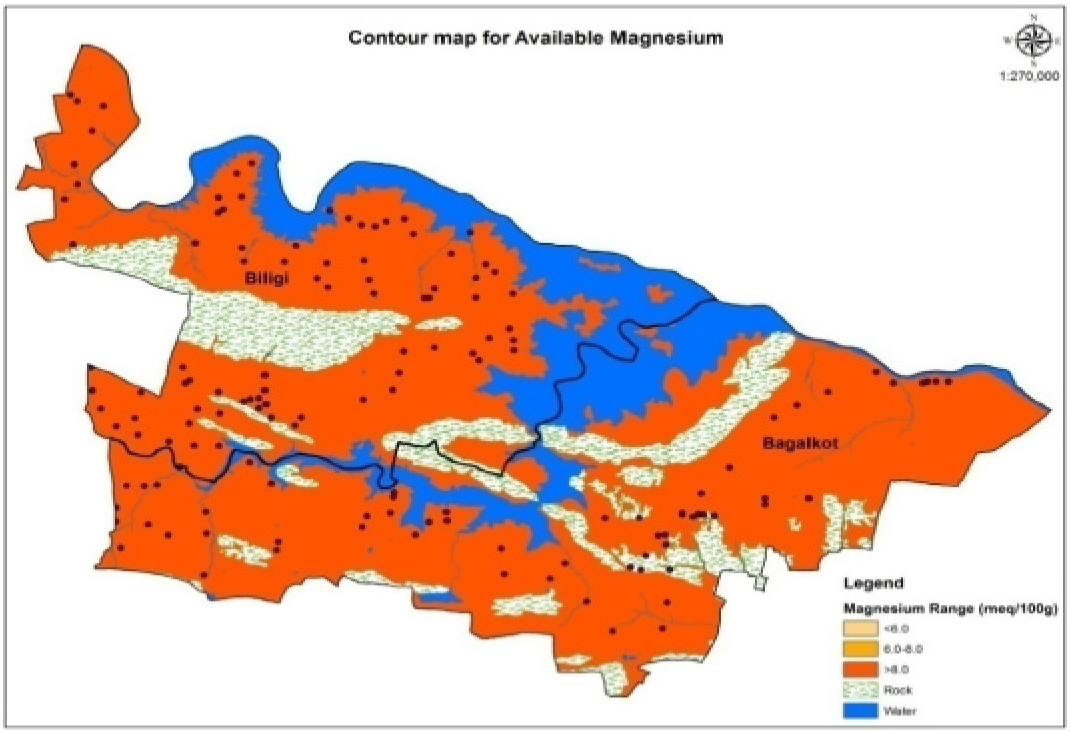


Figure 21: Grid and contour maps of Bilagi and Bagalkot talukas for available magnesium

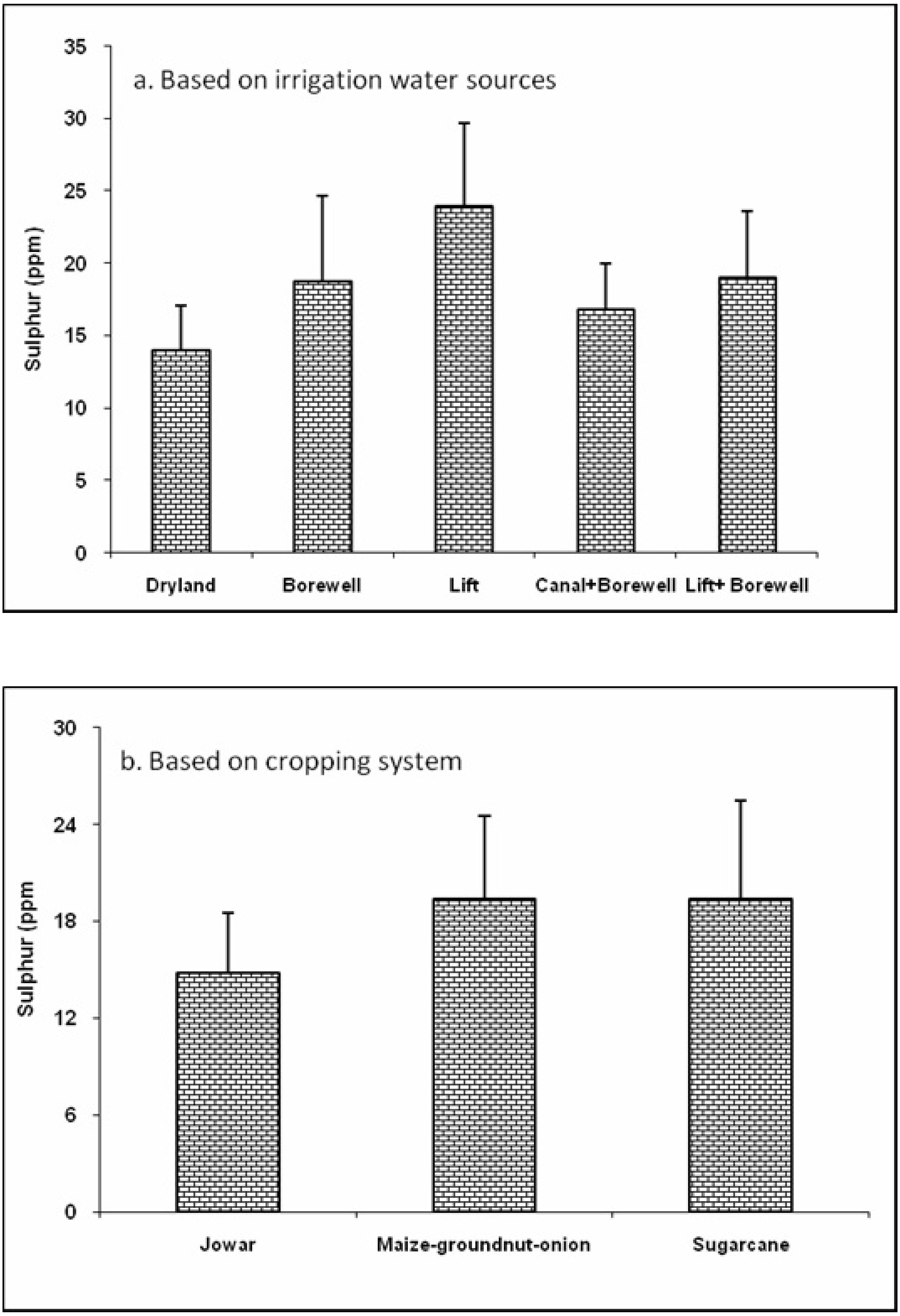
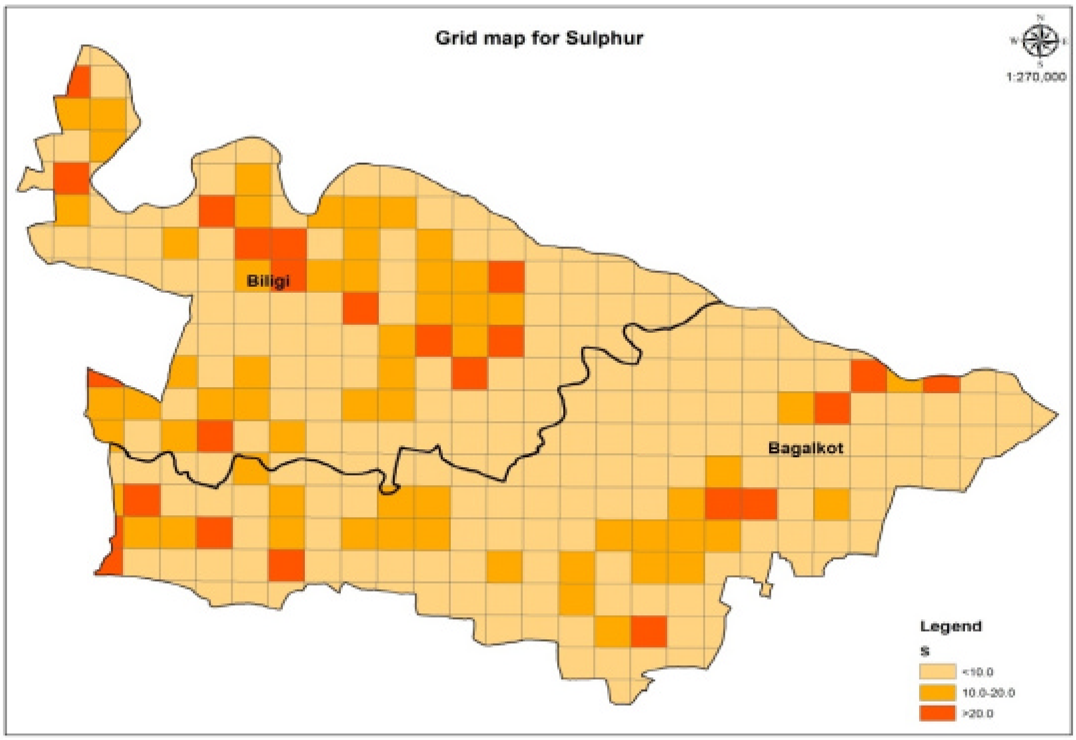


Figure 22: Magnitude of available -S in black soils of Bilagi and Bagalkot talukas



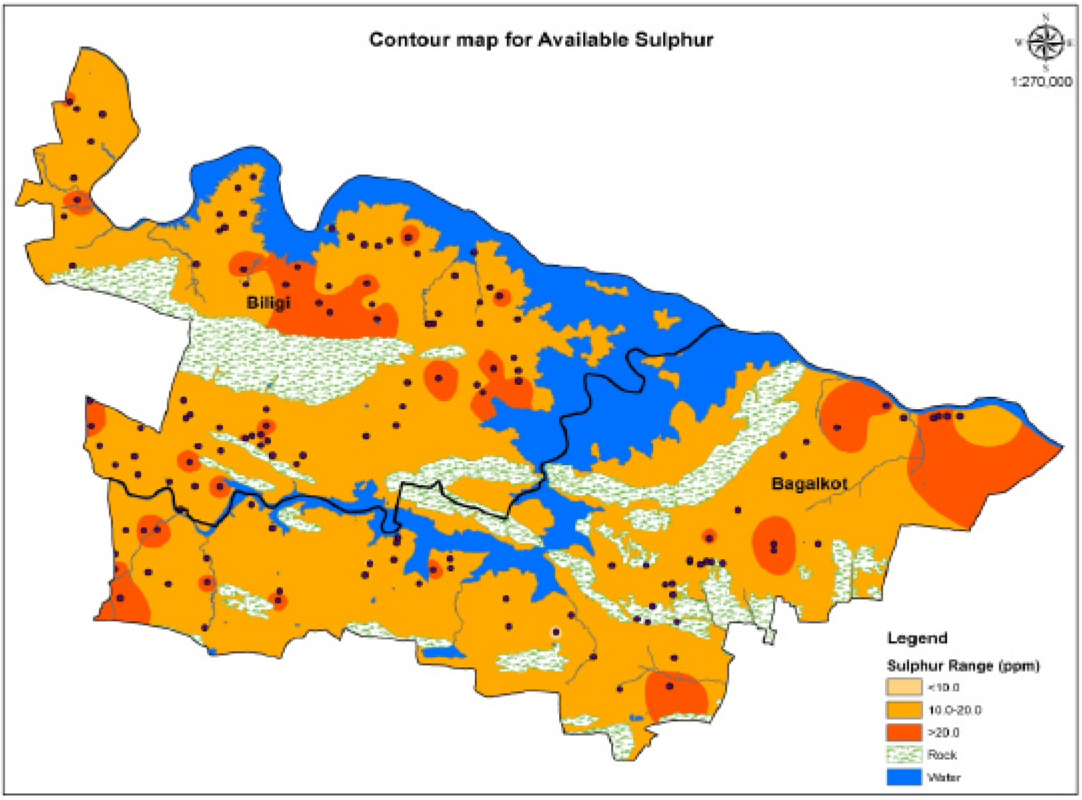


Figure 23: Grid and contour maps of Bilagi and Bagalkot talukas for available sulphur

enhanced sulphur content in soils. Application of sulphur containing fertilizers in sugarcane and maize- ground nut/ onion systems might have resulted in observing high sulphur content compared to jowar cropping system where sulphur is not applied (Rekha *et al.,* 2015).

5.2.7 DTPA- extractable iron

Analysis of black soils of Bilagi and Bagalkot talukas for available-Fe content (DTPA-Fe) revealed that more than 2/3rd of the samples (68.7%) were observed in higher range (> 4.50 ppm) while, 27.2% of the samples were observed in medium range. The extent of DTPA-Fe in soils of Bilagi and Bagalkot talukas are given in Figures 24 and 25. Among land use categories, soils of dryland and borewell areas recorded lower DTPA-Fe compared to other irrigated areas. Irrigation with stream water (lift practices) increased the DTPA-Fe in soils significantly. These variations in DTPA-Fe content may be attributed to alteration in soil pH. The solubility of iron bearing minerals and hence, its availability is largely influenced by soil pH (Lindsay, 1979; Obreza *et al.*, 1993; Rekha *et al.,* 2015).

Occurrence of higher amounts of carbonates and bicarbonates in both dryland areas and borewell irrigated areas might have reduced iron availability (Vijayshekar *et al.,* 2000; Rekha *et al.,* 2015).Frequent irrigation practices in lift irrigated areas might have enhanced anaerobic conditions in micro environment (Ravikumar *et al.,* 2007). The solubility of iron increases under anaerobic soil environment conditions as ferric form gets reduced to ferrous forms (Arora and Shekon, 1981; Lamture and Patil, 2015). These observations are in conformity with contrasting management practices observed in irrigated in sugarcane and dryland cropping system (Keshavaiah *et al.,* 2012).

5.2.8 DTPA- extractable manganese

Distribution of DTPA- Extractable Mn (DTPA-Mn) in black soils of Bilagi and Bagalkot talukas is depicted in Figure 26 and its spatial distribution in Figure 27. All the soil samples were observed in medium to higher range of available-Mn (DTPA-Mn). Soil DTPA-Mn contents varied among land categories based on irrigation sources and cropping systems. The dryland areas with no irrigation recorded least DTPA-Mn content. However, its availability increased significantly with the

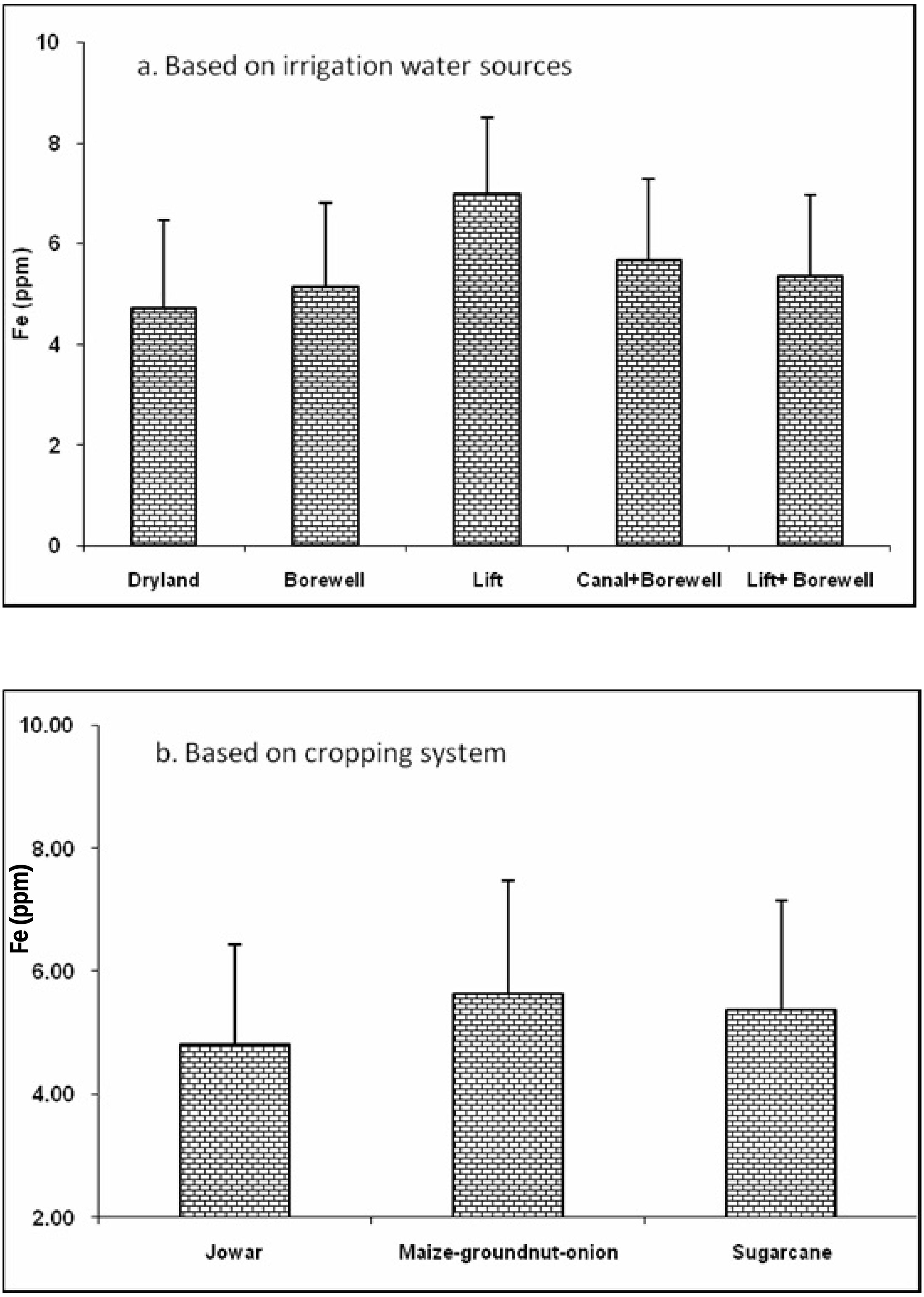


Figure 24: Magnitude of DTPA extractable iron in black soils of Bilagi and Bagalkot talukas

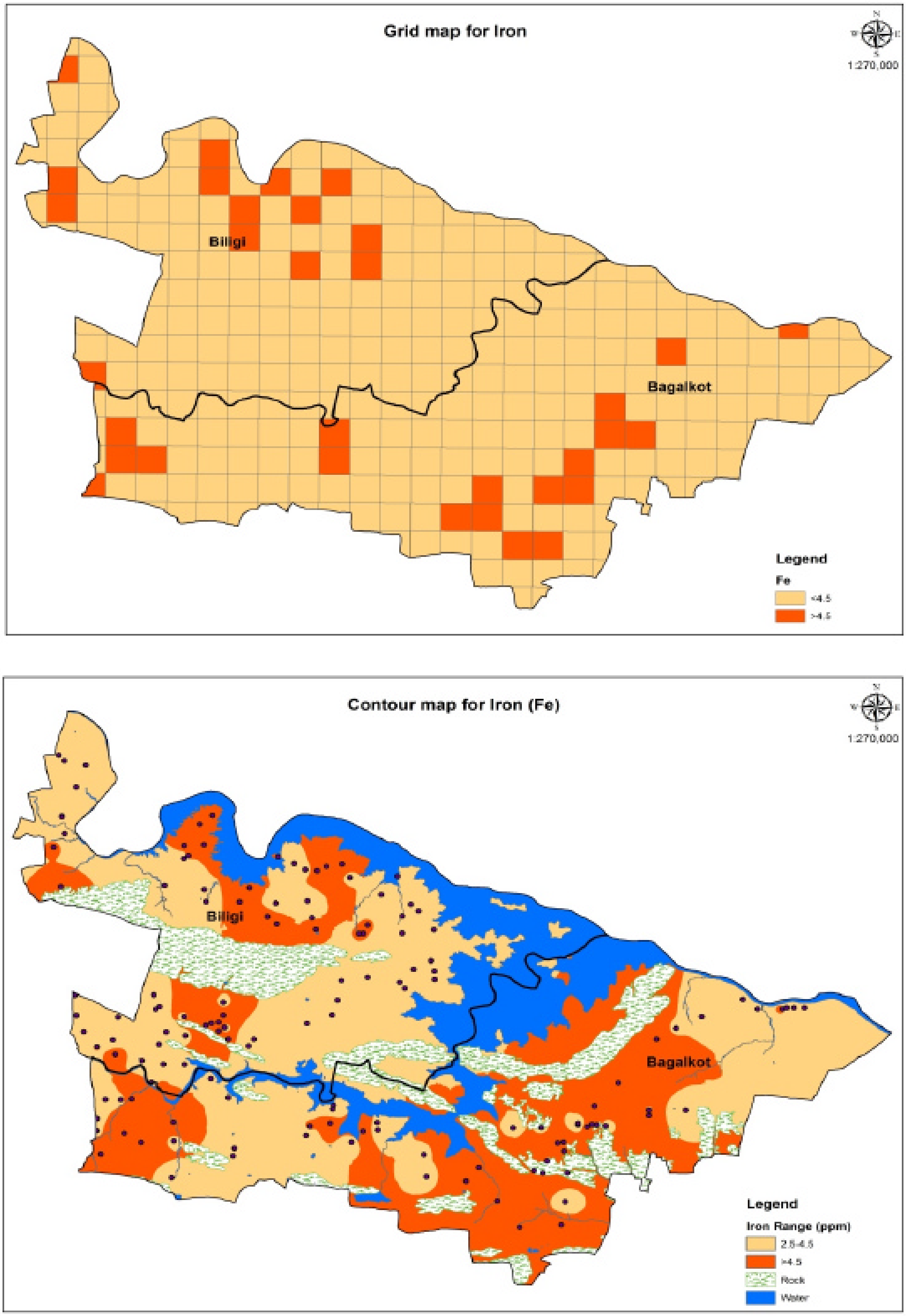


Figure 25: Grid and contour maps of Biligi and Bagalkot taluka for DTPA extractable iron

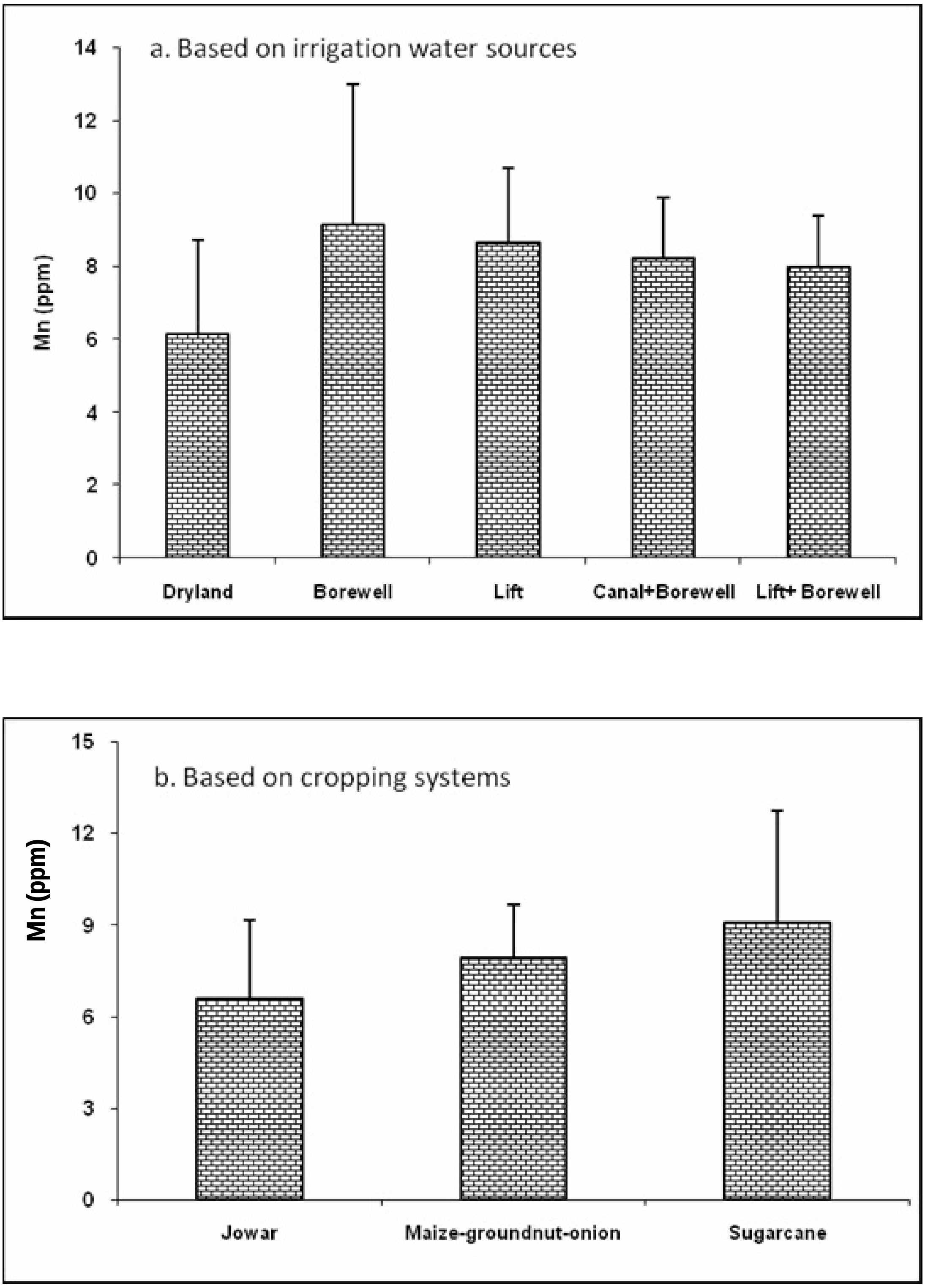


Figure 26: Magnitude of DTPA- extractable manganese in black soils of Bilagi and Bagalkot talukas

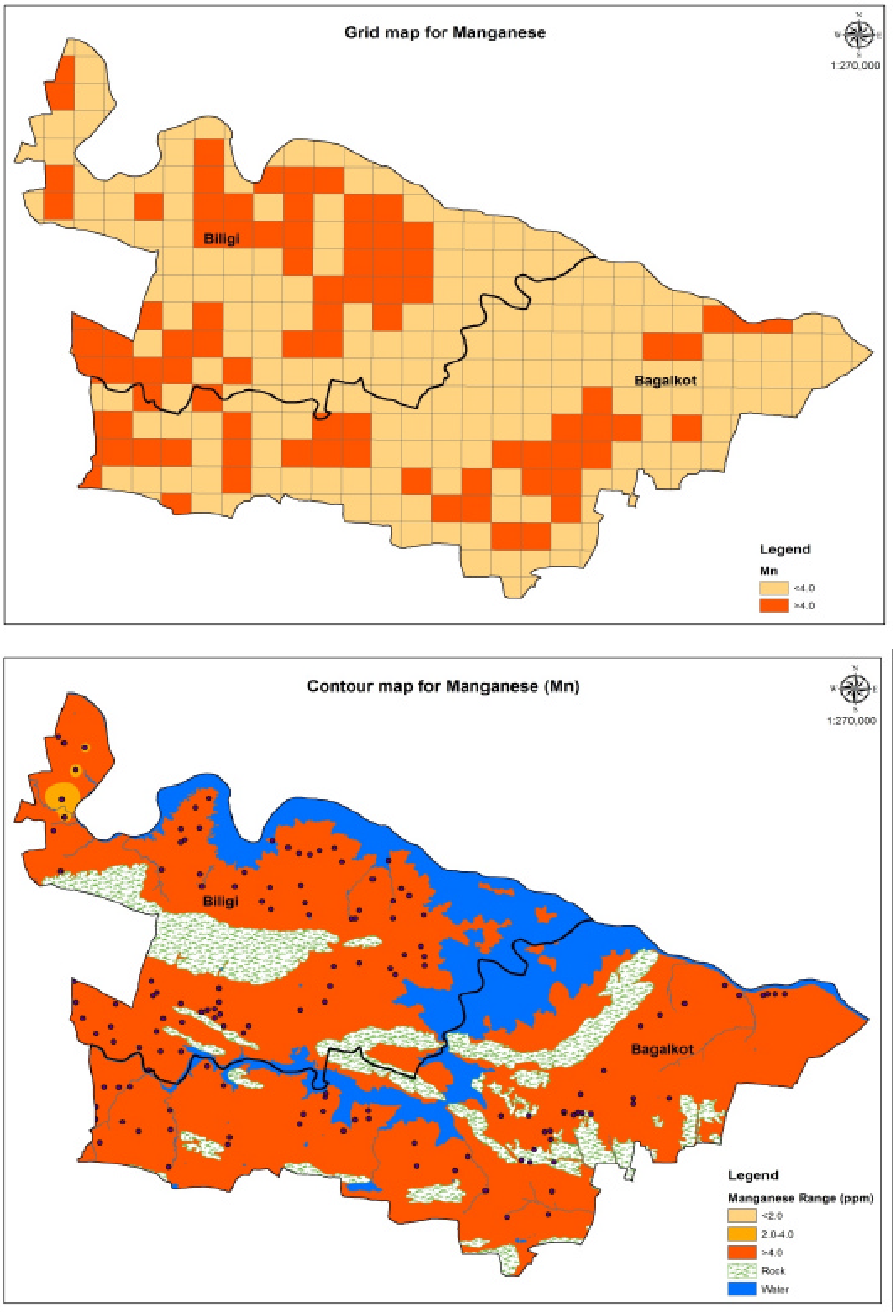


Figure 27: Grid and contour maps of Biligi and Bagalkot taluka for DTPA extractable manganese

introduction of irrigations. Interms of cropping systems, jowar recorded significantly lower amounts in contrast to irrigation based sugarcane system.

The variations in DTPA-Mn among different land use may be attributed to the effect of pH (Cleick *et al.,* 2008), anaerobic conditions in micro-environments (Arora and Shekon, 1981; Lamture and Patil, 2015) and high biomass turnovers (Punithraj, 2012). The solubility of DTPA-Mn increases with decrease in pH, decrease in Eh and organic molecules (acids) produced during decomposition (Chouhan *et al.*, 2012). The applied fertilizers especially urea, ammonium sulphate *etc*. might have caused soil acidity in micro environments resulting in its higher availability (Lamture and Patil, 2015).

5.2.9 DTPA- extractable zinc

The availability of Zn (DTPA-Zn) in Bilagi and Bagalkot talukas is depicted in Figures 28 and 29. The DTPA-Zn was found in the range of 0.39 to 3.55 ppm. Most of the soils samples (n=85) studied recorded medium range of DTPA-Zn (0.6-1.5 ppm). The soil samples representing lift + borewell irrigated areas recorded significantly higher DTPA-Zn content compared to other irrigated land categories. Lowest mean value was recorded in dryland system. These variations among different irrigation system may be attributed to different soil environment factors such as pH and soil organic matter (Arora and Shekhan, 1981; Lamture and Patil, 2015). Alternate wetting and drying cycles under rainfed conditions in dryland areas is known to precipitate zinc as ZnO and thereby, reduces its availability (Pulakeshi *et al.,* 2012).

Varying amounts of carbonates and bicarbonates in dryland areas and borewell irrigated areas might have altered the availability-Zn (Ravikumar *et al.,* 2007; Kirankumar *et al.*, 2016). Higher availability of Zn in maize and sugarcane cropping system may b attributed to direct application of $ZnSO_4$ (Vijayshekar *et al.*, 2000).

5.2.10 DTPA- extractable copper

The information pertaining to available-Cu (DTPA-Cu) content is given in Figure 30 and its spatial distribution for Bilagi and Bagalkot talukas is depicted in Figure 31. The availability of DTPA-Cu in most of the soils was found in medium to

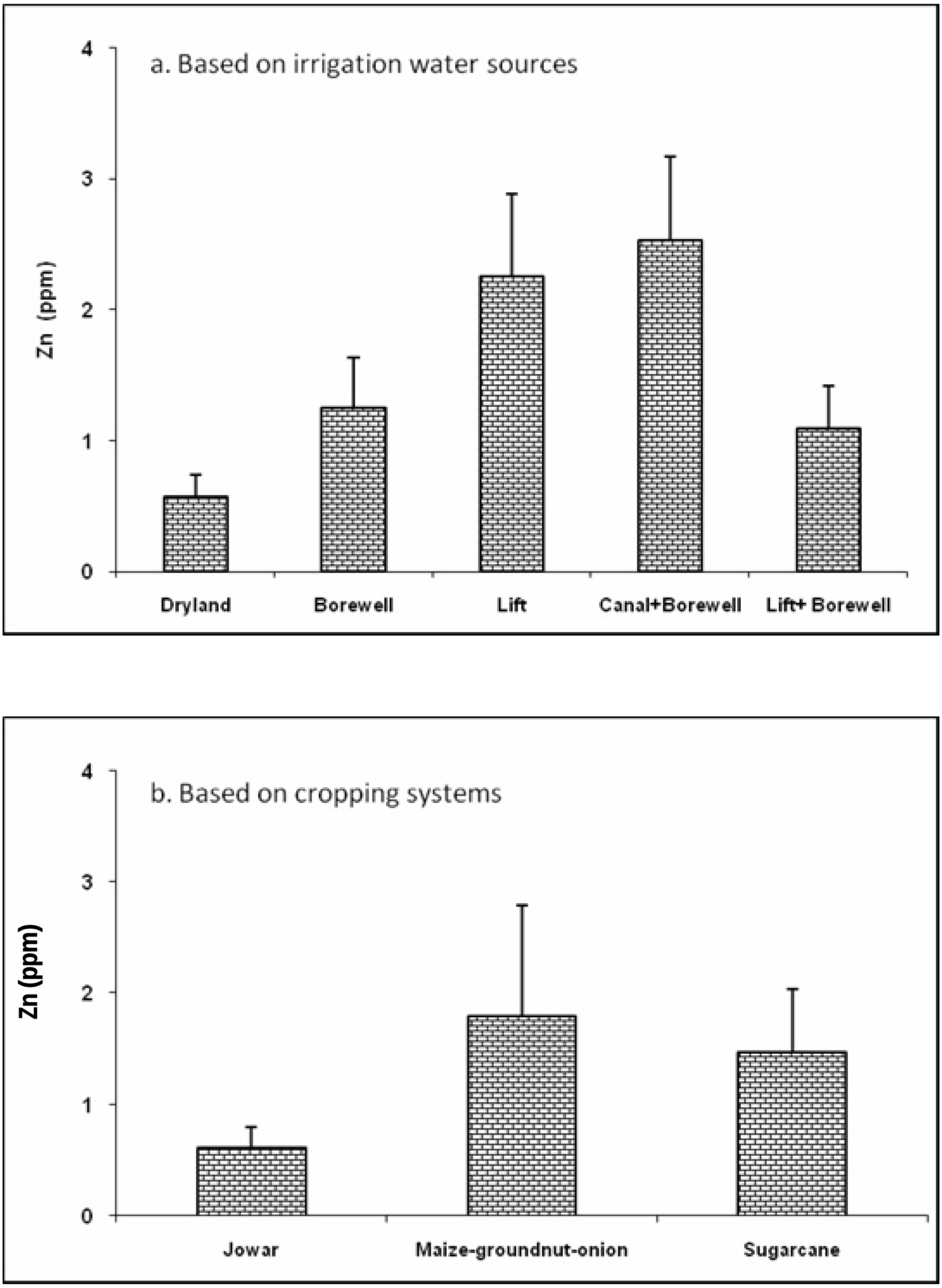


Figure 28: Magnitude of DTPA- extractable zinc in black soils of Bilagi and Bagalkot talukas

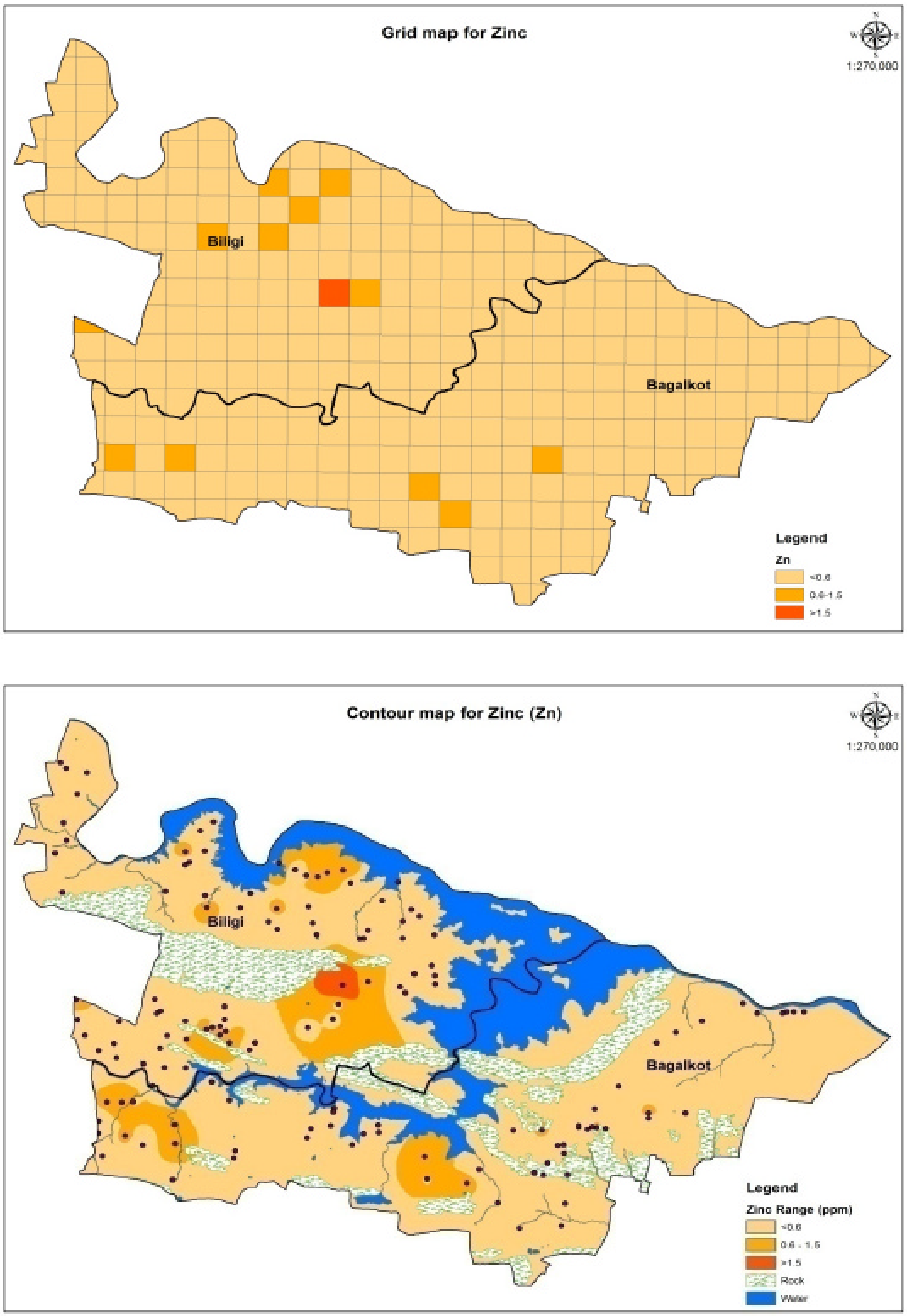
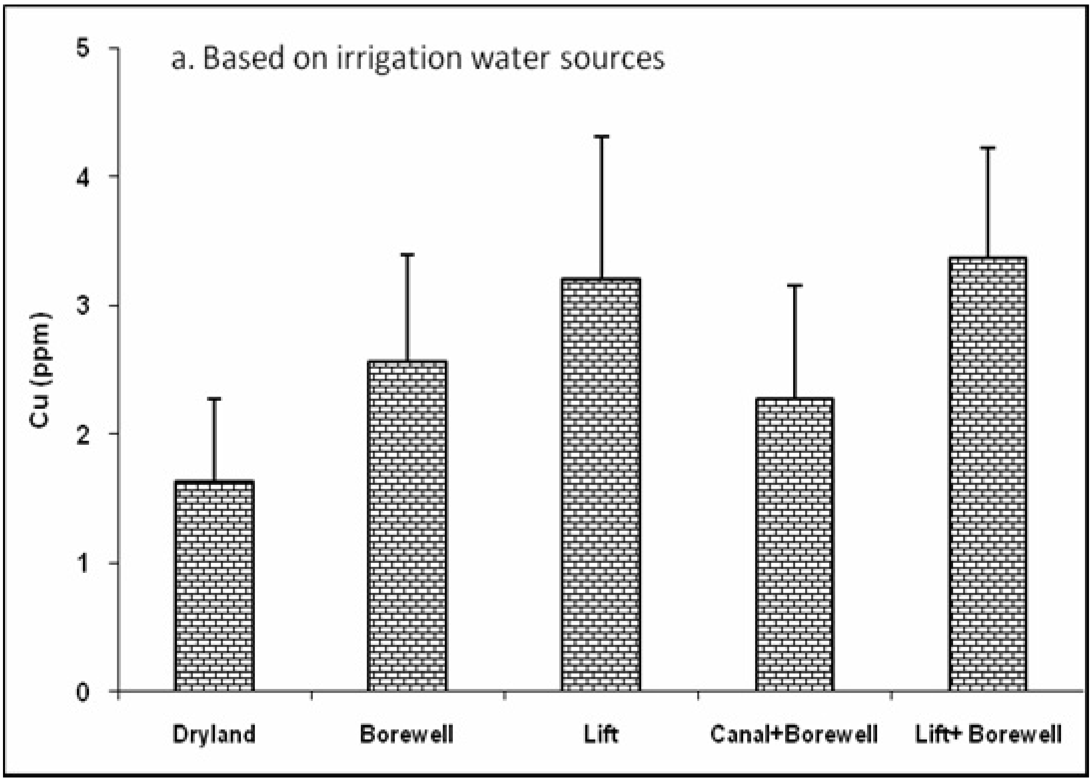


Fig 29: Grid and contour maps of Biligi and Bagalkot taluka for DTPA extractable zinc



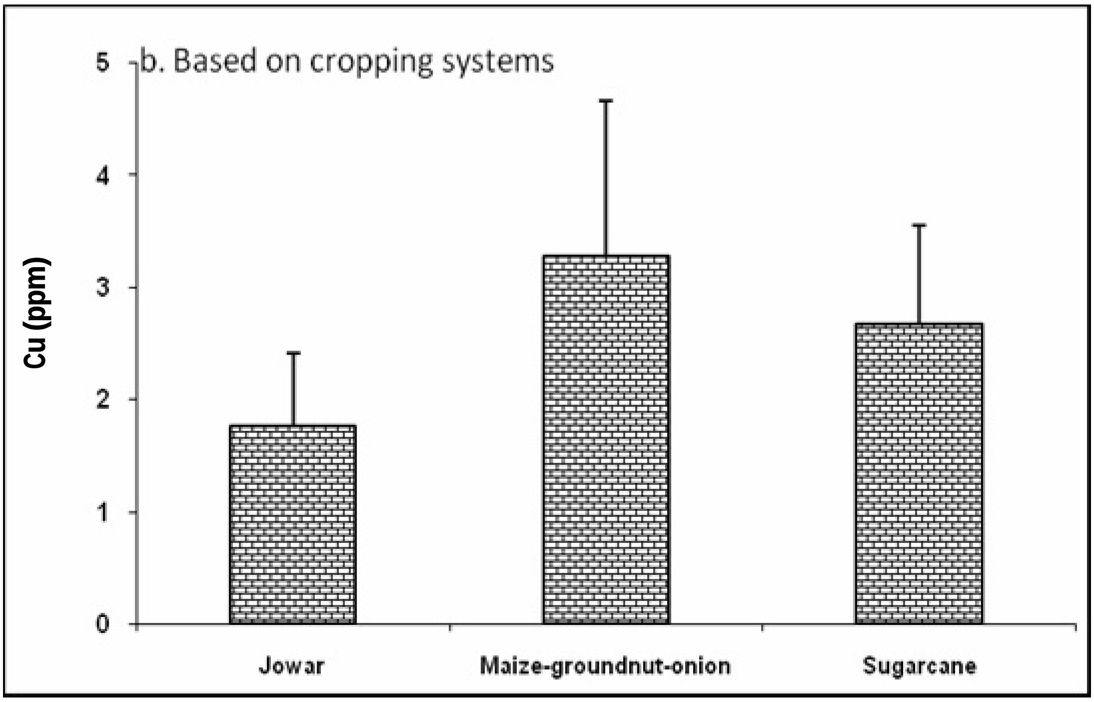
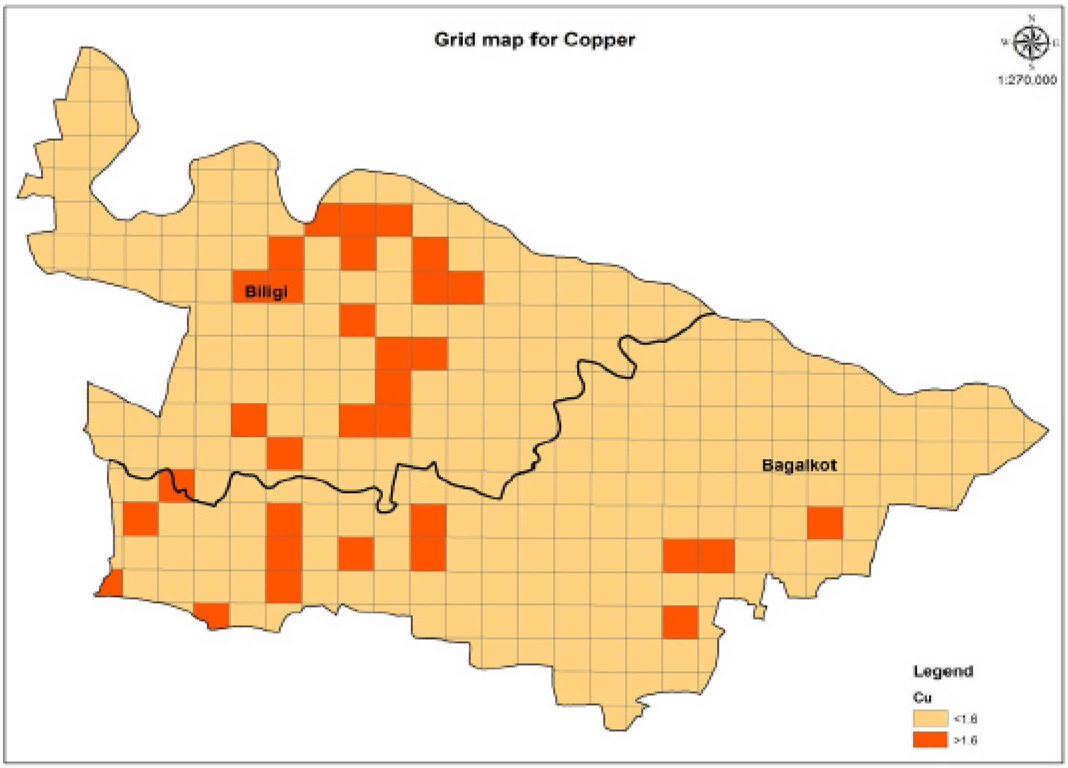


Figure 30: Magnitude of DTPA-extractable copper in black soils of Bilagi and Bagalkot talukas



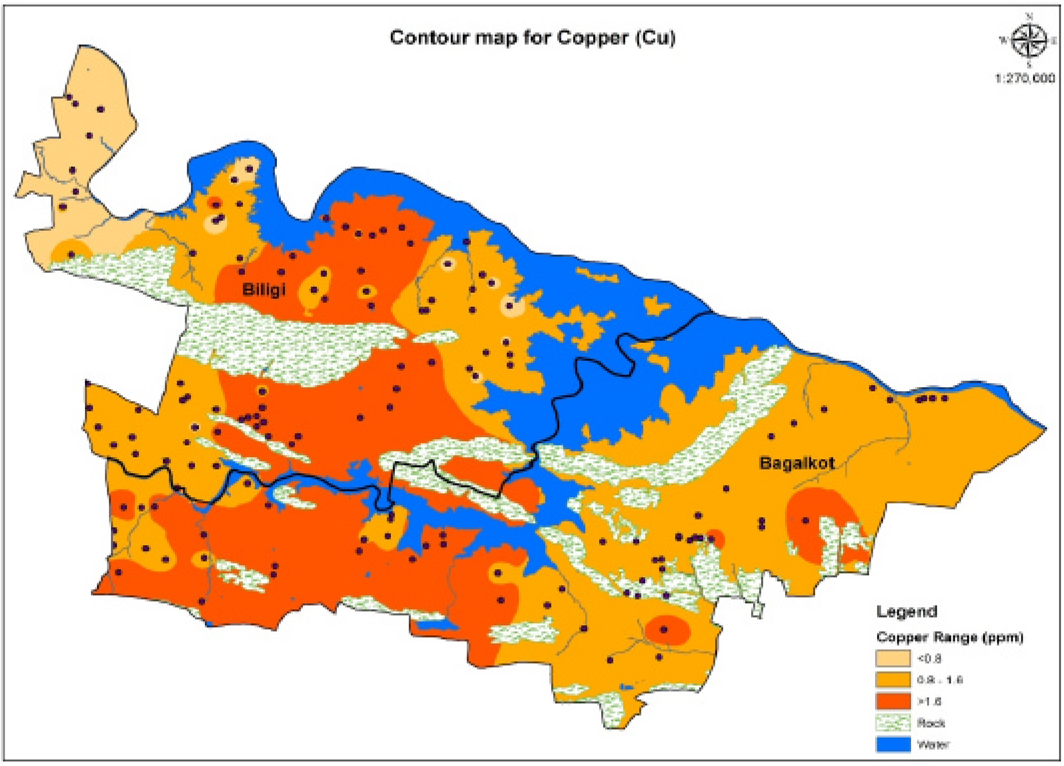


Figure 31: Grid and contour maps of Biligi and Bagalkot taluka for DTPA extractable copper

higher range. Similar to other micronutrients, DTPA-Cu was also found low in dryland areas compared to irrigated soils. Areas under lift + borewell irrigation recorded higher amounts of DTPA-Cu while, borewell and canal + borewell irrigated areas were found in medium range. As discussed earlier, the presence of carbonates and bicarbonates in soils and its effect on pH and solubility of minerals might have reduced DTPA-Cu in dryland soils. The same factors might have influenced the available-Cu content among different cropping systems (Lindsay, 1979).

5.3 Correlation studies for soil nutrient availability

The observations recorded were subjected to correlation studies and the relationship among different parameters were analyzed and they are discussed below. The soil pH, salt content, free $CaCO_3$ and soil organic-C had major influence on nutrient availability.

The available-N content was significantly influenced by soil pH and it did not show any specific trend on other major and secondary nutrients. Lower nitrogen availability at higher pH (moderate to highly alkaline soil reaction) may be attributed to volatalization losses of NH_3 (Fenn and Kissel, 1973). Similar reports of lesser available-N at higher pH are also reported (Nandi and Dasog, 1992).

Among DTPA- extractable micronutrients, higher soil pH (alkaline soil reaction) significantly reduced the availability of DTPA-Zn and Cu while, the other two micronutrients did not depict significant interaction. It is well established that the presence of carbonates and bicarbonates along with sodium, calcium and magnesium are known to increase the soil pH (Virmani *et al.*, 1982). At these pH levels, the metal ions are likely to get precipitate as respective oxides and hydroxides (Marshner, 1995; Talibudeen, 1981) and hence, reduces their availability.

The positive (correlation) relationship between salt content (EC_e) and available –Ca, Mg and S contents suggest that soil solution possess salts of the above ions (Doddamani, 1994). Sodium and chloride ions also might have playeda role but, observation were not made on them in this study. All the soil samples had free $CaCO_3$ and majority of them were categorized as calcareous (>10% free $CaCO_3$). Higher amounts of free $CaCO_3$ greatly reduced available-N content (-0.153*) while, no specific effect was observed with respect to other major and secondary nutrients.

Increase in soil pH due to presence of free $CaCO_3$ might have induced ammonia to volatalize and there by reduced its availability in soil (Fenn and Kissel, 1973; 1975).

The negative effects of free $CaCO_3$on soil micronutrients (DTPA-Fe, Mn, Zn and Cu) may also be attributed to higher pH resulting in precipitation of metal ions into respective oxides and hydroxides (Pulakeshi *et al.*, 2012). The soil organic-C showed positive effect on nitrogen and sulphur availability. The positive effect is largely attributed to strong association of nitrogen and sulphur with soil organic matter (Kumawat, 2000). The chelating property of SOM might have enhanced zinc availability. These metal ions may be occurring in salts as respective sulphates which might have resulted in showing significant positive effects.

Survey based fertility assessment of black soils of Bilagi and Bagalkot clearly indicated that there is a strong relationship between cropping systems and soil fertility. The source of irrigation water was also found to be an important influencing factor of soil fertility. Thus, the soil fertility varied to different extents as influenced by the source of irrigation water and the existing cropping systems.

6. SUMMARY AND CONCLUSIONS

Assessment of soil fertility on spatial scale is very important for the policy makers to enhance productivity of agricultural lands. A study was carried out to assess the nutrient availability in soils of Bilagi and Bagalkot talukas and summary of the results are briefed in this section.

Soil reaction (pH) was found in the range of 7.42 to 9.31 indicating moderate to high alkalinity. Nearly half of the soil samples recorded moderately alkaline pH of 8.00 to 8.50 and majority of them were seen in dryland areas. The soil pH of dry land areas were significantly higher (8.32 ± 0.50) while, lift and /or borewell irrigated areas recorded lower pH values. Among cropping systems the soil pH found in the order of jowar> sugarcane > maize/groundnut-onion cropping systems.

In terms of soil salinity, nearly 43 per cent of the soil samples were safe with < 2.0 dS m^{-1} while the remaining samples showed > 2.0 dS m^{-1} indicating moderate to high salinity. The ECe of soils of different irrigation system varied significantly in the order: lift = (canal + borewell) > (lift + borewell) > borewell> dryland. ECe of soils of different cropping systems varied in the order of jowar < sugarcane < maize / groundnut – onion cropping system.

Majority of the black soils of Bilagi and Bagalkot talukas (88 %; 129 samples) were categorized as calcareous with free $CaCO_3$ of > 10% and it ranged from 8.5 to 26.0 % and the higher values were observed in dryland soils compared to irrigated areas. Among cropping systems, $CaCO_3$ content was significantly higher in jowar (17.81 ± 3.71 %) compared to sugarcane and mazie/groundnut-onion system.

In terms distribution of soil organic-C, nearly 60 per cent of the soil samples (n = 90) recorded medium range of soil organic-C (0.50 to 0.75%) and nearly $1/4^{th}$ of the samples (n =35) recorded higher range of soil organic-C (> 0.75%). Among irrigated areas, lift irrigation systems with or without borewell recorded significantly higher amounts of soil organic-C. Among cropping systems, maize / groundnut - onion system recorded higher amounts of soil organic-C (0.76 ± 0.09 %) followed by sugarcane (0.66 ± 0.14 %) and jowar (0.62 ± 0.20 %) cropping systems.

The extent of available-N in soils ranged from 197.5 to 450.0 kg N ha^{-1}. Soils from borewell irrigated areas showed significantly higher amounts of available-N (359.1 ± 54.5 kg-N ha^{-1}) while, dryland area was observed with significantly lower amounts (304.0 ± 49.8 kg-N ha^{-1}). Among different cropping systems, soils from maize/groundnut-onion (375.6 ± 27.6 kg N ha^{-1}) areas recorded significantly higher available-N while, the other two systems namely, jowar system and sugarcane systems recorded significantly lower amounts.

The soils of lift irrigated areas recorded significantly high phosphorus availability (42.5 ± 7.2 kg P_2O_5 ha^{-1}) while, dry land soils recorded least (29.0 ± 7.8 kg P_2O_5 ha^{-1}). In terms of cropping systems, maize / groundnut – onion cropping system recorded significantly higher availability phosphorus content (40.7 ± 11.7 kg P_2O_5 ha^{-1}) and least available phosphorus (29.0 ± 7.4 kg P_2O_5 ha^{-1}) was recorded in jowar cropping system

Available potassium in soils varied among irrigation based land categories. The dryland areas with no irrigations (rainfed) recorded significantly higher amounts of available potassium (401.2 ± 42.3 kg K_2O ha^{-1}) while, all other irrigated land categories recorded lesser available potassium. Among different cropping systems, the available-K_2O content varied significantly in all the three systems in the order of jowar> sugarcane > maize / groundnut- onion cropping systems.

Distribution of available-Ca and Mg contents did not show any significant differences among different land categories based on irrigation sources or cropping systems. Mean available-Ca and Mg contents were found in the range of 35.15 to 38.31 meq 100 g^{-1} and 10.78 to 11.89 meq 100 g^{-1} respectively.

Available-S was in medium range (10-20 ppm) in nearly 2/3rd of soil samples studied. The lands irrigated with stream water (lift irrigated areas) were observed with significantly higher amounts of available-S and found significantly lower in dryland soils. Among different cropping systems, it was found in the order: jowar < sugarcane = maize /groundnut – onion based cropping system.

Distribution of DTPA-Fe in soils of dryland and borewell areas recorded lower DTPA-Fe compared to other irrigated areas. Irrigation with stream water (lift practices) increased the DTPA-Fe in soils significantly. Among different cropping systems, sugarcane and maize / groundnut - onion cropping systems recorded significantly higher amounts of DTPA-Fe.

The amount of DTPA-Mn ranged from 2.31 to 18.51 ppm in soils of different land categories. Nearly 90 per cent of the soil samples (n = 132) were observed in high range of DTPA –Mn (> 4.00 ppm). Soils from borewell and lift irrigated areas showed significantly higher amounts while, dryland area was found with lesser amounts. Soils from sugarcane grown areas recorded significantly higher DTPA-Mn followed by other two systems.

The amount of DTPA-Zn in soils ranged from 0.39 to 3.56 ppm. It was observed that majority of black soils (82.2 %) of Bilagi and Bagalkot talukas recorded medium to high range of DTPA-Zn. Majority of sugarcane grown soils recorded medium to high range of DTPA-Zn. Significant differences in DTPA- Zn values were observed among different cropping systems in the order : maize / groundnut- onion = sugarcane > jowar systems.

The availability of DTPA-Cu was also found in medium to high range in almost all the soils. Similar to that of other micronutrients, DTPA-Cu was also found low in dryland areas (98.0 %). In contrast, significantly higher amounts of DTPA-Cu were observed in soils of lift + borewell irrigated soils. Among different cropping systems, soils from maize / groundnut - onion system recorded highest DTPA-Cu (3.27 ± 1.39 ppm). Thus, the availability of copper among different cropping system was found in the order: maize / groundnut - onion = sugarcane> jowar system.

Finally, It was evident that the soil fertility varied to a great extent a determined by the source of irrigation water and the existing cropping system. However, the study remains always incomplete and the future line of work are given below,

1. The information generated can be effectively utilized to delineate the areas suitable for different agricultural and horticultural crops

2. Identification of alternative horticultural cropping systems with low water requirements especially for the borewell irrigated sugarcane growing areas is worth doing to prevent resource degradation further.

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CHARACTERIZATION AND SPATIAL FERTILITY STATUS OF BLACK SOILS OF BILAGI AND BAGALKOT TALUKAS

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ABSTRACT

A soil survey was conducted for characterization and spatial fertility status of Bilagi and Bagalkot taluka areas irrigated with different water sources and different cropping systems.

The pH of soils ranged from moderate alkaline to high alkalinity and it differed significantly with and without irrigations. The electrical conductivity (ECe) also varied significantly among soils irrigated with different water sources. Majority of the soils studied were calcareous in nature with high $CaCO_3$ content. Soil organic carbon (SOC) was in medium range. The available nitrogen content ranged from low to medium while, available potassium ranged from medium to high. Available-P_2O_5 was observed in low to medium range and significant difference was found between irrigation water sources or cropping systems.

Among secondary nutrients, available Ca and Mg contents were observed in high range and no significant differences were observed between sources of irrigation water and cropping systems. Available-S content in these soil was recorded medium to high range. Among micro nutrient contents, DTPA-Cu, Fe and Mn were observed in higher range and differed significantly with water sources and cropping systems. However, DTPA-Zn was found in all the three low, medium and high ranges and differed significantly. In terms of nutrient availability in different cropping systems, It was evident that the soil fertility was varied to a greater extent by the sources of irrigation water, and in terms of cropping system it was observed in the order: Sugarcane > Maize/Groundnut-Onion > Jowar cropping systems..

Correlation showed that the soil pH, ECe, $CaCO_3$ and SOC recorded major influence on nutrient availability. The soil pH was found negatively and found significantly correlated with available-N, DTPA – Zn and DTPA – Cu contents. The soil organic-C had influenced on available-N, available-P, available-S and DTPA-Zn significantly. The soil EC showed correlation with Available- Ca, Mg, S, DTPA – Zn and DTPA – Cu contents. The soil $CaCO_3$ content showed negative correlation with available-N, available-P_2O_5, DTPA-Znand Cu.

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