Status of soil degradation in an irrigated command area in Chikkarasinakere Hobli, Mandya district, Karnataka

Rajendra Hegde[1,*], A. Natarajan[1], R. S. Meena[2], K. V. Niranjana[1], S. Thayalan[1] and S. K. Singh[3]

[1]National Bureau of Soil Survey and Land Use Planning (ICAR), Hebbal, Bengaluru 560 024, India
[2]National Bureau of Soil Survey and Land Use Planning (ICAR), Udaipur, Rajastan 313 001, India
[3]National Bureau of Soil Survey and Land Use Planning (ICAR), Amravathi Road, Nagpur 440 033, India

Of late, the crop productivity levels in many irrigated command areas have plateaued or started declining rapidly due to the deterioration of soil health. Unscientific and excessive irrigation, growing crops not compatible with the soils and unscientific management of soils are the main causes for the present situation. Waterlogging, increased salinity/sodicity, nutrient imbalance, shrinking diversity of micro-flora and fauna have become major constraints limiting the choice of crop and crop productivity. We present a study on this issue from the Cauvery command area. Detailed cadastral-level survey taken up to study the status of soil and other resources occurring in Chikkarasinakere block of Mandya district, Karnataka during 2010 has brought out the alarming state of land degradation observed in the area. Nearly 59% of the area is suffering from various degrees of chemical and physical degradation. The situation becomes alarming because the area had well-drained red soils highly suitable for irrigated agriculture when irrigation was introduced during 1930s. The process of degradation will accelerate if appropriate interventions/investments are not undertaken on priority. Continuation of present management practices can rapidly damage the soil health. As the command area is one of the important rice bowls of Karnataka, there is an urgent need to reverse the process of degradation by adopting site-specific interventions as indicated in the study. The present study reveals that the Cauvery command are in Karnataka is losing Rs 1000 crores every year due to this problem.

Keywords: Crop productivity, irrigated command area, nutrient imbalance, land degradation, soil salinity/alkalinity.

IRRIGATION is an age-old art and is believed to be as old as the history of agriculture itself. References to wells and tanks are found in several ancient scriptures of the world and their important role in irrigation has also been highlighted. References could be quoted to attest that adverse effects of excess water use even from ancient times. According to a hymn in the *Narada-Smirthy*, a Hindu epic, Sage Narada said, 'No grain is ever produced without water, but too much water tends to spoil the grain. An inundation is as injurious to growth as is the dearth of water'.

It is a well established fact that continuous use of land for irrigated crop production increases the groundwater level and consequently the salinity levels in the soil. Over a period of time, if there is inadequate drainage, the depth to the water table will decrease and a shallow saline water table develops, particularly in semi-arid tropics. In the presence of a shallow saline water table, crop production can suffer when salts accumulate in the surface soil through capillary action and/or directly as a result of waterlogging. The twin menace of waterlogging and soil salinization/sodification has threatened the sustainability of irrigated agriculture for centuries. Historical records have revealed that many ancient civilizations that relied upon irrigated agriculture have failed due to these problems. The Sumerian civilization of ancient Mesopotamia declined as agricultural productivity began to decrease due to waterlogging and soil salinization[1]. The same process that contributed to the demise of ancient civilizations continues to plague irrigated areas today. A two-decade-old estimate suggests that worldwide crop production losses associated with salinity on irrigated lands are around US$ 11 billion annually and are increasing every year[2].

The green revolution, witnessed during the 1960s and 1970s in India, was a great success mainly due to the introduction of high-yielding variety seeds coupled with subsidies and such other promotional incentives on crucial inputs like irrigation, fertilizer, pesticides and a policy support system. There is no doubt that these measures really helped India achieve self-sufficiency in food grain production. Subsidies on inputs and output price support motivated the farmers to adopt new technologies. But prolonging those policies in the post-green revolution period resulted in distortion of farm-level incentives for

*For correspondence. (e-mail: rajendrahanagar@gmail.com)

efficient input use and caused the degradation of natural resources. The dramatic increase in production came from the intensification of land use, which generated changes in the production system, such as a greater reliance on canal irrigation and chemical fertilizers, changes in planting schedules and greater uniformity in the varieties cultivated. Those changes resulted in significant environmental degradation, such as the building up of salinity, alkalinity, nutrient imbalance and waterlogging, depletion and pollution of groundwater, and increase in pests and diseases, etc.

Soil salinity and sodicity are mainly associated with high groundwater table that brings salts into the root zone and to the surface through capillary rise when water evaporates. Waterlogging and soil salinity/alkalinity are threatening the very sustainability of agricultural production systems, in once most productive irrigated areas. Salinity and sodicity are neither inevitable hazards nor irreversible constraints.

Karnataka is blessed with rich and varied land resources. From ancient times to the present, the prosperity of the people is linked to a great extent on the productivity of the fertile land resources of the state. Of late, the land resources are under strain due to the increasing severity and extent of degradation, neglect, diversion of fertile lands for nonagricultural purposes and competing demands of various land uses. Due to this, not only the cultivable area, but also the productive and prime land area is shrinking year after year, resulting in the overall decline of productivity of the resource base in the state.

According to the 2010 estimates by National Bureau of Soil Survey and Land Use Planning (NBSSLUP), out of 19 million ha total geographical area (TGA) in Karnataka, 8 m ha (42%) land area is facing various kinds of degradation[3]. About 7.5 m ha area is facing erosion, 167,000 ha is facing sodicity and salinity, and 51,000 ha is facing degradation due to mining. Soil chemical degradation due to salinity, alkalinity and waterlogging, and physical degradation have turned the once agriculturally most productive lands into barren soils, fit for growing only few crops that too at a great cost and poor productivity level. The problem is spreading rapidly in almost all the command areas, particularly in the Tungabhadra and Upper Krishna Project areas of the state (TBP and UKP), where soils are predominantly black. According to the database of 1990s, about 30,000 ha in Tungabhadra Project area is already facing severe salinity/sodicity problems. During the period from 1971 to 1991, the increase in irrigation-induced soil degradation in this area was 160% (ref. 4).

The real extent and spread of the problem is yet to be assessed on sound scientific lines in all these command areas of the state. As the TBP area is dominated by black soils, it was pointed out in the special soil surveys carried out from 1935 to 1937 that the region will face severe salinity and alkalinity problems unless care is exercised in soil, water and crop management. Unfortunately, the prediction has come true today in these areas.

To assess the extent of soil salinization/sodification and its impact in the Cauvery command area, the present study was undertaken at 1 : 12,500 scale covering all the farm holdings in Chikkarasinakere hobli, comprising 42 villages, covering 17,000 ha area in Maddur taluk, Mandya district, Karnataka by the NBSSLUP, Bengaluru during 2010–11. The major part of the hobli is irrigated by Sir M. Visvesvaraya canal (Cauvery command area) from Krishna Raja Sagar (KRS) for more than 80 years.

Methodology

The detailed survey of 42 villages in the hobli was carried out using cadastral map (1 : 12,500) as a base. The digitized cadastral map shows all the field boundaries with their survey numbers, location of tanks, streams and other permanent features of the area. Remote sensing data products (IRS P6, LISS IV MX of the period March 2010) at the same scale of 1 : 12,500 were procured from National Remote Sensing Centre (NRSC), Hyderabad and used in conjunction with the cadastral maps to identify the landforms and surface features of the area (Figure 1). The Hobli area occurs in four imageries at 1 : 12,500 scale (57D14SE, 57D15NE, 57HO3NW and 57HO2SW). The false colour composite (FCC) imagery (57HO3NW and 57HO2SW) shows the boundary between the uplands and lowlands, water bodies, vegetated areas, salt-affected lands, roads, habitations and other natural features of the area. Apart from the cadastral maps and imageries, Survey of India topographic maps (57 D/14, 57 D/15, 57 H/2 and 57 H/3) at 1 : 50,000 scale were also used for initial traversing, identification of geology, landforms, drainage features, present land use and for the selection of field transects.

Field investigations

Preliminary traverse of the hobli was carried out using 1 : 50,000 scale topographic maps and geocoded IRS-P6, LISS-IV MX imageries pertaining to the area (Figure 1). During the traverse, major rock types of the area, drainage patterns, surface features like erosion, rock outcrops, presence of stones and gravels at the surface, slope characteristics, existing land use and landforms were identified and soils studied in a few places. Based on the above information collected and the earlier soil survey information available for the area, an initial legend showing the tentative relationship that exists between the geology of the area, landforms identified and major soils occurring in the area was prepared. This forms the basis for taking up detailed characterization of soil and other land resources occurring in each village of the block.

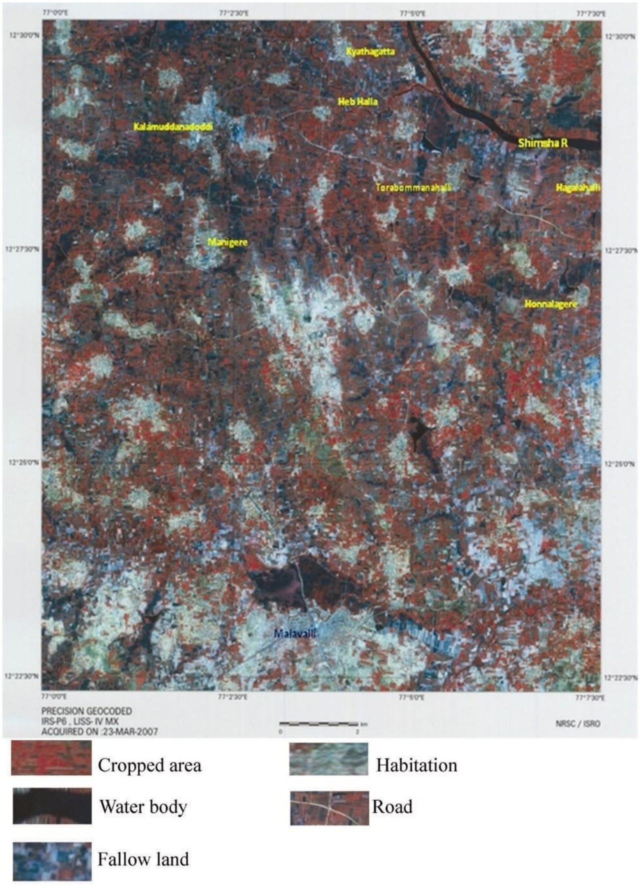

Figure 1. Precision geocoded IRS-P6, LISS-IV MX imagery pertaining to the map sheet No: 57H03NW.

Resource mapping at village level

After establishing the soil–landform relationship for the block, detailed characterization of soil, site and other parameters was carried out for each village separately. In each village, the field boundaries and survey numbers given on the cadastral sheets were located on ground by following permanent features like roads, railway lines, creeks, streams, rivers, tanks, ponds, burial ground, etc. and wherever changes were noticed, they were incorporated on the cadastral maps. After this, intensive traversing was carried out for each physiographic unit like ridges, uplands, lowlands/valleys, etc. by involving all the soil survey party members. Based on the variability observed on the surface, transects were selected across the slope, covering all the physiographic units occurring in each village (Figure 2).

In the selected transect, profiles were chosen at closely spaced intervals to take care of any change in the land features like break in slope, erosion, gravel, stones, etc. At the selected sites, profiles were opened up to 200 cm depth or to the depth limited by rock or hard substratum, and studied in detail for all their morphological and physical characteristics. The soil and site characteristics

Figure 2. Typical landscape of irrigated gently sloping uplands merging with narrow valleys, Arechakkanahalli.

were recorded for all profile sites in a standard proforma according to the guidelines given in the Soil Survey Manual[5,6]. Apart from the transect study, soil profiles were studied at random, almost in a grid pattern, wherever necessary to check the soil variability.

Results and discussion

Based on the soil site characteristics, the soils were grouped into different series (soil series is the most homogenous unit having similar horizons and soil properties, and behaves uniformly for a given level of management). Soil depth, texture, colour, amount and nature of gravel present, calcareousness, presence of limestone, nature of substratum and horizon sequence were the major identifying characteristics of the soil series in the area surveyed (Figure 3). Based on the above characteristics, 13 soil series were identified in the hobli. The soil series were further divided into phases (phase is a subdivision of a soil series), which are based mostly on surface features that affect its use and management. Based on the detailed soil survey, 118 phases were identified and mapped in this hobli. Bedrock geology of the area is dominantly of granite and gneiss.

Landform

The hobli forms part of Bangalore plateau. The elevation ranges from 600 m near Shimsha River to 769 m near Thippur village, Kulagere panchayat. The area was not disturbed by any major geological events in the past. It has been exposed to long periods of denudation under semi-arid climatic conditions. The landscape of the area has evolved over a long period of time due to the process of erosion and deposition of weathered rocks, soils and other materials from one place to another. Sheet wash and retreat of hill slope are the major processes responsible for the evolution of the present landforms. Since the rock types present in the area and their mineralogical composition are almost similar, there is not much variation in the landscapes and landforms of the area. Due to this, the landforms vary from one to another, without any abrupt changes.

Slope

The slope or the inclination of the land surface has played a critical role in the formation of soils in the area. Generally, it has been observed that the depth of the soil formed is directly proportional to the length of the slope. Based on the dominant slope classes observed, the area has been divided into nearly level (<1% slope), very gently sloping (1–3%) and gently sloping lands (3–5%). Nearly level lands occur along the river courses and tankcommand areas and occupy about 29% of the area in the block. Most of the uplands have very gentle slopes and occupy an area of about 8749 ha (52%). About 537 ha (3%) area has more than 3% slope and occurs in small patches in most of the panchayaths in the block.

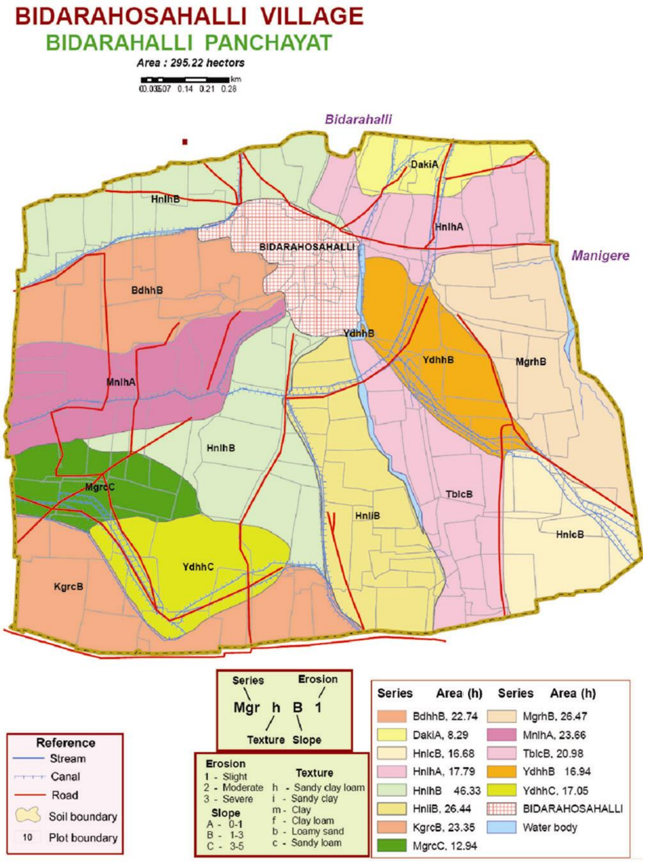

Figure 3. Soil map of Bidarahosahalli village in the study area. BdhhB – Moderately deep, red fine-loamy soil with sandy clay loam on 1–3% slope with slight erosion. DakiA – Very deep, crackling clay soil with sandy clay surface on 0–1% slope with slight erosion. HnlcB – Moderate shallow, red loamy soil with sandy loamy surface on 1–3% slope with slight erosion. HnlhA – Moderately shallow, red loamy soil with sandy clay loam surface on 0–1% slope with slight erosion. HnliB – Moderately shallow, red loamy soil with sandy clay surface on 1–3% slope with slight erosion. KgrcB – Deep, red clay soil with sandy loam surface on 1–3% slope with slight erosion. MgrcB – Moderately shallow, red gravelly clay soil with sandy loam surface on 3–5% slope. MgrhB – Moderately shallow, red gravelly clay soil with sandy loam surface on 1–3% slope with slight erosion. MnlhA – Very deep, balk loamy soil with sandy clay loam surface on 0–1% slope with slight erosion. TblcB – Moderately deep, red gravelly clay soil with sandy clay loam surface on 1–3% slope with slight erosion. YdhhB – Deep, red gravelly clay soil with sandy clay loam surface on 1–3% slope with slight erosion. YdhhC – Deep, red gravelly clay soil with sandy clay loam surface on 3–5%. Slope with slight erosion. YdhhC – Deep, red gravelly clay soil with sandy clay loam surface on 3–5% slope with slight erosion.

Drainage

The block is drained by Shimsha River (also called Kadambi River), Hebbahalla, a tributary of Shimsa, and many small streams and creeks. The numerous small streams and creeks, mostly originating from the southern border of the block, join Hebbahalla at different points, which in turns join Kadambi River, near Maddadodi village in the block. There are a few medium to large and many small man-made lakes (tanks) in the hobli. All the streams and creeks are seasonal in nature and only the main river has flow throughout the year. The general flow is from west to east and the drainage pattern is sub-parallel and dendritic.

Irrigation

The introduction of irrigation from the KRS during 1930s has completely changed the earlier drainage pattern in the block. At present, the block is irrigated by two main branches of the Visvesvaraya canal. The Hebbavadi branch canal runs in the southern border of the block and the other branch from the west runs at the northeasterly direction and joins the Sulekere tank. These two main branch canals with their network of numerous channels and field outlets link all the villages and hamlets in the block in an intricate manner. Due to this network, the area is supplied with Cauvery water almost throughout the year. This has created serious drainage problem, particularly in the low-lying areas of the block.

Climate

The hobli enjoys subtropical monsoonal climate. The average temperature of the area ranges between 16°C and 35°C. April is the hottest month and December is the coldest month. With the onset of the southwest (SW) monsoon in June, the temperature drops considerably in the area; it remains below 30°C up to January and then rises from February onwards and reaches a maximum of 34°C during April–May.

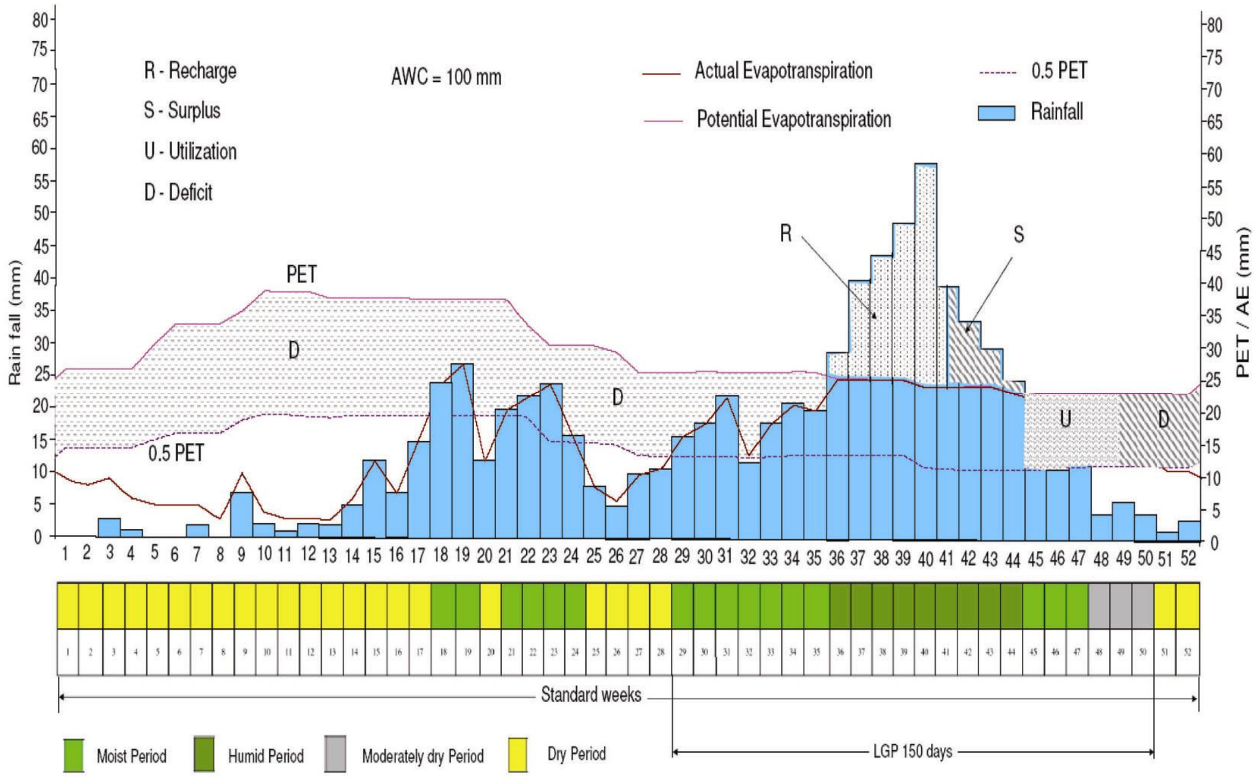

Figure 4. Rainfall, PET and growing period of Chikkarasinakere hobli.

The normal rainfall received in the area is about 770 mm. Out of this, about 50% is received during the SW monsoon, 20% during the northeast monsoon and 30% during summer. The rainfall distribution is fairly widespread and except during the winter months, fairly good amount of rainfall is received in the area for almost eight months (April to November) in a year. It is bimodal in nature with one peak occurring during May and another during October. The average number of rainy days during this eight-month period is about 43 (Figure 4).

The total potential evapotranspiration (PET) of the area is about 1794 mm, which is higher than the amount of rainfall received in the area. Only during September and October, the precipitation is more than the PET. During May, the rainfall received in the area crosses the 1/2 PET, which is considered sufficient for plant growth. However, rainfall becomes less and does not cross the 1/2 PET values from June to August and it crosses the 1/2 PET values again during the period from September to the middle of November. Whenever the rainfall reaches close to the 1/2 PET values, that period is considered favourable for plant growth. This period gets extended to one or two weeks more, if the soil conditions are favourable (soil depth, texture, structure, high organic matter content, etc.) for plant growth. Accordingly, the growing period for the area is about 150 days, which starts from the middle of July (28th week to 50th week) and extends up to the middle of December.

The growing period determines the choice of crops, particularly in the rainfed areas of the block. Due to the introduction of large-scale irrigation in the block, though the significance of this factor in the choice of crops cultivated in the area is very much reduced, it is critical in scheduling irrigation and deciding the cultural practices that are followed in the area.

Land use

Out of the total area of 16,873 ha, about 12,739 ha area is under cultivation, which is more than 75% of the total area available in the block. Forests are almost non-existent in the area. Barren and uncultivable lands occupy very less area. Though the land put to non-agricultural use is less, it shows an increasing trend. Major part of the cultivable lands (7478 ha) is under canal irrigation. The canal-irrigated lands are used for the cultivation of rice, sugarcane, coconut, mulberry, etc. and rainfed areas are used for the cultivation of ragi, pulses (black gram, red gram) and oilseeds (sunflower, groundnut). Vegetables like tomato, brinjal, chillies and cucumber are grown in a small area, mostly for local consumption. This is one of the intensively cultivated blocks in Mandya district. The importance of tank irrigation is very much reduced after the introduction of KRS canal irrigation in this area. Similarly, the area under well irrigation is negligible in most of the villages in the block.

Soils

Soil depth is not a major limitation in the block as moderately deep to very deep soils occupy about 68% of the area. Moderately shallow soils are found in about 15% area of the block. The thickness of surface soil layer varies from 13 to 20 cm in most of the area. The soils of uplands are lighter in texture (sandy loam and loamy sand), and heavy soils (clay and clay loam) are found in lowlands and midlands. In surface soils the gravel content is less than 25%, whereas subsurface soils contain 30–70% gravel. Although soil erosion is not a serious problem in about 82% area, it is a constraint in upland areas. In the block, 53% area is well drained and about 11% area faces poor drainage conditions all along the River Kadambi and its tributaries.

Socio-economic dynamics

With gently sloping landscapes, deep, well-drained loamy to clayey soils, good and fairly well-distributed rainfall, interspersed with network of tanks and many small and medium streams, the hobli is a predominantly agrarian area of the district. Prior to the introduction of canal irrigation, it was mostly under rainfed crops. After the introduction of canal irrigation from the KRS during 1930, all the lowlands and most part of the very gently sloping uplands, after terracing, were brought under irrigation. Due to this, the once predominantly dry, rainfed tract has become a wet zone and consequently, there has been a total shift from the cropping pattern that was practised earlier, from ragi to paddy and sugarcane at present (Figure 2). Consequently, the hobli has become one of the most intensively cultivated and comparatively prosperous regions of Mandya district.

Present status of land resources

Canal irrigation and associated factors have brought in a dramatic change in the landscape of the area, with lush green paddy and sugarcane fields, interspersed with coconut and mulberry gardens seen everywhere in the hobli. But the large-scale, intensive paddy and sugarcane cultivation, year after year during the last 80 years has brought in significant changes in the quality and productivity of the soil, water and other resource endowments. The impact is visible, particularly on the soil resources of the area. Continuous irrigation has changed significantly the drainage pattern, soil morphology, altered or destroyed the soil structure, physical properties and chemical and biological composition of the soil in the entire belt (Figures 5 and 6). The problem is compounded further by mismanagement of soil or lack of appreciation for better water management strategy in the area. The impact is visible today with increasing area under salinization/sodification, symptoms of multiple nutrient deficiencies and plateauing or declining yield in paddy and sugarcane.

Impact of irrigation on drainage

The study has revealed that waterlogging is a major problem, particularly in all the lowlands, and to some extent in the upland areas of the block (Figure 7). The lowlands occupy about 4706 ha (29% of the area) in the hobli. Normally, the lowlands are characterized by nearly level to flat topography and very deep, well-drained, fine-textured soils with good water-holding capacity. They are the most productive soils of the hobli. Even without any irrigation facility one assured crop under rainfed situation is possible and that was the scenario which prevailed in most parts of the hobli before the introduction of the KRS canal irrigation during the 1930s.

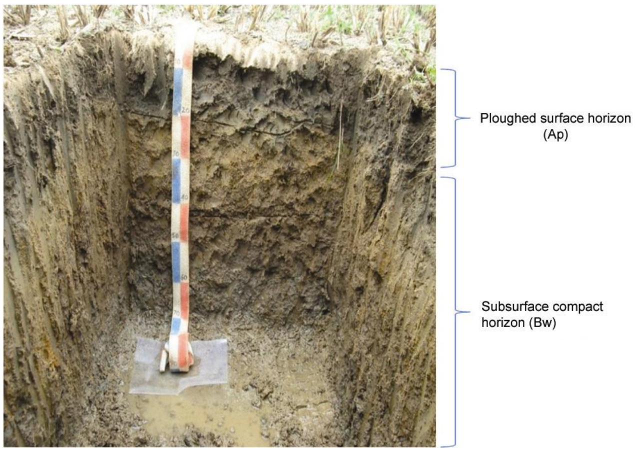

Figure 5. Uncontrolled irrigation, rising water table and high rate of evaporation favour salinization: S. No. 878, Hagalahalli village.

Figure 6. Change in soil colour and reaction, poor aeration, poor soil structure and limited microbial population due to continuous water stagnation in the soil: S. No. 376, Kulagere.

Figure 7. Very gently sloping canal irrigated midlands, S. No. 158, Kyathaghatta. Major part of the area in the village is affected by salinity and waterlogging.

With the introduction of canal water and consequent changes in the cropping pattern, from mostly rainfed crops to paddy and sugarcane, the micro climate has changed dramatically in the area over the years. The water released into the canals and their distributaries moved from the uplands to the midlands and finally into the lowlands. Due to its flat topography, the flow of the collected water is very much hampered. This has resulted in the rise of water table, slowly in the beginning and reaching the surface of the soil in later years (Figures 5–7). The situation is compounded by the continuous addition of water from the upland and midland fields without any check or control. This has resulted in the stagnation of water for a longer period of time within the soil profile and at the surface.

Due to this all the low-lying areas, occurring particularly along the river and stream courses and tank command areas of the block are in a poorly to imperfectly drained condition. These soils occupy about 11% of the cultivable area in the block. Moderately well-drained soils occur in about 19% of the cultivable area in the block, mostly in the transition areas above the lowlands.

The continuous submergence of the soil under water has created significant changes in the physical, chemical and morphological properties of the soil in the lowland areas. The most visible change is in the soil colour, soil structure, aeration, soil reaction and in the microbial population of the soil (Figures 5 and 6). The lack of oxygen has resulted in reducing condition, which in turn has affected the availability of a few macro- and micronutrients in the soil, thereby affecting its overall productivity. The poor drainage condition has reduced the option for crop selection and restricted the choice mainly to paddy and few other crops in the block.

An area is considered waterlogged when either water stagnates on the land surface or the water table rises to an extent that soil pores in the crop root zone become saturated, resulting in restrictions in normal circulation of air, decline in the level of oxygen and increase in the level of carbon dioxide. In practical terms, a land is considered to be waterlogged when the water table is within +150 cm of the natural surface[3]. The condition is also called 'hypoxia', indicating that there is severe deficiency of oxygen in the root zone which is essential for the normal growth of plants.

Impact of waterlogging

The primary effect of waterlogging on crop growth is from reduced soil aeration as a result of excess water. Reduced soil aeration, around the root zone of a crop, results in decreased respiration, which reduces nutrient uptake, crop growth, and yield[7,8]. In general, the performance of many field crops can be related to the depth of the water table. For most crops, there exists some water table depth at which aeration, moisture and nutrients are such that crop yields can be maximized. When the water table rises above this threshold, crop yields begin to decline[7]. The optimum water table depth will not only be a function of crop type, but also of other soil and climatic properties. Many studies have documented the negative effects of waterlogged soils on crop growth and yield. The extent of crop loss in the study area is substantial.

Waterlogging and root environment

All biological processes are strongly influenced by soil temperature. Waterlogged soils have large heat capacity and are relatively colder than dry soils. As a result, crop growth in waterlogged soils starts later and is slower than in dry soils. Since the compressive strength and the load-bearing capacity of a soil decreases with increasing moisture content, it is relatively difficult to employ heavy machinery on waterlogged lands. A direct consequence of this is the delay in the sowing/harvesting operations of the crops and consequent yield reduction.

Bringing large quantities of water to perched lands without adequate provisions of drainage has resulted in an imbalance in the input and output of water, causing inequilibrium. The rising water table in such situations is a foregone conclusion. By acting as driver of change in land use, the massive irrigation systems have added another dimension to the twin problems of waterlogging and secondary salinization. Earlier studies have revealed that the small and marginal farmers are worst affected by soil degradation[9]. The large farmers have also experienced the brunt of soil degradation, but the effect has been marginal, since they have alternative sources of livelihood. The study has further indicated that the extent of inequity is higher on degraded than normal soils. However, this can be reduced to a great extent by launching land reclamation programmes.

Table 1. pH range of the soil series mapped in the block

Soil series	pH (range)	ESP (surface soil)	EC (mS m^{-1})	Remarks
Upland soils				
Kadakothanahalli	7.9-8.1	1.5	Traces	Moderately alkaline
Aravanahalli	6.0–7.1	0.5	Traces	Neutral
Yadaganahalli	5.6–7.3	0.3	Traces	Acidic to neutral
Kudagere	7.9–8.6	3.6	0.20	Moderate to strongly alkaline
Torebommanahalli	7.6–7.9	2.8	0.34	Slightly to moderately alkaline
Bidarahalli	7.7–8.0	0.85	0.09	Moderately alkaline
Manigere	8.3–8.7	5.8	0.37	Strongly alkaline
Honnanaya Kanahalli	7.1–7.9	4.5	0.25	Neutral to slightly alkaline
Midland soils				
Kyathaghatta	8.9–9.4	6.0	Traces	Very strongly alkaline
Lowland soils				
Chikkarasinakere	8.0–9.2	17	0.17	Moderate to very strongly alkaline
Doddarasinakere	8.1–9.2	17	Traces	Moderate to very strongly alkaline
Madenahalli	7.4–8.3	3.5	Traces	Slightly to moderately alkaline
Honnalagere	7.4–7.7	3.0	0.15	Slightly alkaline

Table 2. Surface soil reaction classes

Reaction class	Area (ha)	Area (%)
Medium to slightly acidic	1406	10
Neutral (6.6–7.3)	4311	31
Mildly alkaline(7.4–7.8)	5138	37
Moderately alkaline (7.9–8.4)	3137	22

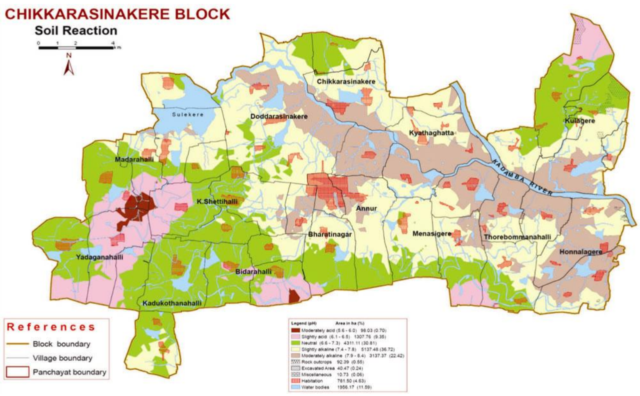

Figure 8. Soil reaction map: area shaded brown all along the river course is salt-affected.

Development of salinity and its impact on productivity

When the drainage is poor, the dissolved salts move to the surface of the soil through capillary rise. With the prevailing high temperature and PET, there is huge loss of water from the soil due to the higher rate of evapotranspiration. This results in the accumulation of salts at the surface and subsequent development of salinity in the area. The impact of this is seen in almost all the lowland and midland soils identified in the block (Figures 5–7).

Out of the four series mapped in the lowland areas, Chikkarasinakere and Doddarasinakere series have moderate to strongly alkaline condition, and Madenahalli and Honnalagere series have slightly to moderately alkaline conditions (Tables 1 and 2). The Kyathaghatta series occurring in the transitional areas between lowlands and uplands, is also strongly alkaline in nature. Even in the uplands, many series have moderate to strong alkalinity problem. Only two series, namely Aravanahalli and Yadaganahalli, which occur in the uplands and are not subjected to irrigation, have acidic to neutral reaction. Moderately alkaline soils occur in about 22% of the area and slightly alkaline soils occur in about 37% of the area in the block (Figures 8 and 9).

Salinity affects crop growth by increasing the osmotic potential of the soil solution[10]. In general, increased osmotic potential in the soil solution decreases the ability of a crop to extract water and results in suppressed plant growth and decreased yield. Additional plant symptoms associated with high salinity levels are similar in appearance to those of drought, such as wilting and unusually green and thick leaves[11]. The impact of salinity on crop yield in the block is significant and based on the present study, it is estimated that the yield loss in the case of paddy cultivated on degraded areas when compared to normal areas is likely to be about 33% (Table 3). Similar loss can be expected in other crops also.

Though salinity has already become a serious problem in about 22% of the area in the block, it is emerging as a serious problem in another 37% of the soils mapped in the hobli, particularly occurring in the transition areas lying between the uplands and lowlands. Apart from the general trend, in many villages salinity has become a major problem seriously affecting the productivity. For example, in Kyathaghatta village, except Aravanahalli soil which is not brought under irrigation, other soils have severe salinity/sodicity problem. Out of the 537 ha area in the village, more than 500 ha has serious salinity problem. In this village, all lowland and midland soils, particularly Kyathaghatta, Chikkarasinakere and Doddarasinakere series have severe sodicity problem (Figure 8).

The situation is similar in many other villages like Doddarasinakere, Chikkarasinakere, Torebommanahalli, Hagalahalli, Madenahalli, Bannali, Menasigere and Mudenahalli in the block. Out of the 722 ha in Hagalahalli more than 600 ha faces salinity problem. The situation is similar in almost all the villages located along the Shimsha River course and tank command areas of the block, due to waterlogging and poor drainage conditions prevailing in the area. This can be clearly seen on the imagery of the area, as light to dark grey tones (Figure 10). In such areas, even the growth and performance of paddy is poor (Figure 10). The leaves are thick and unusually green. It can be inferred with certainty that the productivity of other sensitive crops can be much less than what can be expected in such intensively cultivated areas of the block.

Table 3. Nutrient imbalance in the block (% area)

Available nutrient	Deficient	Excess	Sufficient
Nitrogen	20	50	30
Phosphorus	10	38	52
Potassium	38	2	60
Zinc	30	–	70

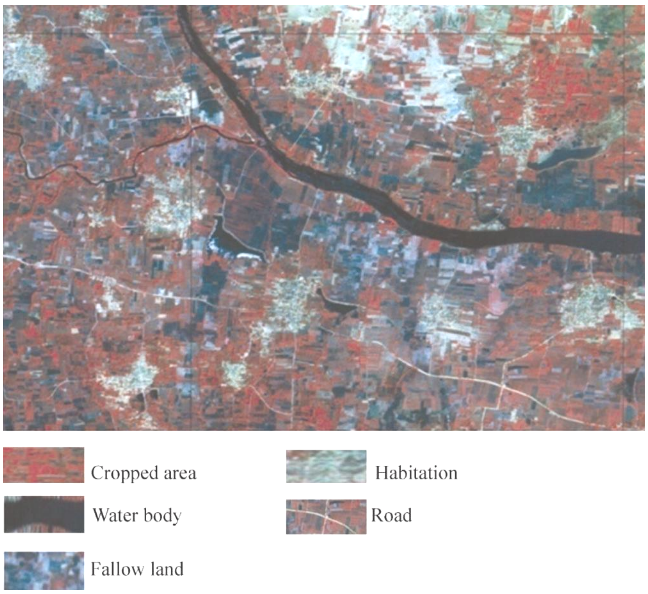

Figure 9. Salt-affected areas seen as grey tones on the imagery in Torabommanahalli village.

Soil nutrient imbalance

Due to intensive cultivation and monoculture system of cropping (paddy/sugarcane) followed in the region for more than 80 years, a severe plant nutrient imbalance is noticed in large parts of the block with respect to all the nutrients studied (Table 3). Under such circumstances the management of nutrients becomes complex, as there are complex nutrient interactions involved. This by itself becomes a major constraint in realizing the desired yield levels. It calls for intensive monitoring of nutrient status after every cropping season and undertaking corrective steps. The best option is to adopt integrated nutrient management strategy involving organic, chemical and biological nutrient sources and regular practice of crop rotation.

The available potassium content has become low in 38% of the area in the hobli. It is predominantly low in Chikkarasinakere, Kyathaghatta, Yadaganahalli, Doddarasinakere, Kadukothanahalli and Bidarahalli panchayaths and medium in Annur, Menasigere, Torebommanahalli, Hagalahalli, Kulagere, Bharathinagar and K. Shettihalli panchayaths (Figure 11).

Figure 10. Impact of salinity on paddy: stunted growth in Doddarasinakere.

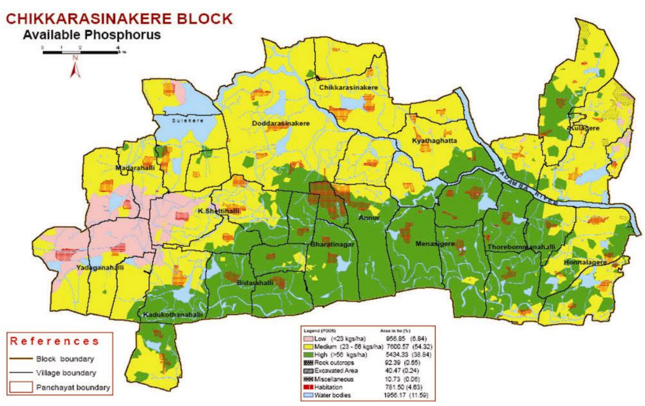

Figure 11. Area shaded green indicates excess levels of phosphorus.

Table 4. Economic consequences of land degradation in the Cauvery command area – a case of paddy production system

Items	Details	Remarks
Farming area in the Chikkarasinakere block	17,000 ha	
Extent of area facing land degradation in the block (59%)	10,030 ha	Salinity, alkalinity
Paddy productivity under recommended level of package of practices in the area	5.5 t/ha	UAS(B) PP
Normal productivity of paddy under farmers' practices	4.5 t/h	
Paddy productivity in degraded lands	3.0 t/ha	Data from farmers
Paddy yield loss in the block due to land degradation	30,000 tonnes	2 crops/year
Value of paddy yield loss in the block per year	Rs 37.5 Crores/year	Support price: Rs 1250/q
Losses due to increased cost of cultivation under imbalanced nutrient status in the block	Rs 10 crores	@ Rs 5000/season
Area irrigated under Cauvery command in Karnataka	280,000 ha	
Area likely to be affected with degradation process	165,200 ha	59% area
Paddy yield loss (@33%)	840,000 tonnes	2 crops/year
Value of crop loss	Rs 630 crores	Support price: Rs 1250/q
Losses due to increased cost of cultivation under imbalanced nutrient status in the command area	Rs 165 crores	
Total loss per year in the entire command area	Rs 795 crores	
Approximate loss of interest on the investments made on irrigation infrastructure	Rs 200 crores	

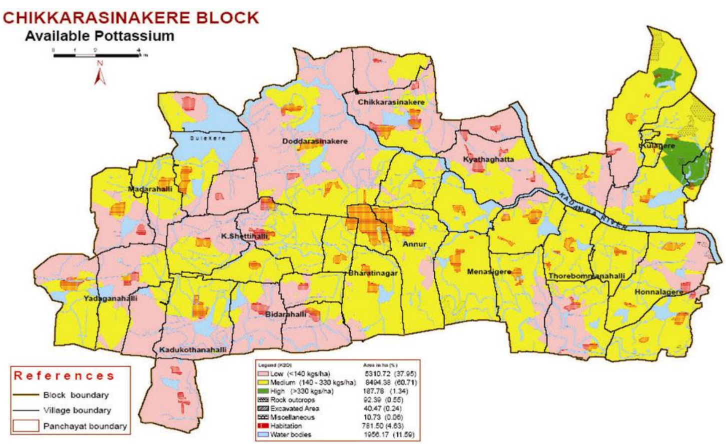

Figure 12. Area shaded with light pink indicates potassium deficiency.

The available phosphorus status is high in 38% of the hobli. It is predominantly high in Bidarahalli, Bharatinagar, Menasigere and Torebommanahalli panchayaths. However, in parts of Yadaganahalli, Madarahalli and K. Shettihalli panchayats (7% area), the available phosphorus status is low (Figure 12).

The available zinc content is deficient in Kadukothanahalli, Bidarahalli, K. Shettihalli, Bharathinagar, Kulagere and Torebommanahalli panchayaths, and sufficient in Menasigere and Hagalahalli panchayaths.

Approximate loss to the local economy due to development of salinity/sodicity and waterlogging

If 1 ha of irrigated land goes out of cultivation, then more than Rs 1 lakh/ha, invested in the development of irrigation potential in the area is blocked[12]. The interest on this investment comes to Rs 10,000/annum. As indicated in Table 4, the extent of crop loss for paddy in the block per year is about Rs 37.5 crores. The cost of cultivation gets escalated at least by Rs 5000/ha/season due to nutrient imbalance, waterlogging and salinity/sodicity. This amounts to Rs 10 crores/year for the entire block. According to the survey, about 10,030 ha in the block is facing the problem of degradation. The total loss in the block per year is about Rs 47.5 crores.

If we assume that the situation is more or less similar in the entire Cauvery command area (280,000 ha), as the terrain and topography are similar in the region, then the value of crop loss is about Rs 630 crores and when we add loss due to increased cost of cultivation, the total loss per year is about Rs 795 crores. This excludes the losses attributable to investment/interest on investment made in the creation of irrigation infrastructure by the government. If the interest on investments on irrigation infrastructure is also taken into account, nearly about Rs 1000 crores worth economic loss is occurring due to the development of salinity/sodicity, waterlogging and multiple nutrient deficiencies in the command area. In the coming years, the situation is likely to worsen further and the expected loss is likely to be higher than what is estimated at present in the command area.

Conclusion

Land and water are the two most important natural resources for agricultural development and economic advancement of any country. With a low per capita availability of land and water in India compared to other countries, enhancing agricultural production has become essential to meet the growing food demands of the population. Thus, available water for irrigation needs to be judiciously utilized. At the same time, land degradation due to soil salinity and waterlogging is threatening the sustainable use of these resources. Efforts to address salinity and waterlogging problems, as they arise, will prevent substantial losses to farmers and to the regional economy. One should also take into account that in arid and semi-arid areas, irrigation systems require a proper drainage system. Without a drainage system such irrigation systems are unsustainable. The feasibility of the drainage systems in such areas should, therefore, always be assessed in combination with the irrigation systems[12].

The present database will help in the holistic treatment and management of the problems identified in each and every village, particularly the fast emerging issue of salinity in the hobli. Further, it can be the basis for formulating various management strategies required for increasing productivity and conservation of the resource base. This can be used for promoting precision farming at local level and will be helpful in equipping the farmers of the hobli with required information, so that they are able to meet the challenges of the future in an effective manner.

1. Hillel, D., Salinity management for sustainable irrigation: integrating science, environment, and economics, World Bank, Washington, DC, 2000.
2. Ghassemi, A. J., Jakeman and Nix, H. A., *Salinisation of Land and Water Resources: Human Causes, Extent, Management, and Case Studies* (eds Datta, K. K. and de Jong, C.), University of New South Wales Press Ltd, Sydney, Australia, 1995.
3. Maji, A. K., Obireddy, G. P. and Sarkar, D., Degraded and wastelands of India: status and spatial distribution. Indian Council of Agricultural Research, New Delhi, 2010, p. 167.
4. Chinnappa, B. and Nagaraj, N., Equity issues relating to irrigation-induced soil degradation under left bank canal of Tungabhadra Project Area, Karnataka. *Agric. Econ. Res. Rev.*, 2006, **19**, 121–128.
5. Soil Survey Staff, *Soil Survey Manual*, Agriculture Handbook No. 18, Washigton, DC, 1951.
6. Natarajan, A. and Sarkar, D., *Field Guide for Soil Survey*, NBSS&LUP, Nagpur, 2010.
7. Evans, R. O. and. Fausey, N. R., *Effects of Inadequate Drainage on Crop Growth and Yield*. Agricultural Drainage, Agronomy Monograph no. 38, 1999, vol. 13–54, ASA, Madison, WI (1999).
8. Wesseling, J., Crop Growth in Wet Soils. In *Drainage for Agriculture* (ed. van Schilfgaard, J.), ASA, Madison, WI, 1974, pp. 7–37.
9. Jai Singh and Jai Pal Singh, Land degradation and economic sustainability. *Ecol. Econ. Ser. A*, 1995, **15**(1), 77–86.
10. Joshi, P. K., Effects of surface irrigation on land degradation – problems and strategies. *Indian J. Agric. Econ.*, 1987, **42**, 416–423.
11. Ayers, R. S. and Westcot, D. W., Water quality for agriculture, FAO Irrigation and Drainage Paper 29 Review Paper no. 1, 1985.
12. Datta, K. K. and Jong, C. De, Adverse effect of waterlogging and soil salinity on crop and land productivity in northwest region of Haryana, India. *Agric. Water Manage.*, 2002, **57**(3), 223–238.

Received 26 August 2013; revised accepted 8 December 2014