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Land use changes and their impact on properties of some soil series of Nagpur district of maharashtra

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ABSTRACT

Six soil series of Nagpur district, Maharashtra were studied to detect land use changes, their causes over a period of nine years and impact on soil properties. Introduction and spread of soybean, irrigation availability through various sources facilitate double cropping in Manori, Kinhala, Takali, Palora and Bahadura series except Hatodi series having triple cropping (rice-wheat-rice or rice-rice-rice) with short duration rice verities and provide assured income to farmers and caused the land use changes. The soil morphological properties indicate few variation and showing reduced color value of Ap horizon in Manori series to 3 from 4 whereas in Kinhala and Takali series reduced to 2 from 3 and in Hatodi series sub-surface horizon transformed from brown to dark brown. Impact of land use change on bulk density (BD) of Manori, Kinhala and Takali series recorded slight changes over the earlier status (year 1999) whereas, Hatodi series recorded highest value for surface 1.87 Mg/m^3 followed by subsurface 1.93 Mg/m^3 (year 2008). The soil pH showed slight changes and increase in soil organic carbon (SOC) at surface and subsurface under all soil series except Hatodi series over initial status. Increase in cation exchange capacity (CEC), percent base saturation (BS %) and exchangeable bases such as Ca and Mg were recorded under all series with few exceptions. Soils of examined series were rich in available nutrients especially potassium and nitrogen while Hatodi series showed poor value of available potassium over other soil series. Strikingly, it is observed that fine nodules of calcium carbonate ($CaCO_3$) at surface and subsurface soils of all pedons except Hatodi series, interestingly presence of $CaCO_3$ in these soils except Bahadura series was not reported earlier.

Key words: Land use changes, Nagpur district, Soil series, Soil properties

Land-use and land-cover changes refer to changes in the aerial extent (increases or decreases) of a given type of land use and land cover, respectively. Changes in land use and land cover have been taking place since time immemorial, and have been associated with both natural phenomena and human interference. Land use changes are common in areas of the tropics where the growth of population is high (Jorge and Missing 2005). The FAO's Global Forest Resource Assessment, 2000 (FAO 2001) estimated that in the 1990s, 15.2 million ha of forest were cleared every year in the tropics and most of which was later used for cultivation.

The green revolution heralded a series of land use changes in the country. Notable, among them are the establishment of rice-wheat system in the Indo-Gangatic plains, cotton-wheat system in Punjab and Haryana, rice-rice system in south India (Challa *et al.* 2004). Introduction of soybean and its rapid spread in central India during 1970-71 (Chand 2007), replacing the traditional crops like sorghum and millets is another notable example. Land use changes play an important role in the current global change phenomenon. It is directly related to food security, human health, urbanization, biodiversity, water and soil quality, runoff and sedimentation rate (Turner 1989, Burel *et al.* 1993, and Fu *et al.* 1994). Changing opportunities created by the markets and policy interventions are driving land use changes (Veldkamp and Lambian 2001). Understanding the changing trends in land use, in relation to the driving forces, will provide essential information for land use analysis/ planning and ultimately the sustainable management of land resources. The likely effect of these changes on soil properties need to be identified and monitored so as to forewarn any unfavorable consequences. Since these effects could modify soil properties, they become important for crop growth and productivity. It is, therefore, essential to monitor the temporal changes in soil properties of the established soil series for proper land use planning.

Nagpur district, Maharashtra, in the last 30 years has witnessed a lot of land use changes and major land use changes occurred in a sizable area of the district from 1980 in the form of soybean introduction (Hajare *et al.* 2005) due

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Table 1 Location details of selected soil series

Series and pedon no.	Tehsil	Physiography	Site location	Elevation (MSL*)	Classification
Manori	Umrer	North Deccan Maharashtra lower plateau (metamorphic) plain lands	20°42’38''N 79°06’88''E	600 m	Fine-loamy, mixed, hyperthermic, Typic Ustorthents
Kinhala	Umrer	North Deccan Maharashtra lower plateau (metamorphic), Gently sloping to moderately sloping undulating lands	20°41’49''N 79°08’33''E	630 m	Fine, montmorillonitic, hyperthermic, TypicHaplusterts
Takli	Kuhi	North Deccan Maharashtra lower plateau (metamorphic), Gently to moderately sloping plains	21°02’00''N 79°29’55''E	260 m	Fine, montmorillonic, hyperthermic, TypicHaplusterts
Palora	Parseoni	North Deccan Maharashtra lower plateau (metamorphic), alluvial plains	21°21’49''N 79°10’38''E	300 m	Fine-loamy, mixed, hyperthermic, TypicHaplustepts
Hatodi	Ramtek	North Deccan Maharashtra lower plateau (metamorphic), gently to moderately	21°20’06''N 79°21’44''E	300 m	Coarse-loamy, mixed, sloping plains hyperthermic, TypicHaplustepts
Bahadura	Nagpur	North Deccan Maharashtra lower plateau (metamorphic), valleys	21°06’05''N 79°09’47''E	280 m	Fine, montmorillonitic, hyperthermic (calcareous), TypicHaplustepts

*MSL,mean sea level

to availability of market infrastructure (for soybean), changing food habit of rural masses and high input requirement for cotton. However, various soil types under some land use systems showing changes in soil properties, decline nutrient status in low-input system and affect the sustainability of system. Monitoring these changes would consequently be important to prevent undesirable developments with negative effect on soil and environment. In proposed investigation, the attempt has been studied to identify the changes in land use at six identified soil series of Nagpur district over a period of nine years (1999-2008) and also to study their impact on soil properties using availability of base line data on soils in 1999 (Challa *et al.*) and 2008 (present study) of the same series.

MATERIALS AND METHODS

Six soil series, namely, Manori and Kinhala series of Umrer tehsil, Takli series of Kuhi tehsil, Palora series of Parseoni tehsil, Hatodi series of Ramtek tehsil and Bahadura series of Nagpur tehsil of Nagpur district were selected to carry out the present investigation. The general features and location of study area are given in Table 1.

The geology of the region under study belongs to North Deccan Maharashtra lower plateau. It has a lower pre-cambrian to Pleistocene exposures. The climate is characterized by medium rainfall, high temperature, and hot summer. The average annual temperature is 26.5°C. May is the hottest month (45.5°C) and December is the coldest month (8.1°C). The average rainfall is 1113 mm and more than 90 percent of rainfall is received during June to September with relative humidity as high as 80 per cent during the rainy season.

The selected sites are mostly under agricultural use and cultivated during *kharif* and *rabi* seasons. Some of these lands lying in the lower elevation are irrigated and vegetables are also grown successfully.

Six soil profile sites representing the aforementioned soil series were geo-coded. Pedons were dug (P1 to P6) and horizon wise soil samples were collected for analysis. Morphological properties of the soils were studied and recorded as per Soil Survey Staff (1951). Soils were classified according to Soil Taxonomy (Soil Survey Staff 1998). Soil samples were analyzed for physical and chemical properties by standard procedures (Jackson 1973), available nitrogen by alkaline permanganate method (Subbaiah and Asija 1956), available phosphorous (Olsen *et al.* 1954) and available potassium was extracted from soil with 1N – ammonium acetate solution (pH 7) by flame photometer (Jackson 1973). Analysis of land use changes was undertaken through revisiting the sites and interactions with the farmers in the field.

RESULTS AND DISCUSSION

Land use changes identified and their causes

It is observed that considerable changes in land use have taken place in all the soil series under study (Table 2). Introduction and spread of soybean with assured market price and availability of irrigation water through canal in Manori and Kinhala series have been changed the previous land use of rainfed cotton+pigeon pea due to poor infrastructure facility and highest cost of cultivation for rainfed cotton. The introduction of water tank in Takli series caused the land use changes and facilitates double cropping which provide assured income to farmers.

Poor net return from rainfed cotton and wild pig damage in sorghum (due to shortage of forest land) as well as

Table 2 Land use changes identified and their causes

Soil Series	Land use		Causes for land use change(s)
	Previous (1999)	Present (2008)	
Manori	Rainfed cotton + pigeonpea (8:2) strip, intercropping	1. Irrigated double cropping of soybean-wheat with 2-3 months of summer fallow period 2. Rainfed (with life saving irrigation) double cropping of soybean-chickpea/*rabi* sorghum/ sunflower with 3-4 months fallow	Introduction and spread of soybean, availability of canal water facilitating double cropping
Kinhala	Rainfed cotton monocropping	1. Irrigated double cropping of soybean-wheat with 2-3 months fallow period, where canal irrigation is assured. Soybean-chickpea or sunflower where limited irrigation facilities are available 2. Rainfed double cropping of soybean-lathyrus where no irrigation water is available	Introduction and spread of soybean, availability of canal water facilitating double cropping.
Takali	Sorghum-linseed or sorghum-fallow under rainfed condition	1. Irrigated double cropping of soybean+pigeonpea or soybean-wheat (Lok1 variety where water is limited and HD2189 variety where water is not limiting) with 2-3 month fallow during summer 2. Chili-fallow is also followed to limited extent	Spread of soybean, which is less risky and has assured market. Introduction of tank for irrigation.
Palora	Rainfed cotton + pigeonpea-sorghum (2 year rotation)	1. Irrigated cotton + pigeonpea (6:2) or soybean-wheat/ chickpea (2-year rotation) with 2-4 months of summer fallow. 2. Rainfed cotton + pigeonpea (life saving irrigation) with 3-4 months fallow	Low income and damage to sorghum by wild pig Introduction of irrigation water through Pench project
Hatodi	Rainfed paddy	1. Irrigated triple cropping of rice-wheat-rice or rice-rice-rice, without fallow. 2. Rainfed double cropping rice-wheat (with life saving irrigation) double cropping or rice-lathyrus (utera cropping) with 3-4 months fallow.	Availability of canal water facilitating triple cropping, introduction of short duration varieties, to fulfill family requirement
Baha-dura	Rainfedsorghum+pigeonpea intercropping, rainfed sorghum for fodder purpose.	1. Irrigated double cropping of soybean-chickpea/ vegetable/chilli with 3-4 months fallow. 2. Rainfed double cropping of soyabean+ pigeonpea (8:2) with 2-4 months fallow period.	Availability of by well and bore well irrigation facilitating double cropping, introduction and spread of soybean crop

introduction of canal irrigation water through Pench project have changed the past land use of Palora series and facilitated double cropping of irrigated cotton + pigeonpea by soybean-wheat/chickpea with 2 year rotation. Similarly in Hatodi series, availability of canal water and adoption of short duration varieties of rice facilitates triple cropping of rice-wheat-rice or rice-rice-rice without fallow. To fulfill family requirements, farmers changed land use from rice (mono crop) to rice-wheat/lathyrus (double cropping) and to get additional benefits even by triple cropping in a year. Availability of irrigation through well, bore well and growing market demand for vegetables due to rapid urbanization the farmers of Bahadura series have changed their past land use to irrigated double cropping of soybean-vegetables/chilli/ chickpea and get assured market and net return for their produce.

Impact of land use change on soil properties

Soil morphological properties: The morphological properties of six soil series as on 1999 is presented in Table 3 (Challa *et al.* 1999) and those in the present study in Table 4. The soil morphological properties did not vary except in a few pedons where the surface soils became darker than those reported in 1999. The soil color value of Ap horizon in Manori series reduced to 3 from 4. Similarly color value of Ap horizon in Kinhala and Takali reduced to 2 from 3. This may be due to introduction of irrigation. In Hatodi series, soil color in sub-surface horizon have transformed from brown to dark brown which indicates that some sort of segregation of iron has taken place under oxidized conditions resulting from deep tillage practices. Similar findings were reported by Maity *et al.* (2006) under mechanized and intensive cultivation.

The texture of the selected soil series did not vary between pedons during recent study (2008) compared to the base period (1999). Similarly, it is observed that there were no radical changes in soil structure except in the sub-surface of Takli and Bahadura series where there is slight variation in strength which may be due to the current agricultural practices that might have led to development of

Table 3 Earlier (1999) Morphological properties of six soil series

	Depth. (cm)	Soil matrix colour (moist/dry)	Texture	Structure	Calariousness	Other fetures
Ap	0-16	10 YR 4/2D	cl	m2sbk		
Ac	16-28	10YR 4/2D	cl	m2sbk		
Cr	28+	Weatherd Basalt				
Kinhala series: Fine, montmorillonitic, hyperthermic, Typic Haplusterts						
Ap	0-15	10YR 4/2D	c	m 2 sbk		
Bw	15-32	10YR 4/2D	c	m 2 abk		pressure faces
Bss1	32-72	10 YR 4/3M	c	c 3 abk		s.slide
Bss2	72-104	10YR 3/2M	c	c 3 abk		s.slide
Bss3	104-145	10YR 3/2M	c	c 3 abk		s.slide
Takli series: Fine, montmorillonitic, hyperthermic, Typic Haplusterts						
Ap	0-18	10YR 4/3D	c	m 2 sbk		
Bw	18-43	10YR 3/3M	c	c 2 sbk		pressure faces
Bss1	43-72	10YR 3/3M	c	c 3 sbk		s.slides
Bss2	72-105	10YR 3/3M	c	c 3 abk		s.slides
Bss3	105-125+	10YR 3/3M	c	c 3 abk		s.slides
Palora series: Fine-loamy, mixed hyperthermic, Typic Haplustepts.						
Ap	0-15	10YR 4/2D	scl	m 2 gr		
B1	15-50	10YR 4/4M	scl	m 2 sbk		
B2	50-75	10YR 4/4M	scl	m 2 sbk		
B3	75-100	10YR 4/4M	Scl	m 2 sbk		
Hatodi series: Coarse-loamy, mixed, hyperthermic, Typic Haplustepts						
Ap	0-12	10YR 3/3M	Scl			
B	12-26	10YR 4/3M	scl			
C	26-55	Weatherd Basalt				coarse gravels >80%
Bahadura series: Fine, montmorilonitic, hyperthermic (calcareous), Vertic, Haplustepts.						
Ap	0-15	10 YR 3/2M	c	m 1 sbk	e	
B1	15-30	10YR 3/2M	c	m 2 sbk	e	
Bw	30-55	10YR 3/2M	c	m 2sbk	es	Pressure faces
B3	55-70	10YR 4/3M	gc	m 1 sbk	ev	
Cr	70-90	Weatherd Basalt				

Bw horizon having high clay content and structural changes from sub-angular blocky to angular blocky, while the Kinhal series showed the changes in soil structure from angular blocky to sub angular blocky to plough layer, may be due to intensive cultivation from earlier reported structure.

Physico-chemical properties of soil: The temporal variations in physico-chemical properties of the surface and subsurface soils of selected pedons as reported by Challa *et al*. (1999) and later during the present investigation (2008) are presented in Table 5 and 6 respectively. The proportion of soil separates as sand, silt and clay were not affected by land use changes and slight differences may be due to location variations.

Bulk density: The data in Table 5 and 6 pertaining that bulk density of surface and subsurface soils were not changed with respect to land use in most of soil series. Kinahala series under soyaben cultivation recorded a decrease in bulk density from 1.92 to 1.80 Mg/m^{3}at surface soil and increased from 1.40 to 1.59 Mg/m^3 at subsurface. The Manori and Takli series showed slight changes on surface (1.71 to 1.69 and 1.72 to 1.68 Mg/m^3) and sub-surface (1.36 to 1.40 and 1.72 to 1.69 Mg/m^3) respectively, over the period of nine years (from 1999-2008).

The highest bulk density of 1.93 Mg/m^{3}was recorded under Hatodi series at sub-surface followed by 1.87 Mg/m^3 at the surface during present investigation (2008), where the land use of this series changes from mono cropping to triple cropping (rice-rice-rice). This increase in bulk density may be due to continuous cultivation with mechanized farming without fallow.

Available water capacity: The available water holding capacity of soil under present study (2008) showed slight changes in most of series and remains stable at surface soil of Takli series over the earlier (1999) recorded value (12.7%). The maximum percent buildup of available water holding capacity in year 2008 over 1999 was recorded in sub-surface of Bahadura (18.3%) series due to land use changed from rainfed cotton + pegeonpea (8:2 strip cropping) to irrigated double cropping of soybean-wheat followed by Manori series (5.2%), in which land use changed from rainfed sorghum to irrigated double cropping (soybean-chickpea/vegetable/chilli) respectively.

Table 4 Present (2008) morphological properties of six soil series

Horizon	Depth. (cm)	Soil matrix colour (moist/dry)	Texture	Structure	Calcariousness	Other fetures
Manori series (Pedon1):Fine-lomy, mixed, hyperthermic, Typic Ustorthents						
Ap	0-17	10 YR 3/2M	Cl	m 2 sbk	E	
Ac	17-30	10YR 3/2M	Cl	m 2 sbk	Es	
Cr	30+	Weatherd Basalt				
Kinhala series (Pedon 2) :Fine, montmorillonitic, hyperthermic, Typic Haplusterts						
Ap	0-18	10YR 3/2M	C	f 2 sbk	E	
Bw	18-35	10YR 3/2M	C	s 2 sbk	E	
Bss1	35-55	10 YR 3/2M	C	f 2 sbk	E	s.slide
Bss2	55-75	10YR 3/2M	C	f 2 sbk	E	
Bss3	75-100	10YR 3/2M	C	f 2 abk	E	
Takli series (Pedon3): Fine, montmorillonitic, hyperthermic, Typic Haplusterts						
Ap	0-20	10YR 3/2M	C	m 2sbk	E	
Bw	20-45	10YR 3/3M	C	c 2 abk	Es	
Bss1	45-78	10YR 3/3M	C	c 3 abk	E	s.slides
Bss2	78-117	10YR 3/3M	C	c 3 abk	E	
Bss3	117-125+	10YR 4/3M	C	c 3 abk	E	
Palora series (Pedon 4): Fine-loamy, mixed hyperthermic, Typic Haplustepts.						
Ap	0-14	10YR 4/4M	scl	m 1 gr	Es	
B1	14-52	10YR 4/3M	scl	m 2 sbk	Es	
B2	52-79	10YR 4/3M	scl	m 2 sbk	E	
B3	79-110	10YR 4/3M	scl	m 2 sbk	E	
Hatodi series (Pedon 5): Coarse-loamy, mixed, hyperthermic, Typic Haplustepts						
Ap	0-14	10YR 4/3M	scl	- 2 m	Nil	
B	14-28	10YR 4/3M	scl	- 2 m	Nil	
C	28-58+	Weatherd Basaltcoarse gravels >80%				
Bahadura series (Pedon 6): Fine, montmorilonitic, hyperthermic (calcareous), Vertic, Haplustepts.						
Ap	0-18	10YR 2/2M	C	m 2 sbk	Es	
B1	18-35	10YR 3/2M	C	m 2 abk	Es	
Bw	35-55	10YR 3/2M	C	m 2 abk	E	s.slides
B3	55-75	10YR 3/3M	C	m 2 abk	E	
Cr	75-100	Weatherd Basalt				

The percent depletion in available water holding capacity by -9.4% was recorded in subsurface of Kinhala and -5.4% in Hatodi series during year 2008 over 1999. Such variations could presumably be due to corresponding changes in organic matter and type of land use.

*Soil reaction (pH):*The soils were, in general, slightly to moderately alkaline and did not show much changes with respect to time and land use change (Table 5 and 6). During present investigation (2008) the pH of the surface soils ranged from 6.9 (Hatodi) to 8.8 (Kinhala) and that of subsurface soil pH ranged between 7.8 (Hatodi and Bahadura) to 8.5 (Manori and Kinhala). The increased in soil pH at subsurface indicated the accumulation of bases from soil surface to sub-surface. Higher pH in the surface soils of Kinhala series (8.8) indicates accumulation of bases in the surface whereas constant pH values from surface to subsurface soils of Bahadura series (7.8) indicates equal distribution of bases throughout the soil. The lowest pH was observed in surface soils of Hatodi series (6.9) cultivated land use which probably could be due to continuous removal of basic cations by high yielding crop varieties, use of acidifying inorganic N fertilizers and intensive cultivation. The results are in accordance with the findings of Wakene and Gebrekidan (2003).

Organic carbon

There has been slight to moderate increase in organic carbon content under all series with few exceptions (Table 5 and 6). Hatodi series recorded decline organic carbon content by -19.2% (from 0.94 to 0.76%) at surface, but subsurface showed maximum buildup of 23.1% (from 0.39% to 0.48%) over the earlier period (1999) of study.

The surface soil of Kinhala, Manori, Bahadura and Takali series showed percent buildup of organic carbon during the present study (2008) by 12.9%, 10.0%, 10.0% and 8.1% respectively, and also subsurface soil of Kinhala, Manori and Takali series by 7.7% 7.5% and 8.7% respectively, compared to the base period (1999). The increase in organic carbon content of soil series can be attributed to green manuring during *kharif* season and availability of organic matter in the form of crop residues, whereas decrease in carbon content may be attributed to less return of crop residue to the soil (Webb *et al*. 2000) or intensive cultivation.

Soil inorganic carbon (SIC) content

The study by Challa *et al*. (1999) reported the presence of $CaCO_3$ only at Bahadura. But in the present investigation soil inorganic carbon in the form of fine nodules of calcium carbonate ($CaCO_3$) was observed in the surface and subsurface soils of all the pedons except Hatodi series. Calcium carbonate content of surface soil varies from 0.88% to 16.74% and in subsurface it ranged between 0.33 to 17.74% in Manori and Bahadura series (Table 5 and 6) respectively. The increasing content of calcium carbonate under most of the soil series showed soils were being in the processes of calcification and this may be from irrigation water of poor quality through various sources.

Cation exchange capacity (CEC)

There has been slight to moderate increase in CEC of surface soils of all series was recorded during the present study period (2008). The maximum buildup of CEC was observed in surface of Kinhala 17.2% followed by Palora 12.2%, Manori 11.3% and Takli 6.0% over the earlier status (year 1999) (table 5 and 6). Hatodi series showed increased CEC during present study (year 2008) at subsurface (5.7%) compared to surface (3.2%). This might be due to buildup of organic carbon at lower depth compared to surface soil. Such increase in CEC under all soil series could be due to corresponding increase in organic matter content, good agricultural practices and land use over the year's from1999-2008.The sub-surface of Palora, Kinhala and Takali series showed decline in CEC by -10.8, -1.6 and -1.2% respectively over the initial (year 1999) values. The variations in CEC values of the soils could be due to the corresponding variations in clay percent and organic matter content. The high CEC of these soils, in general, is attributed to its smectitic clay mineralogy. These results are in concurrence with earlier findings of Majumdar *et al.* (2001) and Cerri *et al.* (2003).

Exchangeable bases

The exchangeable complex of these soils was dominated by calcium followed by magnesium, sodium and potassium. Exchangeable bases, calcium and magnesium varied markedly due to land use changes compaired to sodium and potassium over the earlier status reported by Challa *et al.* (1999). The exchangeable calcium was increased at surface soil under all soil series with few exceptions and maximum buildup was observed in Palora series from 18.9 to 26.8 cmol (p+)/kg over the earlier study this may be due to the presence of weatherable calcium bearing minerals. Similarly all soil series showed slightly increase in exchangeable magnesium content at the surface soil. However, there was not much variation in exchangeable K and Na amongst the soils.

The subsurface soil of Manori and Kinhala series (Table 5 and 6) showed increased value of exchangeable calcium (21.2 to 23.4 and 38.6 to 38.8 cmol (p+)/kg) and magnesium (7.9 to 10.6 and 7.9 to 8.4 cmol (p+)/kg), respectively over the initial status reported in year 1999, while response of other series was poor. The extent to which the adsorption complex of a soil is saturated with bases (Ca, Mg, Na and K) is frequently used as an indicator of inherent soil fertility (FAO UNESCO 1973).

Base saturation

The data showed that the soils are highly base saturated. High base saturation of these soils was due to basaltic nature of parent material associated with less rainfall and restricted leaching. There has been moderate increase in surface base saturation in almost all series, except Bahadura series (Table 5 and 6).

The maximum increase of percent base saturation has been recorded in surface soil of Palora (74.3 to 90.2%)

Table 5 Surface and subsurfacephysico-chemical properties of six soil series determined by Challa *et al*. (year 1999)

Series	Soil depth (cm)	Bulk density Mg/m^3	Sand (%)	Silt (%)	Clay (%)	AWC%	PH (1:2.5)	Organic Carbon (%)	$CaCO_3$ (%)	Exchangeable bases Cmol(P+)/kg				CEC	BS%
										Ca	Mg	Na	K		
Manori	0-16	1.71	33.8	27.8	38.4	8.5	8.0	0.70	Nil	21.5	9.6	0.32	0.22	33.6	94.0
	16-28	1.36	36.6	21.4	42.0	17.4	8.6	0.67		21.2	7.9	0.17	0.39	32.9	90.0
Kinhala	0-15	1.92	17.4	34.2	48.5	10.9	8.5	0.62	Nil	36.9	6.3	0.22	0.64	46.0	87.0
	15-32	1.40	15.5	33.0	51.5	10.6	8.5	0.39		38.6	7.9	0.23	0.59	49.5	95.6
Takli	0-18	1.72	18.9	32.6	48.5	12.7	8.1	0.37	Nil	36.9	4.8	0.20	0.59	46.9	90.7
	18-43	1.72	17.5	30.5	52.0	10.5	8.2	0.46		42.7	6.4	0.27	0.54	51.2	97.4
Palora	0-15	ND	42.7	21.5	35.8	10.6	8.0	0.70	Nil	18.9	3.3	0.14	1.35	31.9	74.3
	15-50		41.3	20.1	38.6	8.7	7.9	ND		30.7	5.6	0.22	0.57	41.8	88.8
Hatodi	0-12	ND	47.0	21.0	32.0	ND	7.0	0.94	Nil	16.8	2.5	0.20	0.26	25.0	79.2
	12-26		45.0	15.4	39.0	7.4	7.9	0.39		17.2	2.6	0.20	0.28	26.1	78.0
Baha-	0-15	ND	25.6	28.9	45.5	9.0	7.8	0.70	15.76	39.7	5.3	0.14	0.44	46.0	98.9
dura	15-30		22.2	26.8	51.0	9.8	7.9	ND	16.70	40.3	6.9	0.22	0.46	49.4	96.8

Table 6 Surface and subsurface physico-chemical properties of present investigation (year 2008)

Series	Soil depth (cm)	Bulk density (Mg/m^3)	Sand (%)	Silt (%)	Clay (%)	AWC (%)	pH (1:2.5)	Organic Carbon (%)	$CaCO_3$ (%)	Exchangeable bases Cmol(P+)/kg				CEC	BS%	Major available nutrients (kg/ha)		
										Ca	Mg	Na	K			N	P	K
Manori	0-17	1.69	33.6	29.2	37.3	8.6	7.8	0.77	0.88	24.6	10.8	0.31	0.29	37.4	96.2	251.9	25.8	668.3
	17-30	1.40	36.6	21.4	42.0	18.3	8.5	0.72	0.33	23.4	10.6	0.20	0.42	34.9	99.1	ND	17.2	663.4
Kinhala	0-18	1.80	15.6	35.2	49.1	11.1	8.8	0.70	1.90	43.4	7.6	0.25	0.67	53.9	96.3	238.3	30.2	602.0
	18-35	1.59	15.4	33.3	51.2	9.6	8.5	0.42	1.44	38.8	8.4	0.24	0.58	48.7	98.6	ND	24.6	521.4
Takli	0-20	1.68	20.4	31.2	48.3	12.7	8.3	0.40	1.74	38.6	7.2	0.24	0.59	49.7	93.8	181.9	18.9	623.6
	20-45	1.69	19.0	30.0	50.9	10.4	8.4	0.50	1.56	40.8	7.0	0.23	0.50	50.6	95.9	ND	15.1	596.7
Palora	0-14	1.79	41.6	22.1	36.2	10.1	8.0	0.72	0.95	26.8	4.9	0.18	0.44	35.8	90.2	238.3	20.2	499.9
	14-52	1.62	41.6	20.4	37.5	8.7	8.1	0.65	0.95	29.2	5.6	0.20	0.49	37.3	95.1	ND	11.2	505.3
Hatodi	0-14	1.87	47.0	20.7	31.5	7.0	6.9	0.76	Nil	17.2	3.4	0.23	0.28	25.9	81.6	175.3	19.6	290.3
	14-28	1.93	43.0	16.4	40.6	7.0	7.8	0.48	Nil	17.0	3.8	0.24	0.28	27.6	75.5	ND	16.8	290.3
Bahadura	0-18	1.78	23.5	29.8	46.6	9.1	7.8	0.77	16.74	38.8	5.8	0.13	0.70	46.4	97.4	224.6	18.9	641.8
	18-35	1.73	22.5	27.1	50.3	11.6	7.8	0.54	17.74	39.8	7.1	0.22	0.57	50.0	95.2	ND	16.8	602.1

*ND; Not determined

fallowed by Kinhala (87.0 to 96.3%), Takli (90.7 to 93.8%), Manori (94.0 to 96.2%) and Hatodi (79.2 to 81.6%) series. Whereas percent base saturation of surface soils of Bahadura series has been decreased from 98.9 to 97.3%, but change was not much identical.

The percent base saturation of subsurface soil of Manori (90.0 to 99.1%), Kinhala (92.5 to 97.9%), Takli (93.6 to 96.2%), Palora (86 to 92.7%) and Bahadura (90.3 to 96.2%) series have moderately increased, whereas B S of Hatodi series has not changed with respect to change in land use (Table 7 and 8). The increase of base saturation may have been due to the high values of exchangeable calcium fallowed by magnesium.

Available nutrients

The major plant available nutrients as nitrogen, phosphorus and potassium were not determined during earlier study (Challa *et al.* 1999). The present study (year 2008) examines the available nutrient status under all soil series. The maximum value of available nitrogen at surface soil was recorded in Manori series (251.9 kg/ha) fallowed by Kinhala and Palora series (238.3 kg/ha) and lower most available nitrogen was observed in Hatodi series (175.3 kg/ha) may be due to less organic carbon content of the surface soil, type of land use (rice-rice-rice or rice-wheat-rice triple cropping) and higher demand of nutrient for crop growth. The phosphorus content of surface soil varied from 30.2 (Kinhala) to 18.9 kg/ha (Takli and Bahadura series) while that of sub surface soil ranged between 24.6 (Kinhala) to 11.2 (Palora series).

The available potassium of all series varied from surface to sub-surface soil and higher value of available potassium recorded in Manori series (668 and 663 kg/ha) fallowed by Bahadura (642 and 602 kg/ha), Takali (624 and 597 kg/ha), Kinhala (602 and 521 kg/ha) and Palora series (500 and 505 kg/ha) this may be due to potassium bearing parent materials like basalt. Hatodi series showed lowermost value of available potassium (290 kg/ha) on surface and subsurface soil compared to other soil series, may be due to mining of potassium by higher yielding variety crops (rice) for their growth and the type of parent material.

The study reveals that the availability of irrigation, spread and introduction of soybean with assured market and net return and rapid urbanization changes the past land use under respective series. The minor variation recorded in soil morphological properties and increasing or decreasing trends observed in soil physico-chemical properties, either is immediate or slow depending on soils and land use changes. Increased organic carbon contents, cation exchange capacity, base saturation and exchangeable Ca and Mg were in general under all series with few exceptions. Characteristically, soil of Manori, Kinhala, Takli and Palora series were non calcareous during earlier study period, and are in process of being calcareous. Soils are rich in available nutrients under all series with exceptions. Monitoring these temporal changes in soil properties with respect to land use changes under established series helped for proper land use planning of any cultivated area.

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