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LAND-USE CHANGE DRIVEN IMPACT ON SOIL QUALITY THROUGH THE SOIL PROFILE IN THE DRY TROPICAL REGION OF INDIA

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Abstract

The impact of land-use change on soil physicochemical properties was studied through upper (0-10 cm), middle (10-20 cm) and lower (20-30 cm) soil layer during summer season involving natural forest, degraded forest, agro ecosystem, and *Jatropha curcas* plantation. Land-use change from natural forest to agro ecosystem, had negative impact on soil organic carbon, total nitrogen, porosity, bulk density and water holding capacity. *J. curcas* plantation on cleared patches of degraded forest increased soil organic carbon, total nitrogen, porosity, water holding capacity but decreased soil bulk density compared to degraded forest and agro ecosystem at all the soil depths. It is suggested that *Jatropha curcas* plantation improved various soil physicochemical properties that were rendered disproportionate during land use changes. Hence it may be adopted as the alternative for restoration of degraded lands.

Key words: Land-use change, *Jatropha*, physicochemical properties, dry tropics, soil depth

Introduction

Land-use change is responsible for the release of 120 Pg carbon since 1850 globally (Houghton, 2005) and currently, the rate of carbon loss from soils in tropical regions due to land-use change, is about 1.6 ± 0.8 Pg C y^{-1} on one hand, (Smith, 2008) and land degradation on the other (Zhao *et al.*, 2005). Conversion of natural forest to agro ecosystem (perturbed ecosystem) with periodical input and output of organic matter and modified biotic and abiotic environment, has lost 75% of the carbon pool in dry tropical regions (Lal, 2004). Changes in land-use practices affect not only soil organic carbon but also the soil nitrogen and other physicochemical properties (Cambardella and Elliott, 1992, Srivastava *et al.*, 2020). Most studies evaluated the effect of land-use change on distribution and storage of soil organic carbon and nitrogen (Wu *et al.*, 2003; Zhou *et al.*, 2007; Yan *et al.*, 2012; Kucharik and Brye, 2013), nevertheless, studies on other physicochemical properties with respect to dry tropical regions are almost lacking. It is a prerequisite in terms of sustainable management of lands to evaluate the impact of the land-use change on soil properties such as organic carbon, total nitrogen, bulk density, porosity and water holding capacity. Land-use change also affects soil properties by altering the transport of organic matter in the deeper soil horizon either through variations in the belowground input of organic matter or surface mixing by soil organisms (De Gryze *et al.*, 2005). Therefore, studies on deeper soil horizons regarding soil properties are much needed to decipher the complete scenario of impact of land- use change on soil properties.

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Conversion of natural forest to other land-use types leads to degradation of soil physicochemical properties with regard to soil organic matter, nutrient contents along with the climate change, biodiversity loss, reductions in soil fertility, and changes in ecosystem services (Tilman, 2001; Ashagrie *et al.*, 2007). Therefore, monitoring and mitigating the negative effects of land-use change while adopting sustainable management practices for the essential resource such as soil, is by now, the major issue. Land-use change significantly affects the soil processes and properties especially soil functioning (Post and Kwon, 2000), that can be examined through estimates of soil physicochemical properties (Shukla *et al.*, 2006, Manpoong and Tripathi, 2019).

Major drivers responsible for the degradation of natural forests are, repeated and/or intensive disturbance including excessive harvesting of various forest products, grazing and poor management. Such practices severely degrade the lands and erode the soil to the extent that inhibits or retards the restoration process (ITTO, 2002; Fu *et al.,* 2010). The deviations of natural forest from its own native state result in reduction of ecosystem services and the dominance of grasses and shrubs. Therefore, restoration of degraded lands and forests in the dry tropics is of paramount interest. Some workers suggested the alternative for restoration of degraded lands by woody perennials as such vegetations improved organic matter and nutrient additions by plant litter and roots. Plantation of *Jatropha curcas* (a perennial shrub of Euphorbiaceae family) may be the ideal alternative for the restoration of degraded lands as it is drought resistant, and not preferred by grazing animals (Krishnamurthy *et al.,* 2012). Extensive work is on record to overcome the problem of soil erosion and land degradation by restoration strategies for entisol and sodic soils in India (Ogunwole *et al.,* 2008; Singh *et al.*, 2012; Wani *et al*., 2012) but is almost lacking for ultisol in the dry tropical regions.

In this study, we hypothesized that (i) land-use changes from natural forest to other land-use types alter the soil physicochemical properties up to the lower depth and (ii) *Jatropha* plantations serve as an alternative to recover the soil properties following degradation in dry tropics. To examine these hypotheses, the present study aimed to (i) evaluate the impact of land-use change on soil physicochemical properties involving natural forest, degraded forest, agroecosystem and *Jatropha curcas* plantation and (ii) examine variations in soil physicochemical properties at lower depths.

Materials and Methods

Site description

Four land-use types selected for the study during summer season 2012 were: natural, degraded forest, agro ecosystem and bioenergy crop plantation in form of *Jatropha curcas*. Degraded forest, agro ecosystem and bioenergy crop plantation were situated at Rajeev Gandhi South Campus, Banaras Hindu University, Barakachha Mirzapur, Uttar Pradesh, India (25.15''N latitude, 82.58''E longitude, and 81 m msl), while, natural forest in the Marihan range, about 7-8 km away from Barakachha, Mirzapur. The climate of the region is dry tropical monsoonic with marked seasonality. The annual average rainfall is about 1876 mm (ranging between1700 to 2052 mm) of which, 95% occurs during rainy season. The mean monthly minimum and maximum temperature ranged from 14.2 to 32.5ºC and 25.5 to 42.8ºC, respectively. The USDA soil taxonomy categoriesed soil of the entire region as reddish to reddish-brown and residual ultisol. The parent soil material has been derived from the Kaimur sandstones, *i.e* Dhandraulorthoquartzite.

The forest site represented mixed dry deciduous type with minimum human disturbance. The major species of plants in forest site were *Acacia catechu* Wild., *Albizia odoratissima* Benth., *Acacia nilotica* (L.) Willd., *Boswellia serrata* Roxb., *Nyctanthes arbortristis* L., and few scattered trees of *Azadirachta indica* Juss. and *Zizyphus glaberrima* Santap. The herbaceous vegetation in forest floor was *Ocimum americanum* L., *Pisum arvense* L., *Rhynchosia minima* L. DC., *Cassia sophera* L. Roxb., *Acrocephalus indicus* (Burm. f.) Kuntze., *Cynodon dactylon* L., *Oplismenus burmannii* Ritz. Degraded forest was the result of mismanaged and uninterrupted logging and grazing, and was dominated by woody shrubs mainly *Zizyphus glaberrima* Santap, *Chrysopogan fulvus* Spreng., *Heteropogan contortus* L., *Adina cordifolia* Roxb., and scattered trees of *Butea monosperma* Lamk were the dominant species along with the herbaceous vegetation mainly of *Cassia tora*L., *Oldenlandia diffusa* Roxb., *Sporobolus* spp. *Panicum psilopodium*Trin., *Alysicarpus varginalis* L. DC. Croplands originated by cultivations of a cleared patch of the degraded forest for almost 35 years with the crop sequence rice (*Oryza sativa* var. HUR 3022), barley (*Hordeum vulgare* var. Manjula), summer fallow with application of chemical fertiliser (Urea: single super phosphate: muriate of potash:: 100 N, 60 P, 40 K kg ha^{-1}) continuously for the past 25 years. *Jatropha* plantation started in 2002 on a patch of the degraded forest (100 ha) with the inter row as well as inter plant distance of 2 m. The herbaceous vegetation in *Jatropha* plantation was dominated by *Evolvulus nummularis* L., *Glinus oppositifolius* (L.) DC., *Tephrosia purpurea* L. and *Cassia tora* L.

Soil sampling and analysis

Soil samples were collected during summer at upper (0-10 cm), middle (10-20 cm) and lower (20-30 cm) soil layer for the analysis of soil organic carbon, total nitrogen, bulk density and water holding capacity from all the land-use type sites. Each site was first divided into three study sites, which got further sub-divided into nine sub-sites for natural forest, degraded forest and *Jatropha* plantation, and eight for the agroecosystem; out of which, five were randomly selected for sampling at a time. The soil samples were collected using soil corer having diameter (4 cm) and height (10 cm) from each sub-site (*i.e.*, total of 10 soil samples from each study site) and mixed together to represent the single composite sample for a study site.

Analysis of soil physicochemical properties

Soil organic carbon was estimated by the dichromate oxidation and titration method (Kalembasa and Jenkinson, 1973). Total N was measured by the nitrogen analyzer (Gerhardt). Water holding capacity was determined using perforated circular brass box (Piper, 1966). Soil bulk density was determined by removing soil cores with the help of a metal corer of height and diameter of 10 cm and 2.8 cm, respectively from upper (0-10 cm), middle (10-20 cm) and lower (20-30 cm) layer and oven drying at 105^{0}C (24 h).

Porosity (%) of soil was calculated using the equation:

$$[1-(BD/PD)] \times 100$$

Wherein, BD =bulk density, PD =particle density (assumed to be 2.65 Mg m^{-3} soil).

Statistical analysis

Data were analyzed using SPSS (version 16.0) package. All values are expressed as mean ± standard error. Mean values were compared using the least significant difference (LSD). Differences between land-use types and soil depth were tested using two-way ANOVA. Significance of difference was indicated at $p < 0.05$ and $p < 0.01$. Pearson's correlation test was performed to account for the relationship of the soil physicochemical properties among themselves.

Results

Soil organic carbon

Soil organic carbon varied significantly (0.16% – 0.85%) across all the land-use types and soil depths. The soil organic carbon content was maximum in natural forest followed by *Jatropha* plantation, degraded forest and agro ecosystem at all the soil depth. It showed a decreasing trend with soil depth being highest at the upper layer and followed by middle and lower soil layer for all the land-use types table 1. Two-way ANOVA indicated land-use types to have pronounced effect on soil organic carbon (f = 796.20, df = 3, $p<0.001$) than the soil depth (f = 793.74, df = 2, $p<0.001$). Significant effect of combined interaction of land-use types and soil depth (f =84.64, df =6, $p<0.001$) was observed.

Soil total nitrogen

Significant variation in soil total nitrogen among the land-use types was observed. It ranged from 0.051 - 0.136% across all the land-use types and soil depth. Among the land-use types, it was highest in natural forest followed by *Jatropha* plantation, degraded forest and agro ecosystem at all the soil depths. Total nitrogen concentration was maximum at the upper soil layer and decreased with middle to attain its minimum at the lower layer in all the land-use types table 1. Two-way ANOVA indicated land-use types to have pronounced effect on total nitrogen (f= 982.42, df= 3, $p<0.001$) than soil depth (f= 104.53, df= 2, $p<0.001$); significant effect of combined interaction of ecosystem with depth (f=18.23, df=6, $p<0.01$) was also observed.

Soil bulk density

Bulk density was significantly different across the

Table 1: Annual mean of soil physicochemical properties at upper (0-10 cm), middle (10-20 cm) and lower (20-30 cm)layer in land use types i.e. natural forest (NF), degraded forest (DF), agro ecosystem (AG) and *Jatropha* plantation (JP) at the end of the study. Values are mean ± SE. In each row and column values having same alphabetic and numeric superscripts respectively are not significantly different from each other (P < 0.05).

Soil depth (cm)	Land use types				LSD
	NF	DF	AG	JP	
Soil organic carbon (%)					
0-10	0.85^{d3} ± 0.03	0.42^{b2} ± 0.02	0.27^{a2} ± 0.01	0.67^{c3} ± 0.02	0.06
10-20	0.48^{d2} ± 0.02	0.26^{b1} ± 0.01	0.19^{a1} ± 0.01	0.44^{c2} ± 0.02	0.06
20-30	0.39^{d1} ± 0.02	0.23^{b1} ± 0.01	0.16^{a1} ± 0.01	0.27^{c1} ± 0.01	0.04
LSD	0.07	0.04	0.03	0.05	
Total Nitrogen (%)					
0-10	0.136^{c3} ± 0.003	0.067^{a2} ± 0.002	0.063^{a2} ± 0.002	0.083^{b3} ± 0.002	0.006
10-20	0.110^{c2} ± 0.003	0.057^{a1} ± 0.002	0.054^{a1} ± 0.001	0.076^{b2} ± 0.002	0.007
20-30	0.101^{c1} ± 0.002	0.055^{a1} ± 0.001	0.051^{a1} ± 0.001	0.071^{b1} ± 0.002	0.005
LSD	0.008	0.006	0.005	0.005	
Bulk density (gcm^{-3})					
0-10	1.13^{a1} ± 0.03	1.25^{b1} ± 0.02	1.36^{c1} ± 0.02	1.20^{ab1} ± 0.02	0.07
10-20	1.18^{a12} ± 0.02	1.27^{b12} ± 0.02	1.41^{c12} ± 0.02	1.23^{ab12} ± 0.03	0.06
20-30	1.24^{a2} ± 0.02	1.32^{b2} ± 0.03	1.46^{c2} ± 0.03	1.28^{ab2} ± 0.03	0.07
LSD	0.07	0.06	0.06	0.08	
Porosity (%)					
0-10	57.23^{c2} ± 3.57	52.99^{b2} ± 1.80	48.52^{a2} ± 2.75	54.79^{bc2} ± 2.30	2.58
10-20	55.46^{c12} ± 2.71	51.83^{b12} ± 1.66	46.86^{a12} ± 2.50	53.65^{bc12} ± 3.41	2.54
20-30	53.40^{c1} ± 2.18	50.09^{b1} ± 3.12	44.78^{a1} ± 2.82	51.59^{bc1} ± 3.10	2.72
LSD	2.80	2.23	2.62	2.90	
Water holding capacity					
0-10	45.41^{c2} ± 1.18	40.96^{b2} ± 1.31	36.56^{a2} ± 0.90	43.77^{bc2} ± 1.50	3.78
10-20	42.25^{b12} ± 1.54	37.02^{a12} ± 1.47	34.34^{a12} ± 1.24	41.19^{b12} ± 1.25	4.15
20-30	40.42^{c1} ± 1.37	34.52^{ab1} ± 1.05	32.26^{a1} ± 1.48	38.49^{bc1} ± 1.70	4.32
LSD	4.14	3.99	3.80	4.61	

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land-use types (1.13-1.46 gcm^{-3}) at all the soil depths and in land-use types. The bulk density was lowest in natural forest, followed by *Jatropha* plantation, degraded forest and agro ecosystem at all the soil depths. The bulk density values was the least in 0-10 cm soil depth followed by 10-20 and 20-30 cm in case of all the four land-use types table 1. Two-way ANOVA indicated land-use types to have pronounced effect on soil bulk density (f=22.03, df=3, p<0.001) than soil depth (f=9.28, df=2, p<0.001) whereas, no significant effect of combined interaction of land-use types with depth (f=0.16, df=6, p>0.05) was observed.

Soil porosity

The soil porosity ranged from 44.78 – 57.23% in all the land-use types and soil depths. Porosity showed a trend reverse to that of soil bulk density being highest in natural forest followed in decreasing order by *Jatropha* plantation, degraded forest and agro ecosystem for all the soil depths. The porosity was highest in 0-10 cm soil depth followed by 10-20 and 20-30 cm depth in all the four land-use types table 1. Water holding capacity was more influenced by land-use types (f=30.22, df=3, p<0.001) than soil depth (f=17.41, df=2, p<0.001) whereas, no significant effect of combined interaction of land-use types and soil depth (f=0.32, df=6, p>0.05) was evident from Two-way ANOVA.

Soil water holding capacity

Soil water holding capacity ranged from 32.26 – 45.41% across all the land-use types and soil depths. It showed a decreasing trend with soil depth being highest at the upper (0-10 cm) followed by middle (10-20 cm) and lower layer (20-30 cm) in all the land-use types. A decreasing trend of water holding capacity was observed being highest in natural forest followed by *Jatropha* plantation, degraded forest and agro ecosystem at all the soil depths table 1. Two-way ANOVA indicated land-use types to have more effect on water holding capacity (f= 28.48, df= 3, p<0.001) than soil depth (f= 27.38, df= 2, p<0.001), whereas, no significant effect of combined interaction of land-use types and soil depth (f=0.10, df=6, p>0.05) was observed.

The soil organic carbon showed strong positive correlation with total nitrogen (r^2 = 0.72, p = 0.01, n = 12), water holding capacity (r^2 = 0.86, p = 0.01, n = 12) and porosity (r^2 = 0.74, p = 0.01, n = 12) whereas, it was significantly and negatively correlated with bulk density (r^2 = 0.73, p = 0.01, n = 12) Fig. 1. Total nitrogen also showed a strong positive correlation with water holding

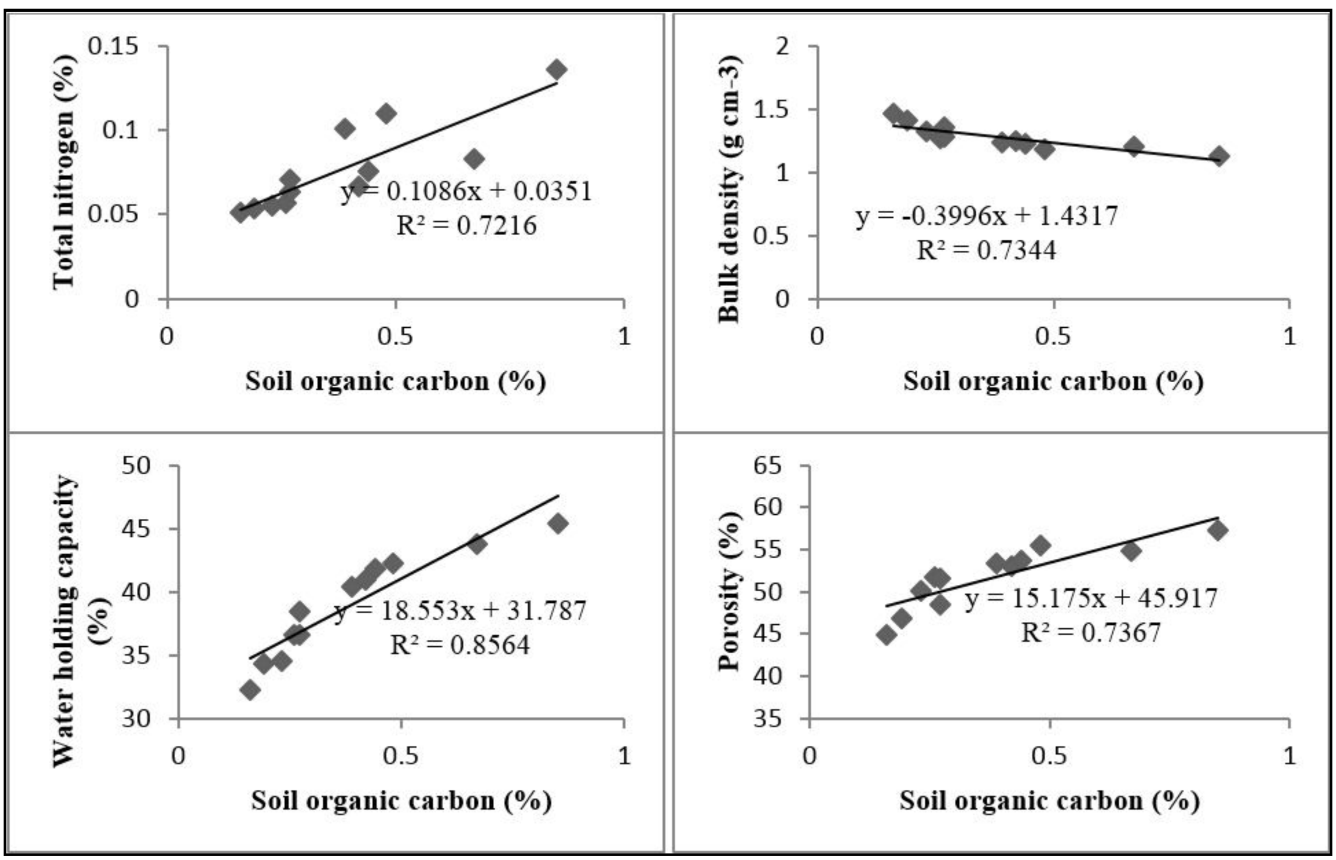

Fig. 1: Relationship of soil organic carbon with total nitrogen, bulk density, water holding capacity and porosity across the three soil depth (0-10, 10-20 and 20-30 cm) and four land use types; n = 12 for each parameter.

capacity (r^2 = 0.69, p = 0.01, n = 12), porosity (r^2 = 0.67, p = 0.01, n = 12), and strong negative correlation with bulk density (r^2 = 0.67, p = 0.01, n = 12) Fig. 2. Bulk density was significantly and negatively correlated with water holding capacity (r^2 = 0.88, p = 0.01, n = 12) and porosity (r^2 = 1.00, p = 0.01, n = 12) Fig. 2. Porosity showed strong positive relationship with water holding capacity (r^2 = 0.90, p = 0.01, n = 12).

Discussion

Impact of land-use change on soil physicochemical properties

Conversion of forest from natural to the degraded one leads to 51% reduction in concentrations of soil organic carbon at the upper soil layer in the present study table 1, which might be attributed to the lower input and higher decomposition of organic matter than the natural forest as the degraded counterpart faces severe logging and grazing. Intensive disturbances in degraded forests accelerate loss of vegetation cover and soil erosion which results in loss of soil organic carbon and other nutrients, and ultimately, the land degradation (Houghton 1991b; Tripathi and Singh 2009). Whereas, regular and more input of organic matter into the soil in the form of above and below ground plant parts and its minimal oxidation through disturbances might be the reason for the highest

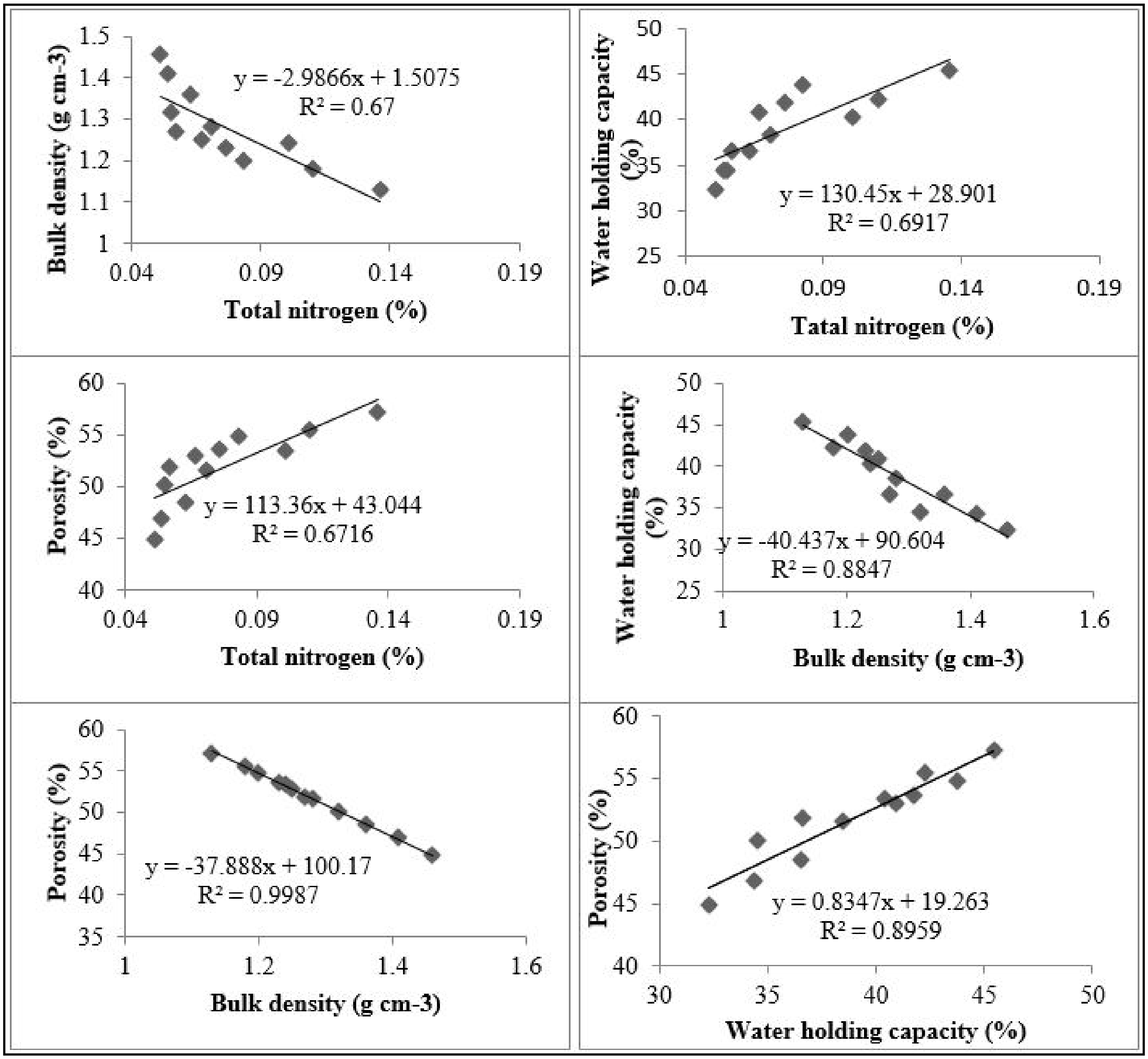

Fig. 2: Relationship of soil total nitrogen with bulk density, water holding capacity, porosity and bulk density with water holding capacity, porosity and water holding capacity with porosity across the three soil depth (0-10, 10-20 and 20-30 cm) and four land use types; n = 12 for each parameter.

soil organic carbon concentration in natural forest compared to other land-use types in the present study table 1. Catovsky *et al.,* (2002) also stated that accumulation of carbon in soil was proportional to the biomass inputs in the soil depending on plant biodiversity. Elaborated root system of perennial trees and ground flora of natural forest might attribute more to the accumulation of soil organic carbon in natural forest as it is reported that the contribution of roots in accumulation of soil organic carbon was more compared to above ground biomass (Puget and Drinkwater, 2001). Tilman *et al.,* (2006) also reported that change in land-use practices and the composition and diversity of plants collectively exert major impact on the transfer and accumulation of carbon in soil.

As Wang *et al.,* (2009) showed a positive correlation between total nitrogen and soil organic matter, therefore, it may be predicted that variability in soil organic matter was the major factor responsible for variations in concentrations of soil total nitrogen. Aghasi *et al.,* (2011) stated that undisturbed area extensively covered with vegetation amended its residue to the soil and thus increased the soil organic matter that prevented soil erosion and nitrogen loss due to sedimentation and increase the concentration of soil total nitrogen. A 51% reduction in total nitrogen concentration in degraded forest than the natural forest at the upper soil layer might be due to reductions in organic matter through vegetation cover, which might also accelerate total nitrogen loss from the soil. Degraded forest facing anthropogenic disturbance, resulted in soil compactness that in turn, increased its bulk density. Cattle grazing in degraded forest might also be the reason of soil compactness through mechanically compacted clods (Wiesmeier *et al.,* 2012). Whereas, higher accumulation of soil organic matter in little disturbed natural forest than other land-use types, might be the reason for lower soil bulk density and higher porosity than the other land-use types in the present study table 1. As the natural forest gets converted to degraded one, the input of organic matter decreases due to anthropogenic activities, and soil bulk density increases due to grazing. These two factors cumulatively, explain a 10% reduction in water holding capacity in degraded forest relative to natural forest in the present study table 1. This could be attributed to water retention in soil pore spaces in addition to adsorption of mineral particles and organic matter on the surface.

Conversion of natural forest to agro ecosystem led to 68 % loss of soil organic carbon at upper layer in the present study table 1. It might be due the removal of a major portion of crops through harvesting and leaving behind only stubbles and roots in the field. Therefore, the organic input to the soil through aboveground biomass was lower than other land-use types, which resulted in lower concentration of soil organic carbon. Lower input of organic matter in soil and its higher loss by repeated tillage practices in agro ecosystem disturbs the carbon input and output equilibrium. Such alterations in the equilibrium of carbon input and output might be the major drivers of reductions in soil organic carbon in the agro ecosystem. The removal of higher proportion of organic carbon occurs through the annual harvest when the system passes through a transition of natural forest to agro ecosystem (Smil, 1999). Changes in land-use practices from natural forest to agro ecosystem, also change the quantity and quality of organic matter input to the soil, nutrient additions and loss and stimulate the decomposition of organic matter which alters the soil organic carbon levels (Murty *et al.,* 2002). Lal, (2004) also reported 75% loss of organic carbon from soil through conversion of forest to agro ecosystem in the dry tropics. The rate of decomposition of organic matter increases with soil cultivation because physical fragmentation and redistribution of residue occurs due to tillage leading to rapid oxidation of soil carbon to CO_2 to the atmosphere (Vitousek, 1983). Abera and Belachew, (2011) reported lower concentration of soil organic carbon in the agro ecosystem than the virgin forest and grassland due to reduced input of organic matter and minimum protection of soil organic carbon by ploughing activity, and the accelerated rate of soil organic matter oxidation. Houghton, (1991a) also stated that loss of vegetation after conversion of natural forest to agro ecosystem accelerated soil erosion and decomposition of the organic matter with the resultant reductions in the organic carbon content. Other researchers also reported loss of organic carbon from conversion of native vegetation to agro ecosystem elsewhere (Murty *et al.,* 2002; Lal, 2004; Golchin and Asgari, 2008; Gami *et al.,* 2009; Khormali *et al.,* 2009; Chen *et al.,* 2010; Emadi *et al.,* 2008; Singh and Ghoshal, 2011; Beheshti *et al.,* 2012 ; You *et al.,* 2014). Lowest total nitrogen in agro ecosystem (54% lower than natural forest at upper layer of soil) in comparison to other land-use types, might be due to high disturbance by tillage activity which leads to loss of soil organic matter table1. Aghasi *et al.,* (2011) also reported loss of soil total nitrogen in agroecosystem over the undisturbed lands and that land-use change-induced vegetation loss and soil disturbance collectively affect the soil moisture content and temperature and the increased biological decomposition of soil organic matter results in accelerated rate of mineralization of nitrogen and so also reduction in soil total nitrogen. Soils of agroecosystem are considered to have higher bulk density than forest because cultivation leads to breakup of aggregates and compaction (Murty *et al.,* 2002). Celik (2005) stated cultivated plots to have higher soil bulk density than grassland probably due to loss of soil organic carbon and aggregation following repeated sowing and harvesting. Beheshti *et al.,* (2012) reported that agricultural lands formed by the conversion of natural forest had increased soil bulk density probably due to the disruption of soil macroaggregates by wet plowing (pudding). Continuous tillage and agricultural practices lead to breakdown of soil aggregates and the soil compaction increased soil bulk density and decreased the porosity (Raiesi, 2012). As natural forest got converted in agricultural lands, 17% reduction in water holding capacity was evident in the present study table 1, which might be due to reductions in soil organic matter and increase in soil compactness due to agricultural practices which lead to decreased pore spaces in soil, and the resultant lowered water holding capacity. It is well established that cultivation loses the labile organic matter pool *e.g.* polysaccharide (Piccolo and Mbagwu, 1999) which are hydrophilic so cause deficiency in the adsorbent soil surface and this results in lower water holding capacity (Li *et al.,* 2007). Singh *et al.,* (2009) also reported loss in water holding capacity in cultivated plots than the protected grassland. Decrease in water holding capacity with the change of natural grassland to croplands was also reported by Chen *et al.,* (2010).

In *Jatropha* plantation, major portion of plant litter added to the soil as the system was less disturbed by anthropogenic or grazing and, this might be the reason of higher soil organic carbon compared to the agro ecosystem or the degraded forest. All the leaf litter of plants left on the ground, act as soil amendments since this system was comparatively less disturbed. The leaves, along with the profusely branched root system limited to the upper 20 cm, could have added large amounts of organic matter to the soil, in turn stimulating the microbial biomass (Singh and Ghoshal, 2014). Chaudhary *et al.,* (2008) and Behera *et al.,* (2010) also suggested that addition of nutrient rich leaf litter to the soil and recycling of these nutrients, was the reason for accumulation of soil carbon *Jatropha* plantation. Plantation of *Jatropha curcas* on degraded lands increased the soil organic carbon (60% and 148%) to that of the degraded forest and agro ecosystem within 10 years duration implying that degraded land without extensive vegetation cover if developed and managed properly with *Jatropha* plantation the concentration of soil organic carbon will improve gradually, and promote vegetation growth on the degraded land. This collectively leads to more input of organic matter to the soil and carbon sequestration together with the restoration of degraded lands in the dry tropical region of India. The lower soil bulk density in natural forest and *Jatropha* plantation than the degraded forest and agro ecosystem might be due to the greater return of plant residue in the soil which increased the soil organic matter, and also improved the aggregation process and increase in volume of soil micropores. Vanden-Bygaat *et al.,* (1999) also illustrated that more root penetration and biological activity in the no tillage area might facilitate the entry of air and water percolation due to formation of biopores which may lead to decreased soil bulk density.

Variations in soil physicochemical properties with depth

Significant variations in soil organic carbon and total nitrogen with soil depth contrary to insignificant ones in soil bulk density, porosity, water holding capacity revealed that land-use change affects more the soil chemical than the physical property through soil profile. Significantly high concentration of soil organic carbon and total nitrogen at the upper layer of soil than middle and lower layer across all the land-use types was observed table 1, which might be attributed to more root activity and formation of a bed of leaf litter and other plant parts at the upper soil horizon. Higher levels of soil microbial biomass at the upper layer (Singh and Ghoshal, 2014) might help in conversion of litter into soil organics and ultimately increase of soil organic carbon and total nitrogen, in comparison to middle or lower layer in the present study table 1. This implies that the upper layer was the most active part of the soil profile in terms of biological activity and therefore, protects the soil profile from degradation; the conservation of this layer is essential. The decrease in concentration of soil organic carbon and total nitrogen with depth in present study in dry tropics, is in agreement with studies of other regions. Trujillo *et al.,* (1997) reported a decreasing trend of SOC content with soil depth in silvopastural systems of Florida, Haile *et al.,* (2008) in Southwest Ethiopia (Kafa), Aticho (2013) reported a negative correlation between SOC content and the sampling depth. Almost similar trends were reported by Gami *et al.,* (2009), Saha *et al.,* (2010), Abera and Belachew (2011) and Singh *et al.,* (2012) with regard to degraded sodic soils. Gregorich *et al.,* (1995) reported 10- fold decrease in soil organic carbon from 0-15 cm to15-30 cm of soil depth in the forest land. Abera and Belachew (2011) and Wang *et al.,* (2012) reported decrease of soil organic carbon and total nitrogen with soil depth. Aghasi *et al.,* (2011) stated that destruction of natural soil surface by disturbance had harmful impact on soil organization and infiltration rate which led to increasing runoff and became the major factor of depletion of high amounts of nitrogen from the upper soil layer. Singh *et al.,* (2012) and Wang *et al.,* (2012) also reported declining trend for total nitrogen with soil depth. Yi *et al.,* (2014) reported increase in soil bulk density with soil depth in the pasturelands.

In the present study, the decreasing trend of water holding capacity, soil porosity with soil depth and increase in soil bulk density was observed able 1, but the variations among these parameters along the soil layers was not significant in contrast to soil organic carbon and total nitrogen. This implies that soil nutrients are more affected by land-use change than the soil physical properties (bulk density, porosity and water holding capacity). The soil physical properties among the upper and lower soil layer, varied significantly contrary to the middle layer. This implies that middle layer could behave as transitory to that of upper and lower layer.

In the present study, significant positive correlation of total nitrogen with soil organic carbon indicated that the factor responsible for variability in soil organic carbon was the main driver with regard to soil total nitrogen concentration Fig. 1. Wang *et al.,* (2012) also reported significant positive correlation between total nitrogen and soil organic carbon ($r = 0.95$, $p<0.01$). The significant negative correlation of soil bulk density with soil organic carbon in the present study indicated that higher accumulation of organic carbon in soil was responsible for the lowering of soil bulk density Fig. 1. Inverse proportion of bulk density to that of soil organic matter is also reported earlier (Arvidsson, 1998; Zhang *et al.,* 2010; Zhu *et al.,* 2010 and Raiesi, 2012). Variations in water holding capacity through the land-use change may be explained from fluctuations the variation in concentrations of soil organic carbon and porosity as evident from the correlation analysis Fig. 1. A significant relationship between these parameters revealed that soil physicochemical properties were very sensitive to land use Fig. 2.

Conclusion

Land-use changes in the natural forest inflict severe alterations in soil physicochemical properties. The consequence is limited not only to upper soil layer but also affects the soil physicochemical properties up to the lower layers of soil. The decade old plantation of *Jatropha curcas* on a patch of degraded forest significantly improved soil physicochemical properties relative to degraded forest and agro ecosystem. It can be suggested that plantation of *Jatropha curcas* on the degraded lands may be adopted as the crucial strategy for restoration of degraded lands.

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