Influence of the land use on dynamic soil quality; a review

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ABSTRACT: Since soil is the foundation for nearly all land uses, increasing population pressures and human demands for services from a fixed land area are severely increasing. Mismanagement of land resources leading to land degradation, not only limits the prospects of increasing flexibility of land in reaping further services, but also increase the investments required for conservation, rehabilitation and reclamation of land. Dynamic soil quality is important in studying the effect of the land management practices on soil attributes of a given soil. Therefore, studies focused on change in dynamic soil quality to different land management practices have been receiving special attention of the researchers from different regions. After critically reviewing the available scientific information, it is observed that there is a significant impact of intensive alteration of land uses on dynamic soil quality. Nitrogen, Phosphorus and Soil Organic Matter significantly deviated from the natural vegetation compared to other land uses. The trends shown were parallel around the world but most studies were focused on temperate regions. Due to the significant impact of different land uses on soil quality, assessment of dynamic soil quality with respect to land use is important at both regional and local level, to design appropriate management strategies for local conditions. Therefore, in order to retain and improve the present soil quality status, the legislative authorities and other interested parties have a crucial role to play in ensuring the sustainable productivity of soil.

1 INTRODUCTION

Soil quality is the "continued capacity of soil to function as a vital living system, within ecosystem and land use boundaries, sustain biological productivity, to promote the quality of air and water environments, and to maintain plant, animal and human health" (Doran and Safley, 1997). It can be subdivided into inherent soil quality and dynamic soil quality. Inherent soil quality is the inherent capacity of the soil to promote crop growth and it is based upon the parent geological materials of the soil and the process of soil genesis. Hence, the typical characteristics or inherent soil quality is mostly static and change slightly over time. To evaluate inherent soil quality extrinsic factors such as climatic, topographic and hydrologic parameters should also be considered. On the other hand, dynamic soil quality is the soil properties that change in a short period of time and it is influenced by anthropogenic use and management activities like agronomic practices. Dynamic quality of soil can be assessed with the use of soil quality indicators or the soil physical, chemical, and biological properties which can determine the capacity of the soil to function (Carter et al, 1997; Karlen et al., 1997, Shukla et al., 2006).

Land use changes are the modifications made to the land covers without changing the existing land cover types or complete replacement of original land cover types by another (Turner et al., 1993; Fresco, 1994). Land use changes influence the dynamic soil quality, as extensive cultivated land use patterns leads to a gradual decline in soil quality. Sustainable use of land is therefore the fundamental objective of development, utilization and protection of land resources (Doran et al., 1994; Liu et al., 2013).

2 SIGNIFICANCE OF THE EFFECT OF LAND USE ON SOIL QUALITY

Since soil is the foundation for nearly all land uses, increasing population pressures and human demands for services from a fixed land area are severely increasing. This trend is threatening the quality and the natural regulating functions of the soil, water and air resources on which sustainability of all life forms depends. Sustainable soil use depends on three interacting factors, namely; soil characteristics, related environmental conditions and land use (Toth et al, 2007). Therefore, the change of one factor causes alterations in other factors making the sustainability of soil resource dynamic. Mismanagement of land resources, leading to the land degradation, not only limits the prospects of increasing flexibility of land in reaping

further services, but also increase the investments required for conservation, rehabilitation and reclamation of land (Oldeman et al., 1990). Hence, studies focused on change in soil quality in response to management, or resilience of soil towards natural and anthropogenic forces, have been receiving special attention of the researchers from different regions in the recent past.

Pressure reflected on land resources is the reason for soil degradation in Sri Lanka, evident from the fact that only 3 million ha is arable from total land areas of 6.5 million ha due to unsuitable terrain, forest reserves and inland water bodies. Furthermore, soil fertility decline is among the three major soil degradation processes of Sri Lanka (Mapa, 2003). Removal of top soil, most fertile part of the soil, also contributes to the fertility decline, reducing crop yield by almost 50%. Depletion of soil nutrients by leaching is another cause for fertility decline of soil and most farmers are not fully aware of the adequate and recommended amount of fertilizer inputs, in Sri Lanka. In addition, if the depleted nutrients are not properly replenished soil fertility decline will be accelerated. Therefore, maintaining or improving soil quality in lands used for agriculture is highly significant for the sustainability of Sri Lankan agriculture (Mapa, 2003; Wanniarachchi and Shyamalee, 2005). Thenabadu (1988) stated that due to the extensive plans envisaged for future agricultural development and the greater demand made by the increasing population it is necessary that soil, valuable natural resource, be conserved. He further stated, although conservation and development often seem incompatible, conservation is a prerequisite. Dumanski and Pieri (2000), also agrees by stating that there is clearly a major requirement both at national and global levels for increased agricultural production and intensification, but the challenge is to achieve this while maintaining and enhancing the quality of the land resource on which production depends. They further state that it is important to know if current land management is leading towards or away from sustainability. This implies the need for standards, on which to measure and assess dynamic soil quality. Additionally, assessment of soil properties with respect to land use is important at local scales, to design appropriate management strategies for local conditions as it can affect the livelihood of local communities (Gebrelibanos and Assen, 2013).

3 GLOBAL LITERATURE

3.1 *Studies in African region*

A study conducted in Hirmi watershed and adjacent agro ecosystem of Northern Ethiopia showed plantation forest soils had better C:N ratio, Total Nitrogen, and Soil Organic Matter content as compared to cultivated and grassland soils. However, Soil Organic Matter, Total Nitrogen and Exchangeable K^+ in forest soils were higher than that of other land uses. Cultivated land has shown significantly higher Available Phosphorus, but lower Soil Organic Matter, Total Nitrogen and Exchangeable K^+ (Gebrelibanos and Assen, 2013). Gebrelibanos and Assen (2013) argue that the cause of lower Soil Organic Matter values in soils of cultivated lands were primarily due to soil erosion and anthropogenic factors such as selective removal of organic matter of both floral and faunal origin. The results also imply the need of planting trees in de-vegetated areas as it can potentially enhance dynamic soil quality through maintenance of Soil Organic Matter, biological Nitrogen fixation and prevention of nutrient loss by erosion.

Another more recent study in the African region focused on investigating the influence of agricultural land use types on dynamic soil quality and soil degradation in humid environments of Nigeria were also observed least Soil Organic Matter in continuously cultivated soils, compared to the other four agricultural land uses studied (Ahukaemere et al, 2012). Similar to the previous study, relatively higher Soil Organic Matter levels in the surface soils at all land uses (forest, oil palm plantation and uncultivated land uses) except continuously cultivated land use were recorded. However, soil from all four agricultural land uses were acidic, with pH values between 4.27 and 5.56 and Total Nitrogen were also found to be low (0.70 -1.4 g/kg), according to the study. As per the observed results, Ahukaemere et al (2012) states that forest, oil palm plantation and uncultivated land uses have relative higher soil quality than those of continuously cultivated land uses. From the results of a similar study done in Nitosols of Achefer District, Northwestern Ethiopia shows the possible significant influence of the conversion of forest lands to cultivated lands and grasslands of the detrimental effects on the soil physico-chemical properties under subsistence farming systems (Selassie and Ayanna, 2013).

3.2 *Studies in European region*

Similar to the African region, several European studies also have been conducted to study the influence on dynamic soil quality by different

land uses. One such study is an investigation of dynamic soil quality conducted in Galicia Region of Spain. The study revealed that variation of soil bio-chemical properties can be observed under different land uses, such as climax vegetation, reforested land, grasslands with low intensity of management, grasslands with highly fertilized with organic and inorganic fertilizers, crop land under maize subjected to traditional agricultural practices and wine yards (Carmen et al, 2008). Increase of soil pH and soil Phosphate were significant in soils with agricultural land uses. Carmen et al (2008) argues that the acute increment of Phosphorus indicates the intense use of fertilizers with Phosphates. Similar to the African regional studies, Soil Organic Matter indicated a major loss with increased use and management of soil, as the reforested soils had Soil Organic Matter between the maximum Soil Organic Matter observed in climax soils with 60- 70% and least Soil Organic Matter was10-40%. However, decrease of Total Nitrogen was not acute as observed in African regional studies as reforested soils had Total Nitrogen values between climax soils (60-70%) and agricultural soils (20-60%). These results indicate the influence of intense application of Nitrogen fertilizers. These findings consents with Caravaca et al. (2002), as agricultural land use lead to a significant variation in soil bio-chemical quality while Cerdà et al. (2009), in agreement to that further elaborate, agricultural land use can contribute to increased rates of erosion due to desiccation, mechanical destruction, soil compaction, reduce pore volume, and disruption of access to food resources.

Another study in Spain showed a significant influence of land use on the main soil bio-chemical quality parameters. The study was conducted on four representative current land uses in Serra de Rodes Catchment (NE Spain), in sequence from cultivation to early abandonment. Land use types were grouped into four main groups according to the age of abandonment. Significant differences in the main soil bio-chemical quality parameters which are used to estimate dynamic soil quality, such as Soil Organic Matter, Total Nitrogen, pH under different land uses were observed (Dunjo´ et al, 2003).

In the European region, Olive is one of the most important crops, not only in terms of the total cultivated area but also socio-economically. Thus, studies have been conducted to identify the environmental impact of Olive cultivation with special reference to the dynamic soil quality. In one of such studies, main soil bio-chemical quality parameters were analysed under different management systems of Olive groves namely; conventional tillage, no tillage - bare soil and cover crop. Subsequently, results were compared with the soils of uncultivated and native vegetation. Based on the results, Neito et al (2012) indicated that inclusion of cover crops and elimination of tillage significantly improves soil bio-chemical quality in Olive groves. Thus, the significance of the land use change and its influence on dynamic soil quality is understandable. However, since the study was only confined to Olive cultivation the application of the observed results to other crop species is questionable.

A similar study was conducted in an artificially constructed farm to test the dynamic soil quality revealed that soil pH tended to increase in the organic farming systems, compared to the conventional farming systems. It also indicated that field trial of manure based farming systems was favoring an active and fertile soil as Soil Organic Matter and other tested dynamic soil quality indicators were clearly depending on the quantity and quality of the manure types applied to the systems (Fliebbach et al, 2007). Even though the dynamic soil quality was studied in a replicated field trial comprised of organic and conventional farming systems applicability of the results were not confirmed by in typical Swiss farming systems.

3.3 *Studies in Pacific region*

Investigation of the change in dynamic soil quality aroused from altering natural vegetation into pastoral farms as pastoral farms can also be considered as an agricultural land use and of its intensive land management practices. A study conducted by Ghani et al. in 1996, to monitor spatial and temporal variability of dynamic soil quality in pastoral farms in New Zealand, recorded higher soil nutrient status; (Phosphorus, NO_3^- and NH_4^+) on dairy farms compared to the sheep-beef farms, as expected, due to higher input of nutrients. Soil pH was also higher in the dairy farms, but Olsen Phosphorus values were significantly higher in dairy farms, which were about 60-70% increase, however, total Carbon and Nitrogen values were significantly higher in sheep-beef farms (Ghani et al., 1996). Conversely, another study conducted to analyse the soil conditions in long term forests and wetlands, with minimal anthropogenic activities on vegetation, in Waikato Region of New Zealand, found that even though pH and total Carbon met the referenced standards Olsen Phosphorus did not conform with the referenced values (Taylor et al, 2010). Therefore, Taylor et al (2010) questioned how these soils were non desirable as they are in their natural condition and supported native vegetation successfully for centuries. It was suggested that low Phosphorus values may be due

to natural low Phosphorus values in the New Zealand soils.

3.4 *Studies in Asian region*

Similar to African and European regions, studies have been conducted in Asian region to analyse the influence between different land uses and dynamic soil quality. Such study in Loess, China found that restoration of degraded lands has a significant effect on soil properties and nutrients. Further, dynamic soil quality under different studied land uses in descending order was native forest, restored forest, grassland, and slope farmland. Even though the soil quality did not surpass the local climax vegetation, restored forest land for 30 years had improved the quality compared to other land uses. Thus, confirming the importance of vegetation restoration in improving soil quality and impact of severe vegetation destruction entailed with land management approach (Wang et al, 2012).

Another study conducted in Upper Harpan Sub-watershed of Nepal, has shown that the effect of land uses on dynamic soil quality indicators such as pH, Organic Matter, Total Nitrogen, Available Phosphorus and Available Potassium was significant. Further, it was observed that all land uses studied; rain-fed cultivations irrigated rice cultivations and Forest, had medium levels of Soil Organic Matter content and high levels of Total Nitrogen. Lower levels of Available Phosphorus and Available Potassium along with higher amount of Soil Organic Matter content were observed in the forests, comparatively. However, rain-fed cultivations had comparatively higher Soil Organic Matter content compared to that of irrigated rice cultivations. Available Phosphorus increased in order of land uses from forests, irrigated rice cultivations, and to rain-fed cultivations. Similarly, Available Potassium showed high levels in rain-fed cultivations while medium levels in both irrigated rice cultivations and forests (Chhetri, 2007). Since the irrigated rice cultivations were the more human stimulated land use compared to the other two land uses studied, this observation agrees with the statement given by Oldeman et al., in 1990, estimating about 40% of agricultural lands are affected by human induced land degradation.

According to Shrestha et al. (2008) changes in the land use, from forest to rain-fed and irrigated cultivation, may significantly affect not only the quantity but also the quality of the Soil Organic Matter. As Soil Organic Matter plays a major role in retaining soil nutrients and water, if it not retained in soils the fertilizer efficiency will also decrease (Mapa, 2003). Further, it was found that the liable Carbon pool was higher in the un-managed temperate forests and the irrigated cultivated lands than sub-tropical managed forests and rain-fed upland cultivated areas. It was noted that recently reclaimed soil contained less labile Carbon than the historically cultivated soil and liable Carbon was higher in irrigated cultivated areas than rain-fed cultivated areas. However, the study was only focused on the effect of land use change has on quality of Soil Organic Matter and soils were sampled from three cultivated areas and two forests in a mid-hill mountain watershed of Nepal.

4 SRI LANKAN LITERATURE

Although studies have been conducted in Sri Lanka to analyse the impact of land uses on the dynamic soil quality it can be considered as limited compared to the other regions of the world.

Wanniarachhi and Shyamalee (2005) evaluated indicators to assess dynamic soil quality of agricultural lands, in Matara District which belongs to the Low country Wet zone agro ecological region, under six different land uses; Mahogany woodlot, grass, legume, Coconut, Cinnamon and vegetable. The study showed that land management had a significant overall effect on the dynamic soil quality. In addition, it was observed that bulk density and Soil Organic Matter were robust indicators for evaluating soil quality of agricultural lands. Further, they state that plant nutrient levels, such as Nitrogen, Phosphorus, and Potassium are not ideal indicators for evaluating soil bio-chemical quality of agricultural lands as the levels can mask inferior quality by the application of fertilizers. Additionally, Wanniarachchi and Seneviratne (2003), evaluated the influence of land use on seasonal variation of soil inorganic Nitrogen, in an Ultisol in Low country Wet zone of Sri Lanka, using five contrasting land uses; Mahogany forested area, grass, legume, Cinnamon and vegetable cropland. Highest inorganic Nitrogen of 39 mgN/kg was recorded on average in forested areas, while other land uses showed around 25 mgN/kg. Vegetable fields showed higher average of Nitrate compared to other land uses while results revealed that inorganic Nitrogen in soil was highly variable and Ammonium levels were higher than Nitrate levels at any given time.

Another study on spatial variability of soil chemical and physical parameters in a land use gradient around the Bellanwila-Attidiya wetland Sanctuary indicated apparent variations in distribution of soil chemical and physical properties in surface soil samples. Similar to other studies, the highest levels of Nitrate, pH and Electrical Conductivity were observed in industrial areas

while higher levels of Phosphorus were observed in paddy lands in surface soils (Cooray et al., 2012).These findings further reveal the wide-scale alternation of surface soil properties due to increases in anthropogenic pressures.

Gagaweera et al (2005) conducted a short term field experiment in Matara District of Sri Lanka to study the effect of different vegetation cover on dynamic soil fertility, observed higher pH values in grass-covered soil and mild acidic conditions in mixed cultivations, vegetable, bare land and cover crops grown with Rubber. Observed results show that human interventions such as application of chemical fertilizers affect the soil characteristics, since lowest Soil Organic Matter and Nitrogen percentages were recorded in vegetation plots. However, highest Soil Organic Matter and Nitrogen percentages were recorded in mixed cultivations. Since the study was conducted on a farm with controlled conditions and treatments, the applicability of this result in generalized actual situations is debatable to a certain extent. However, these findings can be used as a guide to study the trend in actual situations.

5 CONCLUSION

Available literature indicated that there is a substantial impact of land use on soil dynamic quality. Significant reduction of Soil Organic Matter content was observed in most studies with the intensive alteration of land uses such as intensive cultivations. Nutrient concentrations such as Nitrogen and Phosphorus were also significantly deviated from the natural vegetation land use compared to that of other land uses. Also, the trends shown were parallel in all regions.

When reviewing currently available literature on dynamic soil quality and influence of land use pattern on dynamic soil quality, it is clearly understandable that most of the studies on soil quality have focused on temperate regions and hence these data should be used cautiously, as such these are only validated for temperate soils. There is scant information on dynamic soil quality in the tropics. It was also seen that some of the studies have evaluated dynamic soil quality under replicated and controlled field conditions.

Although there are data available on alteration of soil properties due to land use changes in other regions of the world, limited information is available in Sri Lanka. Therefore it is utmost important to fill the existing information gap to measure the effect of land use pattern on dynamic soil quality which could be utilized in planning and management of the land resource.

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