Soil properties in forest-grassland ecotone: The case of Shola-grasslands in the Palni Hills

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Introduction

The Western Ghats, in peninsular India, are mostly covered by forests and grasslands (Matthew 1999). They are exposed to many anthropogenic disturbances such as fire, deforestation, cultivation, and grazing (Davidar et al. 2007, Pemadasa 1990), which have led to subsequent deterioration of soil quality (Campos et al. 2007, Islam and Weil 2000). As change in vegetation corresponds to change in the physical, chemical, and biological properties of soil (Campos et al. 2007, Jenny 1941, and Major 1951), these disturbances do not only directly impact and maintain vegetation forms like grasslands (Davidar et al. 2007, Pemadasa 1990) but also determine vegetation formations indirectly by changing soil features.

Change of vegetation can alter sustainable ecosystem functioning by altering key processes, such as nutrient cycling and soil organic matter (SOM) development (Aceves and Oliva 2008, Johnson and Wedin 1997, Meyer and Turner 1992). Thus, understanding these changes is important (Rapport et al. 1997, Soyza et al. 1997).

This study aims at identifying and understanding the pattern of change in the physical and chemical properties of soil with changing vegetation, from forests to grasslands. The study site is located in the Palni Hills of peninsular India. The studied vegetation zones include grassland interior, grassland close to grassland-forest ecotone, grassland-forest ecotone, forest close to grassland-forest ecotone, and forest interior; the forests are locally called *Sholas* [for further details on the study area, see Juyal et al. in this proceedings and for methodology and plant communities Juyal and Schmerbeck (this proceedings)].

The effects of fire on soil

Fire alters the physical and chemical properties of soils significantly (Moore 1960). The prominent physical change is the reduction of soil moisture. When fire consumes vegetation and underlying litter layers, hydrophobic or water-repellent soil conditions can form which increase surface runoff and erosion (Shakesby 2011, Shakesby et al. 2007). Fire also acts as a rapid mineralizing agent that eventually decreases nutrient concentration by increased volatilization or leaching, erosion, and run-off (Smith 1970).

Geology and soils of the study area

The lithology of Palni Hills is mainly Charnockite, a bluish granite. The soil texture varies from clay to clay-loam and is also classified as red soil due to the high percentage of iron and alumina (Chatterji 1957). The soils are acidic (pH 4.25–6.6), low in other bases and show signs of leaching. The accumulation of humus in the top layers gives the soil a black colour. Grasslands generally have shallow topsoil whereas under forests they are characterized by great depth (Meher-Homji 1967, Matthew 1999).

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Materials and Methods

The soil samples were collected from the centre of same vegetation square plots (5m × 5m) as installed by Juyal (see this proceedings: uyal and Schmerbeck (Abstract), using a soil profiler.

The depth of various humus horizons — L, Of, Oh, and soil horizons — A, B, and C were recorded using the engraved scale markings on the soil profiler. The humus form was recorded as per visual observations and soil texture tested by the finger (feel) method with reference to the soil texture triangle (Caspari and Schack- Kirchner 2008) A pH metre was used for recording soil pH. The concentrations of soil organic Carbon and available Nitrogen, Phosphorous, and Potassium were tested by the Walkley-Black, Alkaline permanganate, Bray and Kurtz P-1, and Ammonium acetate extraction methods, respectively.

The significance of difference between different vegetation zones for depth of humus and soil horizons, and concentrations of C, N and P was tested by ANOVA (Tukey's test) and for concentration of K by Mann-Whitney-U test. Pearson's correlation was performed to relate coverage of different vegetation layers (grass, her, shrub, tree, and total cover) to trends of C, N, P, and K concentrations. The best indicator for soil quality change was selected by carrying out a cluster analysis (distance measure: Euclidean and group linkage method- Ward's method) between each soil nutrient and the five types of vegetation zones.

Results and Discussion

Soil depth and texture

The mean depths (in cm) of Of and Oh humus horizons and A and B soil horizons varied significantly in the following trend: grassland > ecotone>Shola ($p<0.05$).The soil texture of the A horizon for the sites varied mainly between loam (38%) and clay loam (42%) (Figure 1). The lack of a canopy cover and removal of ground vegetation in grasslands exposes them to erosion and surface run off due to which finer soil particles are washed away (Smith 1970, Gillon 1983).

Soil pH

The soil pH varied from 2.7–3.5, with grassland soil having a higher value than forest soil. This is mainly due to the higher concentration of the soluble salts and nutrients deposited in the ash (Kim et al. 1999, Smith 1970, Campos et al. 2007).

Soil Organic Carbon

Soil Organic Carbon (SOC) increased significantly from grassland to Shola (Figure 2A). The results are concurrent with many other studies (Jose et al. 1994, Johnson and Wedin 1997, Picone et al.

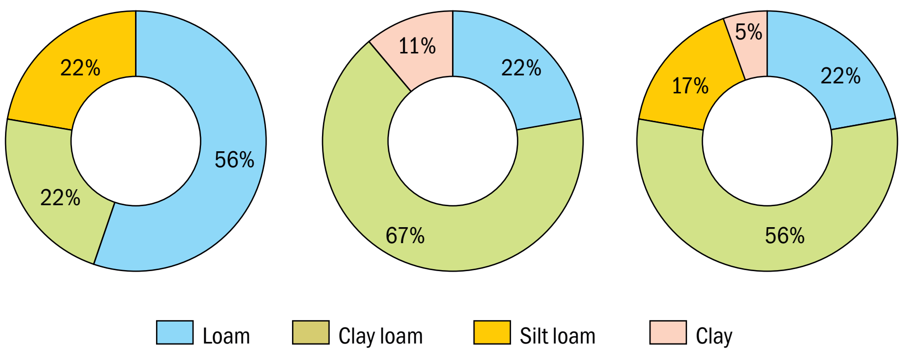

Figure 1: Percentage composition of different soil texture types for the three main vegetation zones: grassland, ecotone, Shola

2003, Cheng et al. 2013). This is attributed to lesser inputs and faster decomposition of organic matter in grasslands.

Available Nitrogen

Available N increased significantly from grassland to Shola (Figure 2B). Similar results have been observed by many other studies (Jose et al. 1994, Lundgren and Lundgren 1972). Nitrogen is easily volatized and lost to ash convection (Kim et al. 1999, Johnson and Wedin 1997) as well as erosion and run-off (Cheng et al. 2013, Kim et al. 1999). Higher forest litter quality and productivity in the forest also leads to greater N inputs in forest soil (Steinaker and Wilson 2005). Kochy and Wilson (2005) relate lower availabe N to grazing. Taller vegetation and canopy edges in ecotone forest increase the rate of N deposition to the ecosystem by filtering the air and reducing wind speed (Kochy and Wilson 2005).

Available Phosphorous and available Potassium

The concentration of available P and K increased from grassland to Shola (Figures 2C and 2D). However, the differences were significant only for available K. Similar findings have been reported by (Johnson and Wedin 1997, Aceves and Oliva 2008, Jose et al. 1994). The prime reasons for decrease are easy volatility at considerably low temperatures (Johnson and Wedin 1997, Kim et al. 1999) and higher rate of leaching after fire (Smith 1970). Solubility of P in soil decreases after fire due to its precipitation with iron and aluminum (Smith 1970). K mobility is also linked to soil texture, with the greatest K accumulation in clay followed by loam and sand (Seiffert et al. 1995).

Correlation of soil chemical properties and vegetation cover

Vegetation cover of life forms showed some significant correlations with soil nutrient concentrations (Table 1). The most striking correlation was observed for reduction in available N with increasing grass and herb cover, which can be attributed to the loss of N during fire events. On the other hand, tree cover — an indication of the long absence of fire — has a positive effect on N availability and accumulation of SOC.

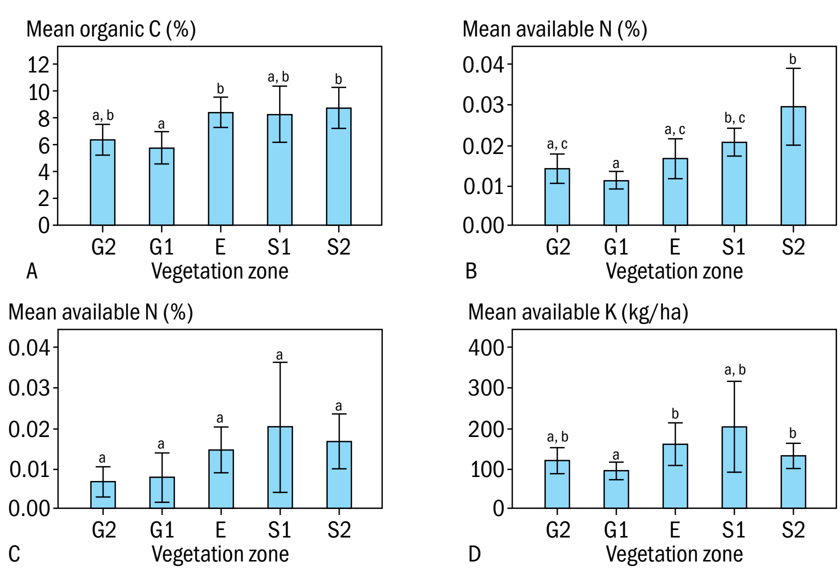

Figure 2: Comparison of (A) mean org. C (%), (B) mean avlb. N (%), (C) mean avlb. P (mg/kg), and (D) mean avlb. K (kg/ha) for the different vegetation zones: Grassland, ecotone, and Shola (At 95% confidence interval. one-way ANOVA – Tukey's test was used for C, N, and P, and Mann-Whitney-U test for K)

Table 1: Correlation matrix for vegetation cover and soil nutrient concentration (at 95% Confidence interval)

Cover of	SOC	Avlb. N	Avlb. P	Avlb. K
Grass	-0.361	-0.393*	-0.352	0
Herb	0	-0.521*	0	0
Shrub	+0.333	0	0	0
Tree	+0.433*	+0.619*	+0.336	0

Note: The values indicate the magnitude of Pearson's correlation coefficient and the sign indicates the nature of correlation, 0 indicates no correlation (*99% confidence interval)

Conclusion

We detected a clear difference in soil quality and nutrient stock amongst the different vegetation zones of the grassland-Shola edge, even though not all the differences were significant. The soil depth and texture indicate a high surface transport of material leading to a leaching of soil and nutrients out of the ecosystem. The lesser soil depth of the grasslands and the relative low content of nutrients in the grasslands seem to support this statement. However, taking the type and number of plant species unique for the grasslands into account, it is up to decision-makers to decide on the type of land use and to deal with the trade-offs associated with it (erosion and loss of nutrient or maintenance of plant communities). Such a decision will include the regulation of land use, especially burning of grassland, which is likely to be the driving force behind the maintenance of grasslands (see Juyal et al.).

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