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Evaluation of physicochemical and vegetative properties of soils under different exotic and indigenous tree species cover comparing to adjacent rangeland, Lesotho

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Abstract

Soil characteristics evaluation under different vegetative cover was conducted on Maliele north and south facing forest soils with 20 different plant species cover. Soil samples were taken from 0-15cm depth of each plot and various parameters: texture, water holding capacity, bulk density, soil porosity, organic carbon, nitrogen, available phosphorus and exchangeable potassium, magnesium and calcium contents were determined. Results revealed that soils are characteristically dominated by sands with low clay and organic matter contents. The Eucalyptus vegetative cover showed very low pH (4.12) compared to other species canopy cover. Significant differences ($p<0.05$) in vegetation cover was observed. Litter was found to be dominated under *Pinus radiate* and Indigenous canopy, while *Eucalyptus rubida* was dominated in Bare and Rock lands of both sites. Complete (100%) cover of plant species was seen in both sites under Indigenous canopy cover followed by Range land in both sites. Unlike the north site of Maliele, the southern site Ecualyptus canopy cover shown high diversity (100%) of plant species at various pattern of growth rate which is also be affected by soil pH. For habitat restoration and come back of animal life, evaluation of forest vegetation by introducing more indigenous tree species is important. We therefore commend to conduct a follow up research on relatively degraded and poorly managed forest sites covering more to develop better forest management practices in Lesotho.

Keywords: Indigenous Forest; Precipitation; Soil Property; Vegetative Property; Exotic Forest Species

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1. Introduction

The vegetation cover of an area has paramount importance in the processes associated with pedogenesis that determine soil properties (Mead and Cornfort, 1995; Noble et al., 2002). Other factors such as soil depth, texture, drainage and moisture storage have also known to determine plant growth because they influence moisture and nutrients of the soil (Mead, 2013). Unlike, the concentration of certain elements such as phosphorus (P) and nitrogen (N) and/or, alternatively, the C: N ratio in the soil, exchangeable cations are generally less important (Mead, 2013).

Conversion of rangelands into exotic forest plantations increased land use change significantly since the beginning of the government forest reserves or woodlots in the 1980s in Lesotho. The transition from rangeland to forest plantations conserves the carbon sequestration capacity as aspects of both land uses in maintained. The degree of extend to carbon sequestration has not been documented in Lesotho. However, there are relatively few studies of changes in soil properties when improved pasture is converted to *Pinus radiate* (Giddens et al., 1997). Trees are planted in large numbers in Lesotho and they are mostly grown on rangelands which in turn influence the improvement of physical properties of the soil. However, no studies have been conducted and/or published on the effect of tree plantations on soil and vegetative properties. It is generally acknowledged that forest soils in comparison to other soils are characterized by the presence of litter with an associated unique micro-flora and fauna.

In Lesotho, though trees are mostly used for provision of fuel wood, the importance of trees is not limited to their energy functions but also play a vital role in climate change mitigation, environmental protection, preventing soil erosion, stabilizing soil, controlling water runoff in catchment areas. Farmers have long recognized that soil properties vary significantly under different forest types based on differences in nutrient uptake, litter quality and growth. Furthermore, computer simulation models that include the effects of soil quality support expectations that species should have strong influences on the dynamics of soil carbon and nitrogen (Mead and Cornforth, 1995).

In Lesotho, large numbers of trees are planted mostly on rangelands. However, land reclamation program in watersheds, have shown controversy about the effect of certain forest species specially Eucalyptus and to some degree Pinus species on vegetative and soil properties on the rangelands. Therefore, there is critical need to scientifically evaluate the perceptions in terms of quantifying soil and vegetative properties in different forest plantation compared to adjacent rangelands, In this study, the impact of exotic forest species: *Pinus radiata*, *Eucalyptus rubida*, *Poplars caneses* on soil and vegetative properties of Lesotho compared with indigenous forest *Leucosidea sericea* and *Rhamnus prinoides* species. This will help for plant restoration that may be helpful for the comeback of animal species associated with the native flora when the ecosystem is recovered to a more natural state.

2. Materials and methods

2.1. Location of the study area

The study was conducted at two catchments near the village of Boinyatso Maliele both on the south and north site on existing exotic forest plantations and indigenous species. The area is approximately 34km from Maseru at the elevation of 1701 masl. The exotic forest were assumed to have been planted in the late 1970 to 1980, it is an unprotected forest however cutting the trees is under the local chiefs supervision.

2.2. The experimental design and sampling strategy

The experimental design was a completely randomized block design with two locations /blocks (Maliele north site and Maliele south site) and forest cover with five types: *Pinus Radiata*, *Eucalyptus rubina*, *Poplars caneses,* a mixed indigenous forest of *Leucosidea sericea and Rhamnus prinoides spp.* and adjacent rangelands.

Five sampling sites were selected on contrasting forest species on the north and south aspects in order to assess the impact on soil properties. Samples were taken in two different locations on south facing slopes in the north and south of the Maliele village respectively. Adjacent areas under indigenous forest and rangeland with matching soils, aspect, and slope were sampled. Thus soil samples were collected under *Pinus radiate, Eucalyptus rubida, Poplars caneses*, indigenous (*Leucosidea sericea and Rhamnus prinoides*) *forest* ecosystems and adjacent rangeland ecosystems.

The samples were taken in four replicates at 0-15 cm depths intervals from three representative areas (10 m by 10 m size) at each forest and pasture site. Under forested sections, the samples were taken at least 1.5 m from the nearest tree. Samples under rangeland were collected at least 40 m from the nearest tree if any. Equal weights of the four field replicates were composited, and the bulked samples were air-dried and sifted through a 2 mm sieve.

2.3. Determination of soil properties

2.3.1. Soil chemical properties

To test the soil reaction, soil pH measurement were made with an electrometric method in water and1N KCL. Total organic C was determined by using Mebius method of Nelson and Sommers (1982), which involves digestion of the soil sample with an acidified dichromate solution and estimation of the un-reacted dichromate by titration of the cooled digest with an acidified solution of ferrous ammonium sulfate with use of an acid indicator.

Basic exchangeable cations (K, Ca, Mg) were determined by atomic absorption spectrometry of the make Spectro AA 300 after replacement with NH_4OA_c, (Gillman and Sumpter, 1986). Inorganic N was estimated in the form of ammonium using the Incubation procedure for nitrogen mineralization and Indophenol Blue Method, while available P was determined according to Bray and Kurtz no. 1 extraction with 0.03M NH_4F and 0.025M HCl.

2.3.2. Soil physical properties

2.3.2.1. Dry bulk density

The values were obtained using the clod method by obtaining a large size aggregate that has been oven dried, then weighed and tied with a piece of thread around the aggregate in a way that it can be suspended from retort stand. Then immense the aggregate into the melted paraffin wax in order to coat the samples in such a way that the coating around the sample was as thin as possible and allow it to cool. Thereafter the samples were weighed again and recorded, and then we took a 500ml beaker and filled it half way with distilled water, place it on the measuring scale and weigh it. Suspend the coated sample from the retort stand and immerse it into the water and then recorded the weight. Four replicates were analyzed from each forest and rangeland sites. Significant differences between treatments were determined using analysis of variance and mean comparison tests.

2.3.2.2. Porosity

Soil porosity was determined using the method described by Lipiec, *et al* (2006) using the equation $ƒ=1-\frac{\rho_b}{\rho_s}$ where ρ_s is particle density assumed as 2.65 g/ cm^{3}and ρ_b is bulk density.

2.3.2.3. Soil Texture and Color

The soil samples were also tested for soil texture where the study employed the hydrometer method as described by Blake and Hartge (1986) and the textural class derived from the textural triangle. Soil color was determined by using the standard color charts known as "Muncell Color Chart". The color of the soil sample was determined by comparing it to the color chips of the chart which is represented by three numbers expressed as hue, value and chroma of the color.

2.3.3. Vegetative characteristics

To determine vegetative cover, the quartet method (1m*1m) was used and samples were taken by counting all individuals within the area and rating them with a coded system out of ten where one was assumed to be 10 percent cover and ten was 100 percent cover based on the soil property and forest cover at each location as depicted in Table 1.

Table1. Background soil properties for each location and Forest Cover

Forest Cover Type	Study Location Soil Property			
	Maliele North		Maliele South	
	Texture	Colour	Texture	Colour
Indigenous	Sandy loam	2.5 YR 2.5/2	Sandy loam	10 YR 4/4
E. rubida	Sandy loam	2.5 YR 3/2	Sandy loam	7.5 YR 4/3
P. radiate	Sandy loam	2.5 YR 4/3	Sandy loam	2.5 YR 3/4
P. canenses	Sandy loam	5 YR 3/1	Sandy loam	7.5 YR 2.5/1
Rangeland	Sandy loam	2.5 YR 3/3	Sand loam	2.5 YR 3/3

3. Results and discussion

3.1. Vegetative cover

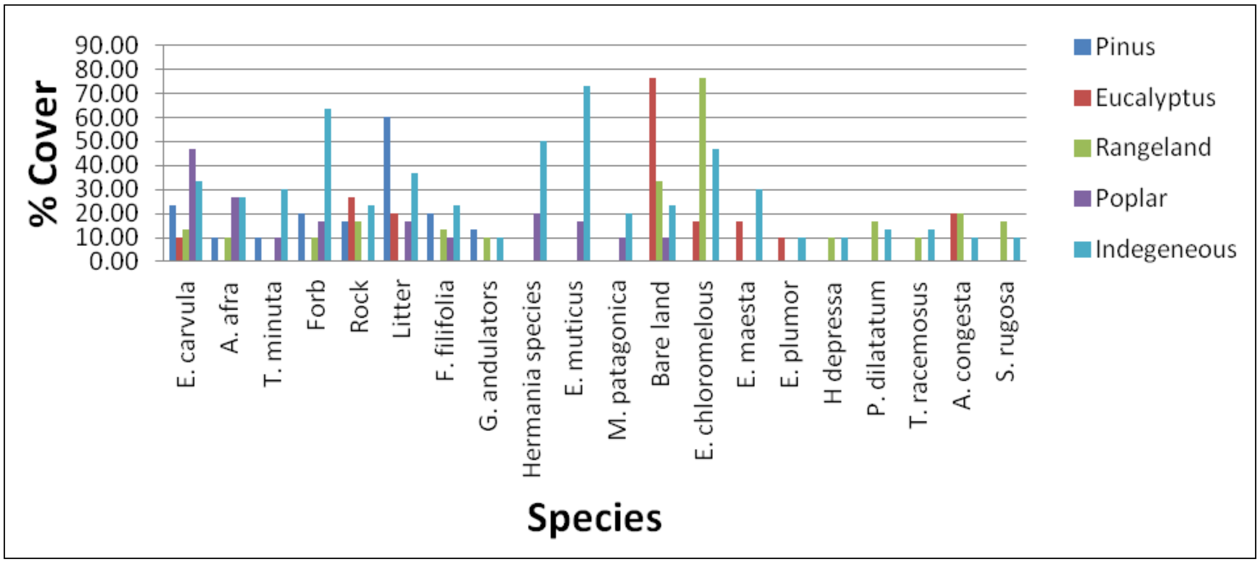

Figure 1. Vegetative cover at Maliele north site

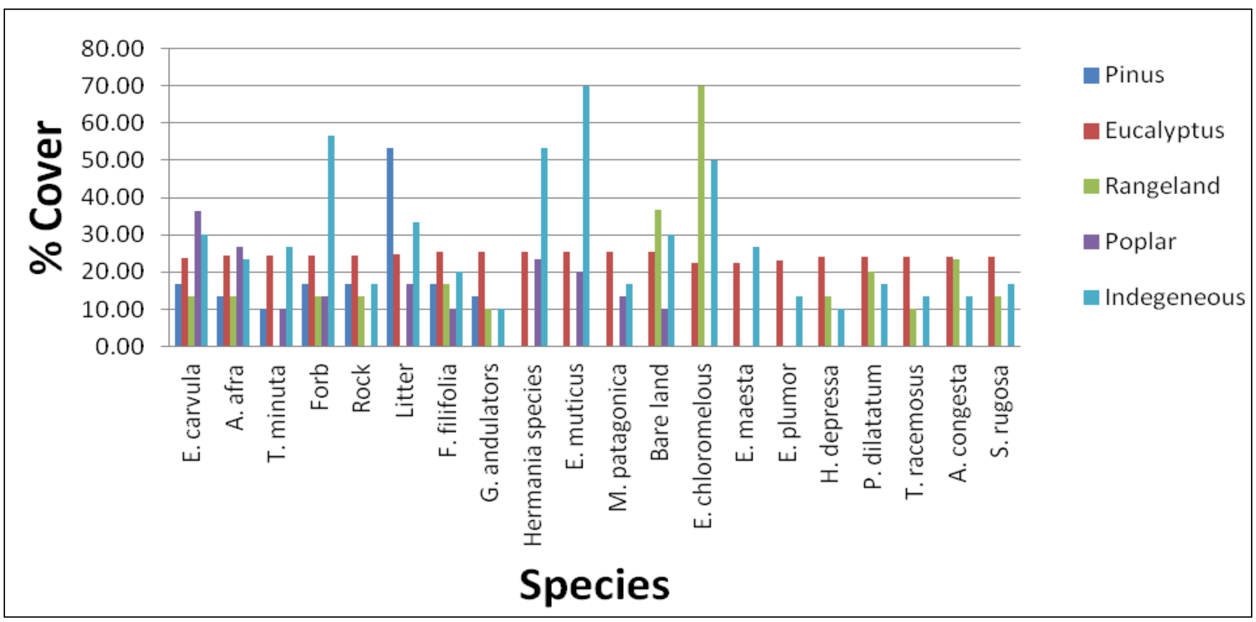

Figure 2. Vegetative cover at Maliele south site

The vegetative cover in the Maliele north and south sites with under story cover have shown to be (10-76%) and (10-70%), respectively (Figure 1 and 2). There is significant difference (P< 0.05) on the growth pattern of 20 different species of plants grown under *Pinus, Eucalyptus*, *Rangeland*, *Popular* and Indigenous tree canopies (Figure 1 and 2). In both areas under *Pinus radiate,* the most dominant cover was litter followed by *Eragrostis carvula*. On the other hand, under Eucalyptus stand, the bare land was more dominant than all others followed by the rock land. In rangelands, the most dominant species was *Eragrostis chloromelous* followed by the bare land. Under poplar stand, the most dominant species was *Eragrostis curvula* and litter, while indigenous stands were dominated by *Elionorus muticus* followed by forbs and others species (Figure 1). The decrease in diversity of plant species under story cover indicates the poor vegetation and less plant productivity of the area (Xiong et al., 2003). The indigenous stands, shown significant vegetative cover (P< 0.05) with diversity and competence in both sites.

3.2. Soil reaction

Soil pH in water was generally high (> 5) regardless of location, while pH in KCL was > 5 under Indigenous, *Pinus* and Rangelands in Maliele north (Figure 3). In the south, pH was more acidic (≤ 5) under all canopies except under poplar species where the mean pH is 5.44. The availability of plant nutrients is considerably affected by soil pH. Acidic soil reaction conditions are associated with comparatively fewer basic cations (calcium (Ca), K and Mg) on the soil exchange complex due to increased activity of acidic cations (Aluminum and iron) in the soil solution (Sparks, 2003; Xiong et al., 2003). The basic cations are then leached out. In this study, the lowest pH levels were observed under Eucalyptus and Pinus species (Figure 3) and this could be associated with the type of plant exudates released by the plant roots. At this ranges, the presence of exchangeable trivalent aluminum is encountered and consequently exchangeable aluminum is immobilized instead the soil solution is dominated by a complex mixture of hydroxyl aluminum ions (Sparks, 1984; Xiong et al., 2003).

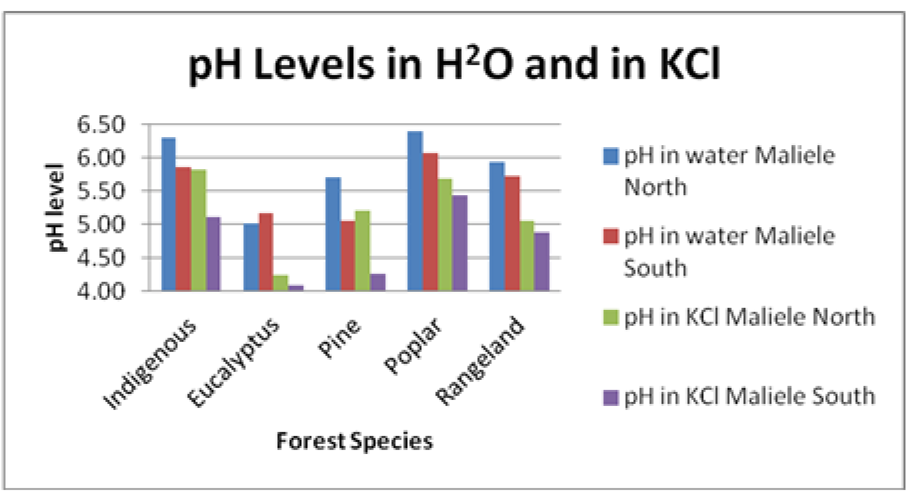

Figure 3. PH measurements at Maliele north and south sites in H_2O and KCl

3.2.1. Bulk Density

Soil bulk density ranged from 1.23 to 1.44 g cm^{-3} with a mean of 1.34 g cm^{-3}. All the species in the north site showed low density values that do not restrict the root growth. In contract, bulk density measurements in Maliele south ranged from 1.51 to 1.67g cm^{-3} with a mean of 1.59 g cm^{-3}. In the south higher values were observed across all forest covers (Fig. 4).

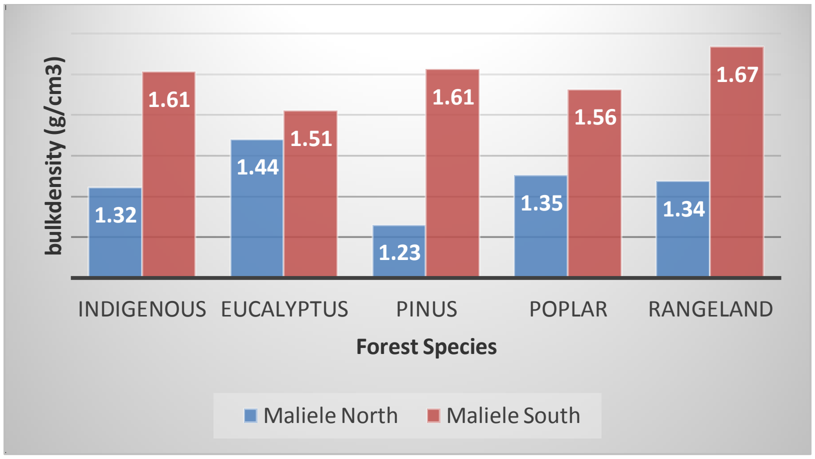

Figure 4. Bulk density measurements in the study sites

3.2.2. Soil porosity

The soil porosity measurements were consistent with the observed bulk densities (Fig. 5) where much lower porosity was observed. For the northern site porosity range is 46 – 54 with a mean of 50% while in the southern site porosity ranges 37 to 43 % with a mean 40. When bulk density is increased from 1.3 to 1.5g/cm^3, porosity decreases from 50% to 43% (USDA, 2008).

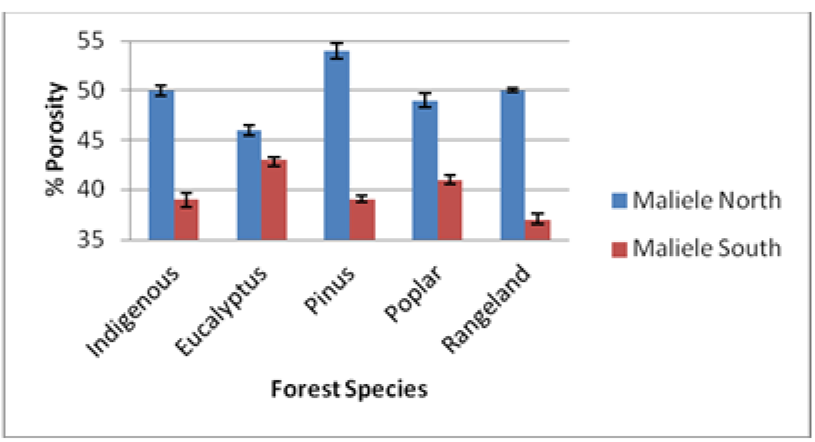

Figure 5. Percentage porosity values at the study sites

3.2.3. Organic carbon

Organic carbon level range from 24 to 38 % across both study sites. The highest OC was observed under rangeland and lowest under Eucalyptus in South Maliele and in the north, the highest was under poplar and lowest under Eucalyptus. The OC level is 32% in the south site compared to 26 % in the north site.

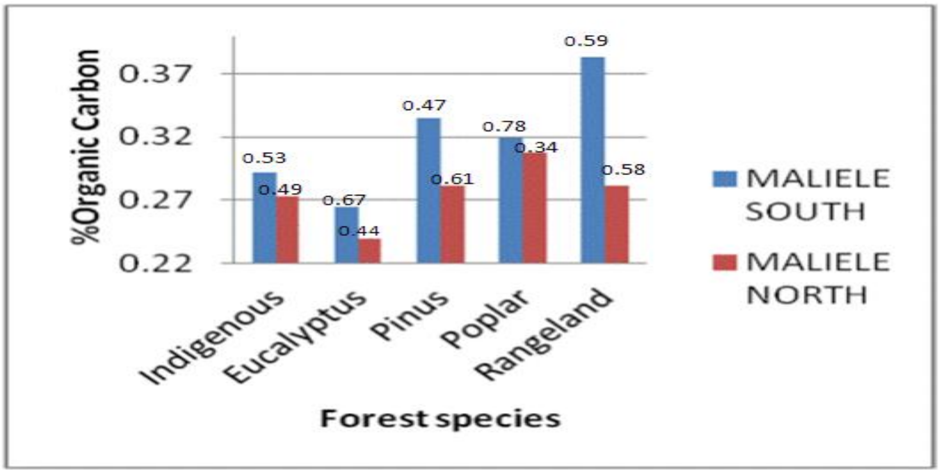

Figure 6. Percentage Organic Carbon at Maliele south and north study sites

4. Conclusions

The study shows apparent difference between the different forest covers. *Pinus* and *Eucalyptus* species seem to have negative effects on soil and vegetative properties in both sites (North and South parts of Maliele), although there was no clear background of these areas. The Forest species clearly have different effect on the soil; they show difference in nutrient pool sizes, nutrient supply and acidity. However, no study has shown that any species uniformly pushes all soil variables in unfavorable directions. Because of lack of evidence of substantial soil degradation by species, this issue remains a viable hypothesis that should receive more testing.

5. Recommendation

In this study, the rate of growth under varying levels of canopy cover, and soil type has been studied. This baseline information will raise a case for re-consideration of which species to plant and for what purposes with the hope that this monitoring can contribute to the decision making process. We recommend exploration of useful tree species such as *Populus* spp., *Artemisia afra*, and *Leucosidea sericea* and a potential shift to sustainable forest management with agroforestry plantations including fruit trees, such as *Mulas domestica* (Apples), *Prunus persica* (peach), *Prunus armenia* (apricots), *Pyrus avium* (pears), *Prunus amygdalus* (Almonds) and *Prunus domestica* (plums). Future studies must follow up on relatively degraded and poorly managed forests covering more sites to develop better and sustainable forest management practices including use of different dryland bamboo species as alternatives to conventional forest species.

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