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INVESTIGATION OF EFFECT OF *ALNUS ACUMINATA* TREE SPECIES ON SOIL BIOCHEMICAL PROPERTIES IN SILVOPASTURE AROUND GISHWATI FOREST WESTERN RWANDA

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ABSTRACT

This research examined the effect of landscape restoration on ecosystem functioning using forestry around Gishwati natural forest in western Province of Rwanda. It specifically examined changes in soil-litter arthropods and soil chemical properties in silvopastoral landscapes dominated by Alnus acuminata tree species planted by Landscape Approach to Forest Restoration and Conservation project. Data were collected in the sites dominated by Alnus acuminata and in control sites dominated by Desmodium intortum (Greenleaf desmodium), Pennisetum clandestinum (Kikuyu grass) and Urtica dioica (stinger/nettle). Leaf-litter arthropods were collected by pitfall traps and hand sampling methods and analysed to the family level using dichotomous keys. Further, soil cores were collected and analysed for soil pH, soil total nitrogen, total phosphorus, soil available phosphorus and soil organic carbon. 1,065 individuals of soil-litter arthropods grouped in 6 orders and 8 families were found in treatment sites, and 864 individuals grouped in 6 orders and 7 families were found in control sites. Higher levels of soil total nitrogen (0.2±0.0%), available phosphorus (11.0±0.9ppm), organic carbon (19.6%) and leaf-litter arthropods (24.6±4) were found in treated plots compared to control sites. The study concluded that Alnus acuminata biomass contributes in maintenance of soil biological and chemical properties, and hence the ecosystem functioning. It is therefore recommended that Alnus acuminata can be a valuable agroforestry tree to plant in pastoral land along with other tree species.

Keyword: Soil quality, soil arthropods, soil ecosystem functioning, *Alnus acuminate*

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INTRODUCTION

Leaf-litter arthropods and soil physicochemical properties are essential for soil fertility and soil ecosystem functioning (Culliney, 2013; Sopsop and Lit, 2015). They have an influence on soil properties mainly soil moisture, soil aeration and soil composition, which are important elements in primary production and decomposition of organic residues (Menta, 2012). Leaf-litter arthropods turn organic nutrients into living biomass that are eaten by consumers, and return them in soil to be used by producers (Hopkins and Gregorich, 2005). Besides soil-litter arthropods, agroforestry activities are appreciated to reduce land degradation (Wolde, 2015). In this regard, livestock and plants are grown together in the same plot (Martínez *et al.*, 2014) with the aim to increase soil productivity through improved soil fertility, and soil biodiversity conservation (Nair, 2011).

Different studies indicated that silvopastoral systems minimize wastes in soil ecosystems, and reduce greenhouse gas emissions (Ibrahim *et al.*, 2010; Martínez *et al.*, 2014). The species of *Alnus acuminata* (genus: Alnus, family: Betulaceae, order: Fagales) (Orwa *et al.*, 2009) is one of tree species used in silvopastoral activities (Sir, Romero, and Hladki, 2015). It is known to have high green biomass, provides shed for livestock, fodder for cattle, supply nutrients for grasses, increase soil nitrogen, soil organic carbon, soil phosphorus and improves soil pH (Fehse *et al.*, 2002).

Alnus acuminata tree species was used in the Landscape Approach to Forest Restoration and Conservation (LAFREC) project to restore the degraded lands around Gishwati-Mukura landscape in Rwanda (Musabyimana, 2014). The landscape was highly affected by human activities from the 1970s to 2002 (USAID, 2008). The historical background of the area indicates that Mukura forest alone has been reduced from 30 km^2 in 1930s to 19.88 km^2 in 2016, while Gishwati has been reduced from 700 km^2 in 1930s to 15.70 km^2 in 2016 (Forest of Hope Association, 2017). High loss of land surface and biodiversity of the area were observed in 1994 due to people displaced during the Genocide against Tutsi in Rwanda (Musabyimana, 2014).

To our knowledge, no any study was done to evaluate the success of restoration activities in the restored Gishwati-Mukura landscape. Specifically, no any study was done to evaluate effects of restoration activities in the pastoral lands focussing on soil quality and soil functioning, specifically leaf-litter arthropods and soil chemical properties to predict sustainable soil biodiversity conservation, land use, and land management. This study aimed at investigating the effects of *Alnus acuminata* tree species on leaf-litter arthropods and soil chemical properties. The specific objective was to evaluate the impact of *Alnus acuminata* on soil pH, soil organic matter, soil total nitrogen, available phosphorus, and soil leaf-litter arthropods in silvopasture of Gishwati-Mukura landscape of Western Rwanda.

MATERIALS AND METHODS

Area of Study

Gishwati-Mukura landscape is a part of Albertine rift, an area rich in biodiversity, some of them being endemic to the area (UNEP, 2014). It is located in Congo-Nile divide region and comprise Rubavu, Nyabihu and Rutsiro Districts in the Northern-Western Rwanda. It is located at the altitude ranging between 2,000 to 3,000 m. The area is characterised by the annual rainfall varying between 1,200 and 1,500 mm (Forest of Hope Association, 2017). Gishwati and Mukura forests were declared Gishwati Mukura National Park by the Law Nº45/2015 of 15/10/2015 (GoR [Government of Rwanda], 2016). The main activities carried around the park are dominated by silvopasture and agriculture practices. Geographically, the silvopasture lands are located between 1.676371°, 1.743492° south, 29.414714°, and 29.425050° east.

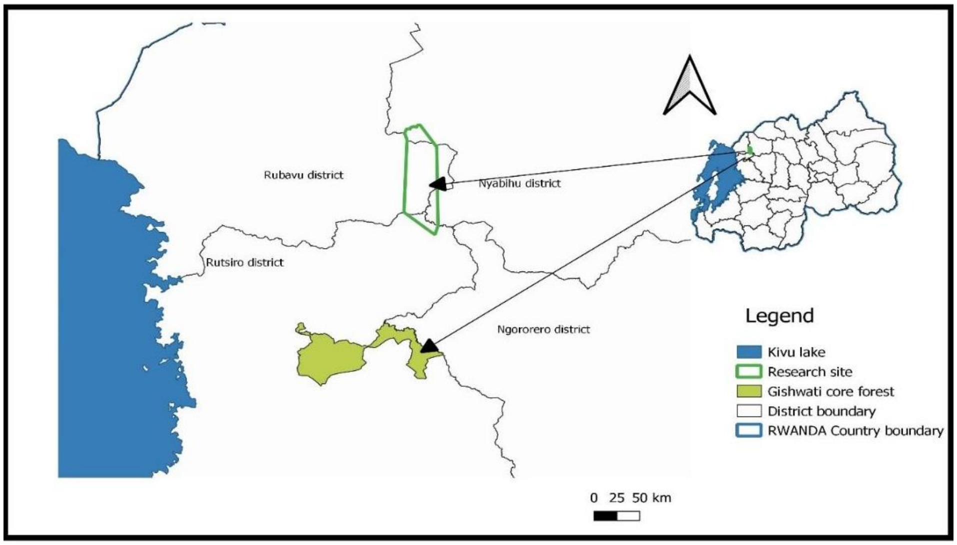

Figure 1 Area of study. The map was generated using the GIS files from field points recorded using GPS receiver and then using QGIS software with google earth pro and google map.

Sampling techniques

Data were collected in silvopasture lands around Gishwati forest (Figure 2), in the sites of Arusha, Yungwe, Nkomane and Busuku located in Nyabihu, Rubavu and Rutsiro Districts (Figure 2). At each site, samples were taken inside (treatments) and outside (control) of the restored lands. The sampling was based on slope gradient, following a line-transect, where each sampling was separated from another by a distance of 20-25 meters. A total of 72 sampling points comprising 36 in treatment and 36 in control sites were randomly selected using sampling quadrats (Dawson and Knowles, 2018). At each sampling point, soil cores were sampled using auger and were put in plastic bags, labelled, and taken to the laboratory of soil analysis located in the College of Agriculture, Animal sciences and Veterinary Medicines (CAVM), University of Rwanda.

Then, soil-litter arthropods were sampled by pitfall traps first, and then by hand sorting (McCravy, 2018). Every pitfall trap contained 75% ethanol to immobilize collected specimens (Nsengimana, 2018), and consisted of a plastic jar of 15 cm in diameter and 15 cm of height. Before collecting soil and litter arthropods using hand sorting, leaf-litter layer was removed, then specimens were captured in one-meter square size ($1m^2$), and put in collecting jars containing 75% ethanol to immobilise them (Moldenke, 1994; Swift and Bignell, 2001). Each sample was labelled and taken to the laboratory of biology, CAVM for analysis.

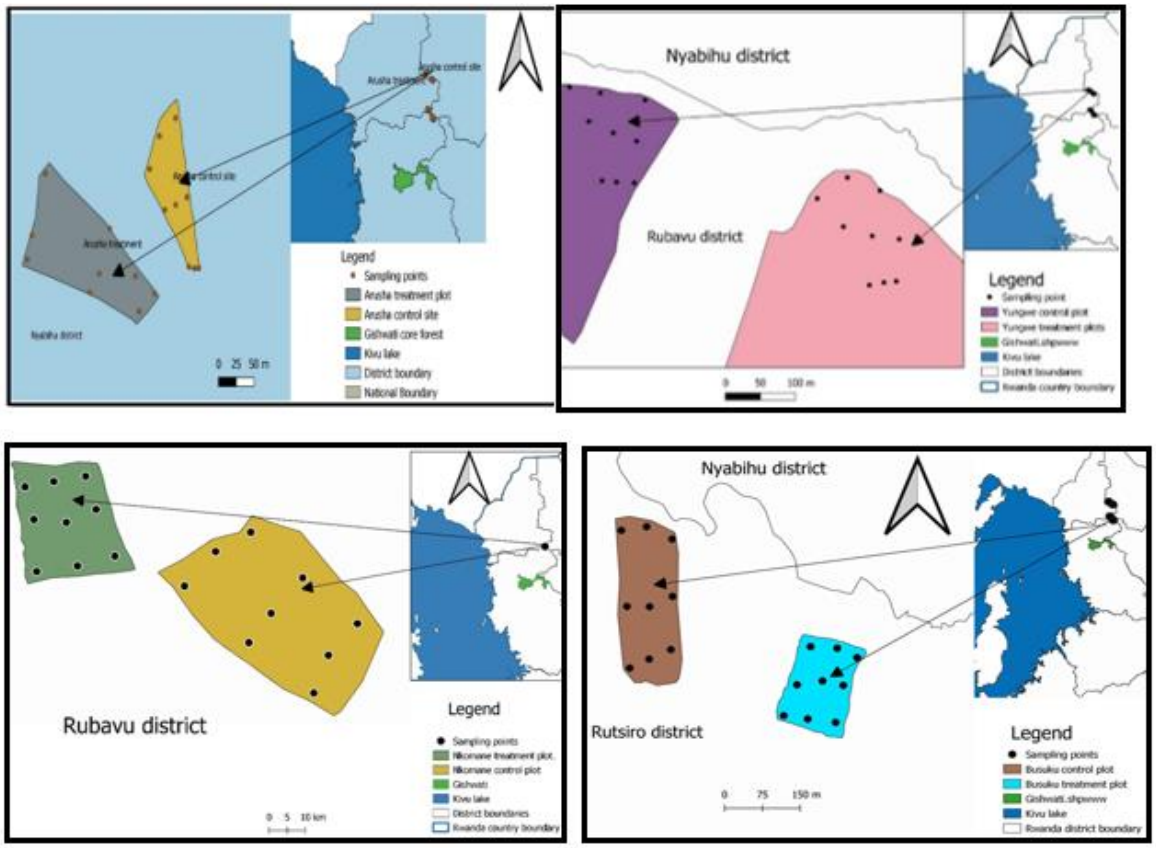

Figure 2. Sampling points at Arusha site (first left side), Yungwe site (first right side), Nkomane site (second left side) and Busuku site (second right side). Arusha site located in Nyabihu district, Bigogwe sector, Arusha cell; Yungwe site and Nkomane locate in Kanama sector of Rubavu district; and Busuku site that is located in Busuku cell, Nyabirasi sector, Rutsiro district.

Data analysis

Laboratory analysis

Identification of soil chemical properties

Soil samples were air-dried in a well-ventilated area at laboratory by placing soil in a shallow tray and remove all gravels, sandstone and plant roots (Okalebo *et al.*, 2002). Samples were crushed by avoiding smashing soft gravel roots and large organic residues. Additionally, soil samples were sieved through a 0.5 mm and 2 mm sieve-mesh. The two different sieve-mesh were preferred to get soil samples of different sizes to use in the analysis of soil chemical properties.

Soil pH was determined in soil/water medium 2.5 suspension. Then 10 g of soil previously passed in 2 mm sieve was introduced in 25 ml of distilled water for $\mathrm{pH_{water}}$ and another 10 g of soil previously treated by a 2 mm sieve was introduced in 25 ml of KCl for $\mathrm{pH_{KCl}}$, shaken for 30 minutes with a grass load and the soil sample was settled for about 30 minutes. Then after, the pH meter was calibrated using the buffer solutions (pH 4 and pH 7). Soil pH was measured using a calibrated pH meter by inserting the electrode in solution suspension. After the measurement of each soil sample, the obtained pH value was recorded for a comparative statistical analysis.

Soil organic carbon was determined by Walkey Black method (Okalebo *et al.*, 2002) through titration of soil solution of 0.3 g of soil passed in 0.5 mm sieve, 10 ml of dichromate solution 1N (normality), 20 ml of sulphuric acid (98% concentration), 10 ml of phosphoric acid (85% concentration), 2 ml of Barium diphenylamine sulphonate (0.16%), and aqueous potassium dichromate 1N (normality) mixed with 1M (molarity) of ferrous sulphate solution.

Kjeldahl method for digestion and UV colorimeter were used to determine total nitrogen and total phosphorus (Okalebo *et al*., 2002). In this perspective, a solution composed of 0.5 gr of dried soil sieved at 0.5 mm, 1.5 gr of catalyst mixture of potassium sulphate (100 gr K_2SO_4); Iron sulphate (5 gr $FeSO_4$); copper sulphate (10 gr $CuSO_4$) and selenium (1 gr Se), and Sulphuric acid (20 ml H_2SO_4 98% concentrated) were mineralized at 300 °C for 2 hours until a green colour appears. After, it was poured in a cool and transverse volumetric flask of 100 ml, then filled to 50 ml with distilled water. Thereafter, the solution (entire digest and blanks) was diluted with distilled water to a ratio of 1:9 (v/v) to match the standards, then 5.0 ml of the reagent N_1, vortex and 5.0 ml reagent N_2 and vortex were added. The mixture was stabilized for 2 hours, and the absorbency was measured at 650 nm. The blue colour is stable for at least 10 hours.

The next step consisted of determining the available phosphorus by $Bray_2$ and colorimetric method, where a soil solution of 2.50 g of air-dried soil (2 mm) was mixed with 250 ml of distilled water. To this solution, a volume of 50 ml of the Bray P2 extracting solution was added, and then the mixture was shaken for about 5 minutes. The solution was then filtered through Whatman No.5 folded filter. Thereafter, the colorimeter measurement was done by mixing 10 ml of P standard series solutions, 10 ml of soil extracts and 10 ml of the blanks, 20 ml of distilled water and 5 ml of boric acid (0.8 M) to suppress fluoride interference from the extractant (Baillie *et al*., 1990; Okalebo *et al*., 2002; Swift and Bignell, 2001). To this solution, 10 ml of ascorbic acid reagent was added, and then the volume of 50 ml was marked with distilled water. The solution was shaken and then stabilized for around 1 hour. After the measurement of the intensity of the blue colour at 880 nm using a UV colorimeter was done.

Identification of soil-litter Arthropods

Soil-litter arthropods were morphologically sorted out and classified to orders and families using dichotomous keys (Choate, 2010; Moldenke, 1994).Then after, collected arthropods were classified based on their functional role in the soil, specifically decomposers, soil engineers, litter transformers, influencers of soil porosity and texture through tunnelling, soil ingestion and transport, and gallery construction (Swift and Bignell, 2001). The functional role of soil-litter arthropods also considered nutrient cycles through transport, shredding and digestion of organic matter (Menta *et al.*, 2018). The order and the family were confirmed after doing a comparative study with the specimens collected previously and stored in the centre of excellence of biodiversity and natural resources management, University of Rwanda.

Statistical analysis

The mean and standard deviation (Mean ± SD) were calculated for both soil physicochemical properties and soil-litter arthropods. The means were used for the analysis of variance (ANOVA) to compare variations in treatment and control sampling points. The biological indices, specifically Shannon diversity (H) were calculated to study variations in biodiversity of soil-litter arthropods within and between control and treatment sampling points. All statistical analysis was performed using Microsoft excel tool PAAK (10) and PAST (4.03) software.

RESULTS

Soil chemical properties

Results of this study indicated differences ($P < 0.05$) in soil physico-chemical properties between treatment and control. Higher levels of pH_{water} (6.1 ± 0.3), pH_{KCl} (5.3 ± 0.3), available phosphorus (8.1± 1.0) and SOM (16.1 ± 3.3) were found in soils sampled under treatment compared to soil sampled under control sites were pH water (5.7 ± 0.2); pH KCl (4.9 ± 0.4); available phosphorus (7.2 ± 1.1); and SOM (14.1 ± 2.7), respectively. No significant differences were found in the levels of soil total nitrogen (0.1 ± 0.0) and soil total phosphorus (0.3 ± 0.0) in both treatment and control lands.

Soil litter arthropods

Results showed differences ($P < 0.05$) in soil-litter arthropods. The results under treatment of Arusha and Yungwe sites showed differences (Arusha 0.03, Yungwe 0.02) and those of Nkomane and Busuku sites indicated that there is no difference (Nkomane 0.16, and Busuku 0.34).

A total of 1,929 individuals of soil litter arthropods grouped into 7 orders and 8 families were identified at both treatment and control. Identified soil-litter arthropods were grouped into three functional groups, dominated by decomposers, litter transformers and soil engineers found in the family of Formicidae, Myriapoda (Julidae, Pyrgodesmidae, and Paradoxosomatidae), Hypogastruridae (springtail) and Rhinotermitidae (termite) (Table 3). The family of Acrididae (grasshopper) was restricted to the decomposers and litter transformers, while the Ctenizidae (Araneae, spider) and Formicidae (Hymenoptera) belong to predators (Table 3).

Higher abundance of soil-litter arthropods was found in Arusha and Yungwe sites (Table 2). The families of Formicidae (24.6±4), Julidae (9.1±2.3), Hypogastruridae (7.3 ± 5.9), Acrididae (5.6 ± 3.6), Ctenizidae (4.9 ± 3.1), Rhinotermitidae (3.2 ± 1.6), Pyrgodesmidae (1.8 ± 1.7) and Paradoxosomatidae (1.6 ± 1.3) showed high abundance. In addition, higher diversity of soil litter arthropods was found in treatment of Arusha (H:1.663) and Yungwe, (H 1.829) compared to control sites of Arusha (H 0.93) and Yungwe (H 1.61), while in treatment of Nkomane (H 1.370) and Busuku sites (H 1.456.) diversity was not high compared to their control sites Nkomane (H 1.369) and Busuku (H 1.592).

Table 1: The mean and standard deviations of soil chemical properties

Soil chemical properties	**Treatment**				**Control**			
	Arusha	**Yungwe**	**Nkomane**	**Busuku**	**Arusha**	**Yungwe**	**Nkomane**	**Busuku**
pH $_{\text{water}}$	6.3 ± 0.3	6.1 ± 0.3	5.9 ± 0.2	5.9 ± 0.3	5.7 ± 0.04	5.7 ± 0.1	5.8 ± 0.4	5.7 ± 0.4
pH $_{\text{Kcl}}$	5.4 ± 0.3	5.3 ± 0.3	5.1 ± 0.1	5.2 ± 0.3	4.9 ± 0.4	4.8 ± 0.4	4.9 ± 0.4	4.7 ± 0.4
SOM	20.4 ± 3.9	19.6 ± 1.5	11.9 ± 3.3	12.6 ± 4.5	14.3 ± 2.8	15.9 ± 1.3	13.4 ± 2.2	12.6 ± 4.3
Total N	0.2 ± 0.0	0.198 ± 0.0	0.108 ± 0.0	0.087 ± 0.0	0.150 ± 0.0	0.142 ± 0.0	0.0948 ± 0.0	0.095 ± 0.0
Total P	0.3 ± 0.0	0.31 ± 0.0	0.27 ± 0.0	0.26 ± 0.0	0.26 ± 0.0	0.28 ± 0.0	0.27 ± 0.0	0.25 ± 0.0
Av. P	11.0 ± 0.9	8.1 ± 0.6	6.19 ± 1.1	7.06 ± 1.2	8.4 ± 1.5	7.59 ± 0.5	6.24 ± 1.3	6.73 ± 1.1

Table 2. Abundance of the families of soil-litter arthropods using means and standard deviation of family individuals collected on field

Order of soil-litter arthropods	**Families of soil-litter arthropods**	**Treatment**				**Control**			
		Arusha	**Yungwe**	**Nkomane**	**Busuku**	**Arusha**	**Yungwe**	**Nkomane**	**Busuku**
Hymenoptera	Formicidae	15.7±13.2	10.1 ± 6.7	24.6 ± 4	9.1 ± 6.7	14.4 ± 11.3	8.3 ± 5.7	22 ± 31.3	8.6 ± 5.4
Collembola (springtail)	Hypogastruridae	7.3 ± 5.9	4.9 ± 4.3	0	0	0.6 ± 1.6	4.4 ± 4.0	0	0
Orthoptera (grasshopper)	Acrididae	3.3 ± 2.9	5.6 ± 3.6	3.2 ± 1.6	6.3 ± 2.5	2.2 ± 1.7	5 ± 4.3	3.8 ± 2.4	6.3 ± 2.5
Blattodea (termite)	Rhinotermitidae	0.9 ± 1.2	0.9 ± 1.1	3.2 ± 1.6	0.9 ± 1.2	0.4 ± 0.7	1.2 ± 1.8	3.8 ± 2.4	1.8 ± 2.1
Araneae (Araneae, spider)	Ctenizidae	4.2 ± 3.7	4.9 ± 3.1	4.7 ± 2.3	0.2 ± 0.6	1.9 ± 2.4	4.1 ± 3.1	7.2 ± 1.4	0.3 ± 0.5
Julida (Millipedes)	Julidae	2.1 ± 1.7	2.5 ± 1.4	2.5 ± 1.6	9.1 ± 2.3	0.1 ± 0.3	1.3 ± 1	1.9 ± 1.3	8.5 ± 5.4
Polydesmida (Millipedes)	Pyrgodesmidae	1.8 ± 1.7	1.3 ± 1	0.3 ± 0.5	0.8 ± 1.1	0.3 ± 0.7	0.1 ± 0.3	0.6 ± 0.7	1.9 ± 2.1
Polydesmida (Millipedes)	Paradoxosomatidae	1.3 ± 1.1	1.6 ± 1.3	0.5 ± 0.8	0.2 ± 0.6	0.4 ± 0.7	0.3 ± 0.7	0.2 ± 0.4	0.3 ± 0.5

Table 3. Functions of arthropods group classification in the study site

Family of arthropods	**Control**			**Treatment**		
	Decomposer and litter transformers	**Ecosystem and soil engineers**	**Predators**	**Decomposer and litter transformers**	**Ecosystem and soil engineers**	**Predators**
Formicidae (ants)	No	Yes	Yes	No	Yes	Yes
Hypogastruridae (springtail)	Yes	Yes	No	Yes	Yes	No
Acrididae (grasshopper)	Yes	No	No	Yes	No	No
Rhinotermitidae (termite)	Yes	Yes	No	Yes	Yes	No
Ctenizidae (Araneae, spider)	No	No	Yes	No	No	Yes
Julidae (Millipedes)	Yes	Yes	No	Yes	Yes	No
Pyrgodesmidae (Millipedes)	Yes	Yes	No	Yes	Yes	No
Paradoxosomatidae (Millipedes)	Yes	Yes	No	Yes	Yes	No

Key: Yes = family does this function; No = family does not do that function

DISCUSSION

Soil chemical properties

Soil pH

Results of this study indicated that soil in Gishwati-Mukura landscape is weakly acidic to neutral. Highest levels in soil pH were found in soils sampled under treatments dominated by *Alnus acuminata* than those under control. Other studies conducted in Rwanda at the same sites by Ndoli *et al.*, (2017) indicated the same trend in soil acidity. The meaning behind could be that the biomass of *Alnus acuminata* improved soil pH from slightly acidic to neutral. This was due to the supply of organic matter, and hence make complexation with Aluminium and Iron ions (Fehse *et al.*, 2002). Good farm management is another factor that may influence soil pH whereby grasses reinforced the soil arthropods activities under *Alnus acuminata* tree species.

The low levels of soil pH at the control sites of Nkomane and Busuku might be associated to the poor management of *Alnus acuminata* associated to the overgrazing. The overgrazing was found to reduce the organic matter, and to increase Al and Fe ions. However, studies indicated that when there is low soil organic matter in soil, the Al and Fe ions increase through soil colloid, and then the increase in soil acidity indicated by low soil pH (Naramabuye and Haynes, 2006).

Soil organic matter

The results of soil organic matter showed changes in organic matter at all sites which are medium to high based to (Landon, 1991). The levels in SOM were found higher under the restored sites compared to the non-restored sites (Table 1). We suspect the improvement in soil OM to be associated to the *Alnus acuminata*. It is possible that *Alnus acuminata* contributes more to the presence of high soil organic matter in treatment than in control. According to Okalebo *et al*., (2002), soil of Arusha and Yungwe sites are medium to high and soil of Nkomane and Busuku site are medium. According to Naramabuye *et al.*, (2008) plant residues decomposition increases soil organic matter, the reason why there is high significance difference at Arusha and Yungwe sites Nevertheless, the results of Nkomane and Busuku sites are not different and may be the similarities come from the absence of *Alnus acuminata*.

Soil total nitrogen

The results indicated that the soil was weak to middle based on interpretation norms of Okalebo et *al.*, (2002). The results obtained are the same as Orwa *et al*., (2009) and Ndoli *et al.*, (2017) which showed that *Alnus acuminata* affect positively soil nitrogen. *Alnus acuminata* fixes more atmospheric nitrogen through its symbiosis with *Actynomyces alni* (Franki alni) which enable its rooting system to fix air nitrogen in sufficient quantities for its development (Orwa *et al.*, 2009; Sir *et al*., 2015). So, this ability of *Alnus acuminata* fixing nitrogen has been observed during this research where the concentration of total nitrogen was high in sites with *Alnus acuminata* in Arusha and Yungwe site which are consequences of this tree species.

Soil total phosphorus

This research indicated that treatment had high concentration than control, in sites of Arusha and Yungwe but in Nkomane and Busuku sites, there was no differences. At Nkomane and Busuku sites, no differences may result from mismanagement of *Alnus acuminata* and overgrazing. Phosphorus is one among many elements found in soil which does not reside in air and it is not fixed by any living organisms but is consumed by all living things due to that it is one among the main constituent of adenosine triphosphate (Baillie *et al*., 1990). The total phosphorus is a component of phosphorus found in soil solid phases that may be potentially available during the course of the life of the plant when the intensity pool is depleted by plant uptake (Marx *et al.*, 1999). There are not more interpretation norms of total phosphorus which can state that a soil is weak, moderate, medium, high, or very high. Only, total phosphorus represents its quantity found in soil since it resides in soil. Many factors affect the availability of soil phosphorus to plant such as soil pH that is in range of 5.5-7.0 in acidic soil (Hartemink, 2000). The total phosphorus concentration is represented in percentage whereas available is in mg/l (ppm).

Soil available phosphorus

The available phosphorus is a portion of total phosphorus, which are soluble in soil colloids and can be absorbed by plant (Marx *et al.*, 1999). According to Okalebo *et al.*, (2002), soil available phosphorus in all sites was very weak to weak. As stated by Ndoli *et al.*, (2017), *Alnus acuminata* recycles many nutrients including phosphorus and it positively improves soil available phosphorus contents in Arusha and Yungwe sites than in Nkomane and Busuku sites.

Soil-litter arthropods

This research indicated that *Alnus acuminata* has positive influence on soil-litter arthropods in all studied sites.

Soil-litter arthropods in Arusha and Yungwe

Many families have been found in Arusha and Yungwe sites dominated by the family of Formicidae which means that there are many prey and other conditions which favours ants to live in the areas (Menta and Remelli, 2020). The presence of spiders indicated that there are prey and glasses where they make food webs for their shelters. There are also grasshoppers, which are prey for spiders and ants. The presence of diplopods showed that there is high biomass which come from *Alnus acuminata* and other glasses planted in pasture. Collembola have been found close to *Alnus acuminata* which means that this agroforestry tree species favours Collembola and other arthropods which feed on plants litters (Kergunteuil *et al.*, 2016). The presence of Rhinotermitidae have indicated the presence of dead trees due to the fact that this family feed on dead trees and they Were found far from *Alnus acuminata* and they are very few.

Soil-litter arthropods in Nkomane and Busuku sites

Soil and leaf-litter arthropods in treatments were similar to those in controls. The ants dominated over others. Grasshoppers were seconds, and there were few millipedes. The presence of ants and spiders was due to their preys because these two families are predators (Alvarado *et al.*, 1981). However, the low presence of Rhinotermitidae in these areas might be due to lack of food. Collembolan have not been found maybe due to the lack of *Alnus acuminate*, while a small number of millipedes could be associated to the mismanagement of pastures.

Role of soil and leaf-litter arthropods in maintaining soil fertility

Soil and leaf-litter arthropods play an important role in maintaining soil fertility through cycling nutrients. They transform litters and they are ecosystem engineers (Decaëns *et al.*, 2006). Leaf-litter transformers arthropods cut down litter through pieces and moisten ingested plant fragments, refining its quality as substrate for further decomposition by microbes and stimulating the growth and spreading of microbial inhabitants (Marian *et al.*, 2020). Soil and ecosystem engineers' arthropods which comprised formicidae (ants), hypogastruridae (springtail), acrididae (grasshopper), rhinotermitidae (termite) and millipedes (Julidae, Pyrgodesmidae and Paradoxosomatidae) modify the physical habitat, indirect or direct regulate the resources availability to other soil organisms (Scheunemann *et al.*, 2015). The leaf litter transformers arthropods change soil mineral, structure and soil organic matter composition, and moisture, millipedes, ants, springtails and termites are the greatest significant arthropod of this association (Culliney, 2013; Lobry de Bruyn, 1999).

Influence of arthropods on nutrient cycling

Leaf-litter transformers arthropods influence decaying of dead plant in nourishing them and enhance microflora, hence changing the contained energy into biomass production and respiration, and they indirectly affect conversion of them into faeces and the re-ingest, mix litter with soil, and control microflora through distribution of microbial such as bacteria. This was found for ants, termite and millipedes, which are grouped in decomposers and litter transformer, and ecosystem and soil engineer (Lavelle *et al.*, 2016). The effects of soil and leaf-litter arthropods processes of decomposition are very important where the decomposition happen rapidly in humid tropics, and it is due to soil arthropods actions and high temperature.

The main influence of soil arthropods on the humification and decaying processes are the reductions of plants debris (Moldenke, 1994).

Soil-litter arthropods are appreciated to physically break down leaf cuticles and expose cell contents in the soil, and hence contribute to soil aeration, soil water-holding capacity and downward movements of particles as well as soluble substances (David, 2010). The break down result in the feaces-rich chemicals released in the soil, and hence enrich soil in chemical nutrients (Kergunteuil *et al.*, 2016).

This study indicated higher abundance of the Collembola, Diplopoda and Termites in soil-litter so according to Yadav *et al.*, (2018) these arthropods can transform large amount of litter through feeding activity. In this regard, it was found that Myriapoda alone can contribute 2% of litter turnover per year (Culliney, 2013). Higher quantity of biomass broken down by arthropods is done by diplopoda at a range varying between 2 and 3 times greater than other arthropods (Pardon *et al.*, 2019). The diplopoda faeces increases the soil pH and soil moisture content through the increase of soil water holding capacity. Diplopoda contributes to decaying processes by microorganisms specifically bacteria (Decaëns *et al.*, 2006). Diplopoda are hence the first contributors in litter decomposition compared to all soil arthropods (Culliney, 2013) then there is a positive sign that *Alnus acuminata* has positive effects on soil-litter arthropods and hence to soil quality.

Mineralization of nutrient elements

Studies have indicated that nutrients have to be available in soil in the inorganic form before they are absorbed by plant roots. The conversion from organic to inorganic compounds is done through mineralization process (Jones, 1990). The process was found to be first facilitated by arthropod decomposers through the conversion of carbohydrate and amino acids into nitrate forms *(*Menta *et al.,* 2018). In collaboration with microorganisms, soil-litter arthropods transform polymers from the plant cell walls into chemical inorganic compounds in soil for future use by plants (Culliney, 2013).

The mineralisation is mainly done by springtail that stimulate fungal growth and respiration, higher abundance of springtail in this study was found in the areas with high soil pH under *Alnus acuminata.* Arthropod feed on microflora and acts to control decomposition rate, to avoid unexpected microbe's population development, due to result from nutrients mineralizing and making available from debris to plant uptake, in a regulated and minimization from system.

It is agreed that the soil arthropods such as termite and millipedes have important amounts of carbon and nitrogen (Abe *et al.*, 2009). The grazers' soil arthropods removed high litterfall amount of tropical soil (Varm *et al.*, 1994), the soil arthropods respiration and their fungal comb transport and digest about 1/10 of litterfall per year in landscapes of the tropics, and can surpass 2/10 when all arthropods groups are considered but the carbon mineralisation is at low rate in this region (Yamada *et al.*, 2005). Termites, leafcutter ants replenish soil nutrients in natural ecosystem through construction of nests and leaf cutting and it is important, the termites' uniqueness in leaf litter turnover and nutrient cycling.

Jones (1990), all arthropods contribute to breakdown litter than all invertebrate that live in soil. Big amounts of plant and animal organic matter sources accumulated in dumps combined with metabolic product and secretions from the soil arthropods which can be incorporate into soil, they do decomposition and mineralization by the microflora, result in increasing nutrients concentration in soil thus they contribute more to soil fertility improvements.

Ecosystem functioning of soil-litter arthropods

The effects of soil and leaf-litter on breaking down and decaying dead plant animal is the basis of ecosystem functioning of all living organisms which includes the release of nutrients from the litter to soil, especially nitrogen and phosphorus which are macronutrients and the essential for agriculture production. The quantity of nitrogen and phosphorus cycled per year by soil arthropods like millipedes and termites' community are high and important for plants growth (Gurjar *et al.*, 2017). The ecosystem functioning of soil arthropods can be assessed through decomposition, which is valuable for nutrients recycling but also as food sources of microbes and others decomposers (Frouz, 2018). Economically the bioremediation of soil and treatment of contaminant are specifically done by soil arthropods and microorganisms. Indirectly soil fauna stimulates detoxification activities of microbe's agents.

The main ecosystem functioning of soil arthropods is visible through facilitating microbes to obtain food after the broken down of dead plant and animals by soil arthropods and then in turn their faeces are assimilated by plants due to their contents of nutrients (Birkhofer *et al.*, 2011). When arachnids such as spider catch prey, they reduce competition and increase food availability to some arthropods and animals. The contribution of soil arthropods in soil erosion as positive effects in agriculture through their activities of creating pores and voids and releasing nutrients in soil colloids (Gómez *et al.*, 2018).

CONCLUSION

Alnus acuminata have high soil chemical properties values compared to the control. The biomass of agroforestry tree species studied improved some soil fertility parameters including: soil organic carbon, organic matter, soil total nitrogen, soil total phosphorus and available phosphorus. Higher values were Significantly concentrated in soil under *Alnus acuminata* than in area without agroforestry tree species. Soil arthropods were favoured by *Alnus acuminata* can be used to explain the high values of soil chemical properties. The millipedes strived more favourable under the biomass of this tree species. *Alnus acuminata* contributed more to ecosystem function through improving positively soil fertility by increasing the soil arthropods that breakdown dead plant and animals and release of nutrient through mineralisation in soil colloids that can be assimilated by plants root.

RECOMMENDATIONS

Alnus acuminata should be a valuable agroforestry tree to plant in pastoral land along with other tree species. A similar research shall be extended in other ecosystems to investigate the effects on other ecosystem functioning parameters. It is also recommended that the biomass for *Alnus acuminata* be analysed over time to investigate the nutrients content and correlate it with its positive impact on soil fertility.

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