A Comparative Study on the Performance of *Alnus acuminata* Planted as Intercrops and in Woodlots in Nyabihu District, Rwanda.

Rono Jennifer[1], Maniriho Festus[1] and Uwezimana Valence.

[1]Higher Institute of Agriculture and Animal Husbandry (ISAE)- Busogo
Department of Forestry and Nature Conservation, P.O.Box 210 Musanze, Rwanda; ronojenni@gmail.com.

Abstract: The study aimed at comparing the growth performance of *Alnus acuminata* planted as intercrops in agroforestry systems and in woodlots by carrying out an inventory on trees planted in Nyabihu District, Rwanda in the year 2007. The height (m), DBH (cm), silvicultural management techniques subjected to the trees and the stocking parameters including the number of trees per hectare, basal area per hectare, volume per hectare and mean annual increment (MAI) of height were compared. Farms and farmers sampled were randomly selected and a questionnaire was used to compare the silvicultural management techniques used on both land use systems. For measurements, 0.04 ha circular plots were used. Data collected from the survey was analyzed using SPSS 16 where percentages were determined using descriptive statistics while inventory data was subjected to analysis of variance using JMP IN 5.1 where the means were separated using Student t' at $P \leq 0.05$. Pruning and coppicing were the main management techniques practiced in both land use systems at varying levels. Thinning (16.7%) and pollarding (33.3%) were practiced in woodlots and intercrops respectively. Trees in the woodlots had attained a higher mean height of 19.55 m, 679 trees/ha, basal area of 15.98 m^2/ha and volume of 153.00 m^3/ha. On the other hand, trees in intercrops had an average height of 13.23 m, 454 trees/ha, basal area of 12.68 m^2/ha and volume of 84.14 m^3/ha. The Mean annual increments (MAI) in height in intercrops and woodlots were 2.64 m/year and 3.91 m/year respectively. There was a significant difference ($P \leq 0.05$) in the average number of trees per hectare, height, MAI in height and volume per hectare between *Alnus acuminata* planted as intercrops and in woodlots. However, there was no significant difference in the mean DBH and basal per hectare in *Alnus acuminata* planted in the two land use systems. Farmers can then choose the planting niches of their trees depending on the desired benefits at tree harvest.
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Key words: Height, DBH, basal area, Volume, MAI, woodlots.

Introduction

Alnus acuminata is a fast-growing pioneer species that regenerates naturally in open, disturbed areas. It grows in moist soil environments, usually along the banks of streams, rivers, ponds and swamps, where it typically forms dense, pure stands; can also be associated with floodplains or moist mountain slopes, and it may be adapted to somewhat drier conditions (Orwa *et al*,. 2009).

Evaluation of performance of any tree is first step towards its promotion and improved adoption and this also applies to the choice of species to be planted in woodlots and in agroforestry systems. Tree planting in Rwanda was generally driven by an urgent need to achieve two major objectives, that is, conservation of fragile landscapes and meeting the ever increasing demand of forest products by the growing population (Nduwamungu, 2011). *Alnus acuminata* is one of the main species that has been promoted for its important role in soil erosion control in steep and unstable soils as it grows well on slopes as its root system tends to be lateral and extended rather than deep and confined making it a very useful species in controlling erosion in steep and unstable soils (NAS, 1980), soil fertility maintenance and improvement, physical protection against crop damaged caused by wind, water conservation by controlling erosion and also being a good source firewood and stakes used to support climbing beans (REMA, 2010; Sande, 2003).

Unfortunately, farmers do not have the knowledge on the planting schemes they can use to maximize their benefits from this species depending on their main desired goals for planting the species (REMA, 2010). For effective management, there is need to gather relevant information on the performance of this species planted in different farm niches. Therefore, the study aimed at assessing the performance by comparing the height, diameter and also number of trees, basal area and volume per hectare of *Alnus acuminata* planted in intercropping systems and woodlots.

Materials and methods

Study area

The study was carried out in Nyabihu District, Western Province of Rwanda. The annual rainfall in the area ranges between 1600 mm and

1800 mm per annum while the monthly temperature ranges between 13°C and 20°C throughout the year. The area is dominated by clay soils. The flora of is composed by artificial forests and woodlots dominated by Eucalyptus spp, Alnus spp, pines, Cypress and different types of herbs. The main cultivated crops in the area include tea, vegetables (cabbage and carrots), food crops (potatoes, bean, maize and Irish potatoes).

Data collection

A semi-structured questionnaire addressing the silvicultural management tools used by farmers was developed and was administered to farmers who were first purposively selected for having planted *Alnus acuminata*. The households to be surveyed were then randomly selected.

Equal allocation of plots was used to sample the two different strata where six plots were sampled in each case. In agroforestry systems, measurements were taken from the farms of the farmers who had been interviewed. In woodlots, the stands to be sampled were purposely selected. *Alnus acuminata* trees planted at the same time (April 2007) in both woodlots and intercrops were taken in to consideration. The parameters taken were tree height and DBH.

The average annual growth rate in height (m/yr) was calculated dividing the height of trees at 5 years by the number of years (5 years).

$$MAI = \frac{\text{Heigh at age of consideration (5 years)}}{\text{Number of years (5 years)}}$$

(Samsudin *et al*., 2003)

The number of trees per hectare (N) was estimated by counting the number of trees in small plots area and dividing it by the plot area in hectares.

The basal area per hectare (m^2/ha) was calculated by use of the formula below:

$$G=\left(\frac{\pi}{40000} * \mathbf{d}^2\right) \mathbf{n}$$ (Samsudin *et al*., 2003)

Where: d is the average DBH and n is the number of trees per hectare.

The volume per hectare (m^3/ha) was calculated by use of a volume equation designed for *Alnus acuminata* as proposed by Segura *et al*., (2005)

$$V=2.71828^{-10.0557 + \ln(d)*2.0369 + 0.927718*\ln(h)}$$

Where d represents DBH (cm) and h is total height (m)

Data analysis

Inventory data was analyzed using JMP IN 5.0 where means that were highly variable were separated using Student t' at 5% confidence level. Data obtained from the survey was analyzed using SPSS 16 where percentages were determined using descriptive statistics.

Results

Silvicultural treatments

Figure 1 shows that pruning is the main silvicultural treatment practiced with all the farmers pruning the trees planted as intercrops while 81.6% prune the trees established in woodlots. Coppicing is also practiced in both systems with 33.3% and 16.6 % of farmers in intercropping systems and woodlots respectively. Trees in woodlots are thinned by 16.7% of the farmers while 33.3% pollard their trees in intercropping systems.

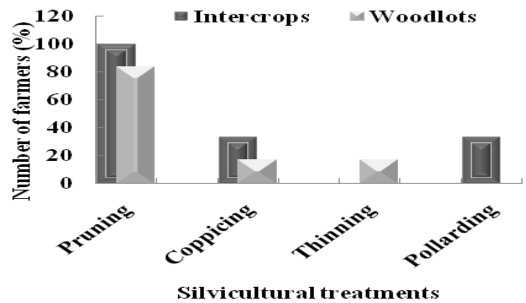

Figure 1: Silvicultural Treatments on *Alnus acuminata* in Intercrops and Woodlots

Height

A higher mean height of 19.55 m was recorded in the woodlots while the mean height in the intercropping system was 13.23 m.

The results analysis showed that land use system influenced the height with the height of *Alnus acuminata* in woodlots being significantly higher (p=0.0013) by 48.5% in comparison to height in intercropping system (Figure 2).

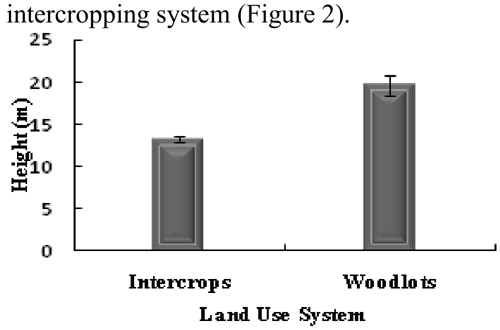

Figure 2: Mean Height of *Alnus acuminata* in Intercrops and Woodlots

Mean annual increment in Height

MAI was highly significantly (P=0.0003) different between the two land use systems with woodlots having a MAI that was greater by 50% as compared to MAI in height obtained in intercropping system (Figure 3).

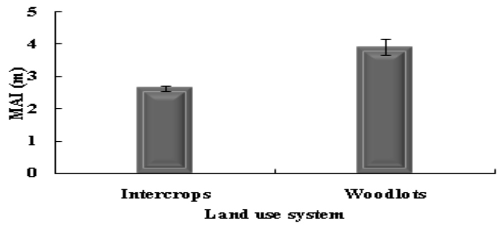

Figure 3: MAI of *Alnus acuminata* in Intercrops and Woodlots

DBH

According to Figure 4, a higher mean of DBH 18.77 cm was recorded in *Alnus acuminata* intercrop compared to a lower DBH of 17.38 cm in woodlots. The statistical analysis revealed that DBH of *Alnus acuminata* in both land use systems was not significantly (P=0.9904) different.

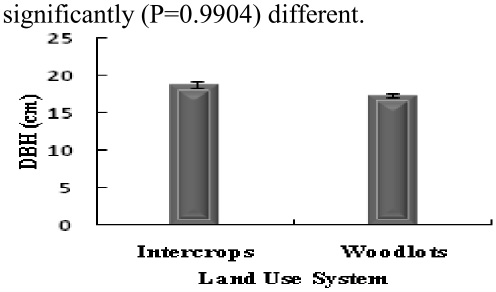

Figure 4: Mean DBH of *Alnus acuminata* in Intercrops and Woodlots

Stocking parameters

1. **Number of trees per hectare (N)**

A higher number of trees per hectare was found in woodlots (679 trees/ha) whereas the lower tree density (454 trees/ha) was found in intercropping system. The results from the analysis indicated a significant (P=0.0246) difference in the mean number of trees in the two land use systems. The number of trees in woodlots was higher by 49.5%.

2. **Basal area per hectare (G)**

The mean basal area of trees in woodlots was higher (15.9 m^2/ha) than that obtained in intercropping system (12.7 m^2/ha). According to results statistical analysis, the mean basal area per hectare was not significantly different (P=0.1079) between the two land use systems (Figure 5).

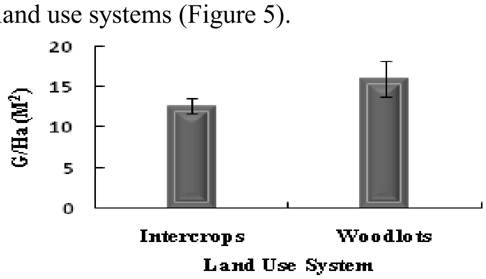

Figure 5: Mean basal area/hectare of *Alnus acuminata* in Intercrops and Woodlots

3. **Volume per Hectare (V)**

The statistical analysis revealed that woodlots had a significantly (P=0.0373) higher volume per hectare of with 153.00 m^3/ha compared to 84.14 m^3/ha obtained in intercropping system (Figure 6).

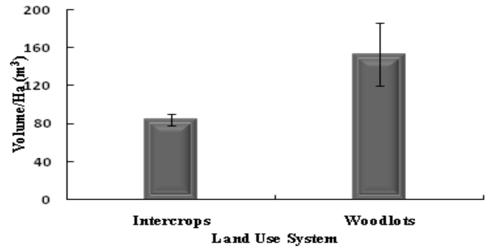

Figure 6: Mean volume/hectare of *Alnus acuminata* in Intercrops and Woodlots

Discussion

Silvicultural treatment of trees is a very important tool in management of competition not only between trees but also between trees and crops in intercropping systems. *Alnus acuminata* has been found to be a more competitive tree in comparison to other species like *Grevellia robusta* when intercropped with crops and this can be attributed to the root architecture, diameter at breast height sizes, and crown size (Sande, 2003). All the silvicultural treatments subjected to *Alnus acuminata* are aimed at reducing competition for light and for the farmers to obtain tree benefits before tree maturity or actual harvest (Sande, 2003). Pollarding reduces yield reduction of crops due to shading, and provides fuel wood and leaf-litter and increases the life span of a tree (Rackham, 2001). Pollarding of trees in intercrops has other benefits to farmers in Nyabihu as it provides firewood and stakes for climbing bean and generally reduces competition for resources between trees and crops and enables continued tree planting on-farm. This is so also for coppicing which gives the farmers the ability to control the trees at juvenile stage (Rackham, 2001) and hence they can derive benefits from them for a longer period of time. Thinning in done in woodlots with the main aims of obtaining wood resources and encourage trees to increase in size. Pruning is done to encourage light penetration and hence reduce competition between crops and trees. Generally, more silvicultural practices are mainly practiced in agroforestry systems to minimize negative interactions between trees and crops (Sande, 2003).

Height growth of trees is both extremely variable and highly predictable and the height growth of similar-aged trees of the same species in different sites may vary due to variations in site quality (Clark and Clark, 2001). Trees grow tall where resources are abundant, stresses are minor and competition for light places a premium on height growth (King, 1990).

Growth rates of Alnus species vary considerably, particularly in response to soil moisture and altitude. *Alnus acuminata* in particular grows faster at higher altitudes (Sande, 2003) and depicts an initial rapid growth in height. From the results from the height obtained from the five-year old trees, the annual mean increment of trees in woodlots was 3.9 m in the woodlots and 2.6m for the intercrops. This is similar to a mean annual increment of 2.7 m in height obtained in Nepal and the exceptionally high annual increment of 4 m in height which was reported in the Philippines (Neil, 1997). For this reason we can say that both sites are good as height is a tree variable used as an indicator of site quality, that is, an indicator of the environmental conditions that exist in the immediate area (Clark and Clark, 2001). Height also can be an indicator for competition for light and this can account for greater height in woodlots as tree were closely spaced and hence the demand for light is greater. Also, the different silvicultural practices like pollarding and can account for the differences in height of the species in the different land use systems especially the lower height in intercrops which are pollarded.

Trees fully occupy a site and compete with one another for light, water, nutrients and space leading to suppression and death of many trees (Rowan *et al*., 2009). This mortality is induced by competition and results in an upper average diameter of a given number of trees that occupy an area. Once site resources, particularly light and moisture, become limiting, any increase in competition will lead to a direct reduction in the size or efficiency of the individual tree canopy (Clark and Clark, 2001). This competition could have resulted to comparatively smaller tree sizes (DBH) in woodlots due to a higher number of trees per unit area as compared to intercrops.

The number of trees per hectare is a very important parameter as it directly influences competition and hence the growth characteristics of trees. The proper spacing for *Alnus acuminata* trees in sole cropping is 3m by 3m (Budowski, 1983) translating to 1,111trees/ha. According to the results, the low number of trees per hectare in the woodlots could either be an indication of heavy thinning or low initial planting stocking rates. In intercropping system, the number of trees/ha is significantly high as compared to about 100 trees/ha as found to be the case used by farmers in Costa Rica who grow Alnus acuminata in pastures and as a shade tree for coffee crops (Budowski, 1983).

Stand basal area is a very useful parameter for quantifying a forest stand. It may be seen as a summary of the number and the size of trees in a stand and can be used to estimate stand volume or as a useful measure of the degree of competition or the density of a stand (Abed and Stephens, 2003. Stand basal area of fully stocked stands frequently lies in the range 20-50 m^2/ha. In the case of heavily thinned stands and young poorly stocked crops, basal areas of 10-20 m^2/ha are common (Abed and Stephens, 2003) which is the case in our study. Despite the fewer number of trees in intercropping systems, a comparatively high basal area is attributed to the higher mean DBH.

Stand volume at a nominated age is related to the site quality, and the total at any time is important to estimate the amount of wood and biomass resource. Although individual tree diameter declines with increasing competition in woodlots, the total volume of wood on the site increases (Rowan *et al*., 2009). Therefore, if the objective is only to maximize the volume of timber, as for pulpwood or fuel wood, then the higher the stocking rate, the greater the yield. Further more, volume is a function of height too unlike basal area which is dependent only on DBH. This explains a significantly high volume of species in the woodlots in comparison to intercrops**.**

Conclusion

The height, diameter, basal area and volume and the density per hectare of *Alnus acuminata* vary depending on the land use system. Depending on the objective of the farmer, an appropriate system can be selected. For instance, if it is for wood production, woodlots will be more appropriate as the yield will be higher translating to more cash returns if the trees are planted for commercial purposes. For the case of multiple benefits, crop production and wood production for household uses such as bean staking and fuel wood, intercropping is more appropriate especially in the region as it is faced with land shortage problems. It is recommended that farmers should be trained on proper spacing to be used so that they can maximize the benefits to be obtained from both land use systems.

Corresponding Author:
Jennifer Rono
Department of Forestry and Nature Conservation,
Higher Institute of Agriculture and Animal
Husbandry (ISAE)- Busogo
P.O.Box 210 Musanze, Rwanda;
ronojenni@gmail.com.

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