Effect of Thinning on Understory Pasture in A Silvopastoral Agroforestry System

Michael Jide Nworji

Department of Forestry and Wildlife Management, Faculty of Agriculture Chukwuemeka Odumegwu Ojukwu University, Igbariam Campus, Nigeria
Bangor University, North Wales, United Kingdom
Anambra State, Nigeria

Abstract: This study determined the short-term effects of thinning on the botanical composition and abundance of pasture species under red alder (Alnus rubra Bong) in a silvopastoral agroforestry system, using the dry-weight rank method of Mannetje and Haydock (1963) as modified by Jones and Hargraves (1979). The response of pasture species composition by weight to thinning was found to vary. Eight most dominant pasture species were generated in each of the three blocks as well as in their adjacent control (open pasture), which comprised of two sown species (L. perenne and T. repens), four grass weeds (A. capillaris, H. lanatus, P. pratensis and F. pratensis), and two forbs weeds (U. dioica and C. arvense), respectively. Though species richness remained the same for the treatments in the present study, the understory percentage composition by weight of the sown species declined, while that of the grass weeds and the forb weeds increased slightly one year after thinning (2013 – 2014) compared to the adjacent open pastures, suggesting some effect of thinning on the composition of pasture species in the short-term, thereby rejecting the hypothesis that thinning will not change the understory pasture species composition and abundance in the short-term (up to 1 year) in this study. However, the change was not statistically significant (P = 0.157). A. capillaris remained dominant in all treatments. The understanding of the dynamics of a pasture in response to thinning treatments can help livestock managers adopt sound pasture management strategies to increase carrying capacity and pasture productivity, and adjust stocking rate.

Keywords: Agroforestry; silvopasture; pasture; thinning; red alder; sown species; grass weeds; forb weeds; species composition and abundance.

1. INTRODUCTION
The productivity, species composition, richness and abundance of understory vegetation are directly influenced by tree density and structure of the overstory canopy, the amount of light reaching
the understory, and the method of pruning and thinning forests. Forest management practices, such as thinning, pruning, harvesting, fertilization and prescribed fire, may reduce stand density and leaf area, increase light transmission to the understory, affect forest soil, increase the amount of organic matter stored in soils, improve tree and understory pasture productivity, reduce wildfire risk and maintain general health of forests.

Despite the extent of thinning as an important and common silvicultural practice, most studies have focused generally on examining the impact of thinning on tree species and understory plant communities in forest stands, while fewer studies have examined the effect of thinning on understory pasture in in a silvopasture. The objective of this study was to determine the effects of thinning on the botanical composition of pasture species under red alder (*Alnus rubra* Bong) in a silvopastoral agroforestry system. Specifically, the study measured the short-term effects of thinning on understory pasture species composition on the same plot before and after thinning; (up to 1 year), and no tree control was considered. The study was restricted to red alder because of its nitrogen-fixing characteristics and fast growth.

The knowledge of the dynamics of pastures in response to thinning treatments is critically important for grazing enterprises as it can help livestock managers adopt sound pasture management strategies for adjusting stocking rate, increasing carrying capacity and pasture productivity. It was hypothesised that thinning will not change the understory pasture species composition in the short-term (up to 1 year).

This manuscript is part of my Doctor of Philosophy (Ph.D.) dissertation in Agroforestry from Bangor University, North Wales, United Kingdom, which may be available from Bangor University’s Library or from services like ProQuest but has not been traditionally published (Nworji, 2017).

2. LITERATURE REVIEW

2.1 The ecological influences of thinning

Forest management practices such as pruning and thinning reduce stand density and leaf area, increase light transmission to the understory, affect forest soil, improve tree and understory pasture productivity, increase the amount of organic matter stored in soils, reduce wildfire risk and maintain general health of forests. The ecological and silvicultural literatures contain examples of positive, negative and neutral responses of understory vegetation to thinning treatments (e.g., Percival and Hawke 1985; Hawke, 1991; Knowles, 1991 Jurgensen *et al.* 1997; Streigl and Wickland 1998; Thomas *et al.* 1999; Smit and Rethman, 2000; Thysell and Carey 2000; Janssens *et al.*, 2001; Brockway *et al.*, 2002; Tang *et al.*, 2005; Jonsson and Sigurdsson, 2010; Olajuyigbe *et al.*, 2012; Ducherer *et al.*, 2013)

While thinning and pruning help to maintain pasture production longer into the timber rotation resulting to increase in carrying capacity, these silvicultural practices can also generate considerable amounts of debris which cover pasture and provide safe sites for rodents and weeds (Hawke, 1991; Knowles, 1991).

Ducherer *et al.* (2013) noted that pruning and thinning of trees will increase the amount of light reaching understory vegetation, and consequently, increase understory plant cover and species richness, increase soil temperatures and decrease soil respiration. In addition, they noted that reducing or eliminating competition from overstory trees can increase soil water and mineral nutrients for understory plants, and allow colonization of bare soil by herbaceous plants. Since understory vegetation responds to increased light, the greatest responses to the increases in light following thinning are expected within the first several years (Ducherer *et al.*, 2013).

Again, Thomas *et al.* (1999) reported that thinning and pruning will increase the amount of light reaching understory vegetation, and consequently, increase understory plant cover and species richness. Conversely, the disturbances associated with thinning can reduce understory vegetation cover, in particular, the process of felling trees and extracting leads to trampling and smothering and compaction of vegetation by cut trees (Thomas *et al.* 1999).

Brockway *et al.* (2002) have observed that disturbance resulting from thinning can increase the availability of new microsites for plant establishment and growth, possibly leading to increased species richness, and that plant species composition, abundance, and litter cover increased the most where the thinning was followed by complete removal or scattering of the tree material two years after treatment. Debris generated by tree pruning and thinning can decrease pasture production despite the increasing
light transmission to the understorey after these operations, because of shading effect of the debris on the available pasture area (Percival and Hawke 1985; Hurst et al. 2000; Benavides et al., 2009). Other research has demonstrated that timber harvesting and extensive site preparation can also reduce the amount of surface organic matter (Jurgensen et al. 1997). Disturbances associated with thinning and tree in-growth have also been reported to reduce the composition and abundance of many understorey species (Page, 2002; Ducherer et al, 2013).

2.2 Dry-weight rank method of measuring botanical composition of pastures

The Dry-weight Rank method (DWR) is specifically designed to estimate quickly and accurately the composition of pastures on a dry weight basis by providing a measure of the relative contribution of various species to the total biomass for a site. It involves the visual observation of various quadrats and the ranking of the three species which contribute the most weight in the quadrat (Mannetje and Haydock, 1963). It is a fast method because it eliminates the need for the labour intensive clipping and hand-sorting of samples. Results are expressed only as percentage values, and do not quantify the actual biomass for each species.

This method entails the selection of the first, second and third heaviest species within each quadrat, each of which is then assigned a weighting based on standard multipliers, which have been shown to be applicable over a range of pasture types in Australia, the United States and Zimbabwe (Jones and Tothill, 1985). The observer decides which three species in each quadrat have the greatest yield of current year’s growth on a dry matter basis. The species with the highest yield is given a rank of 1, the next 2, and the third highest a 3. All other species present are ignored. If there are not three species present in the quadrat, a multiple rank is assigned.

The Dry-weight Rank method assumes that a rank of 1 corresponds to 70% composition, rank 2 to 20%, and rank 3 to 10%. If only one species is found in a quadrat, it would be ranked 1, 2 and 3 (100%). If two species are found, one may be given ranks of 1 and 2 (90%), ranks 1 and 3 (80%), or ranks 2 and 3 (30%), depending on the relative weight for the two species. The values for each quadrat are then summed for each species and expressed as percentages of the total score. This approximates the percentage contribution by weight of each species, from which the overall composition of the sample area is derived. Quadrat size has no effect on the results of DWR and the method is universally applicable regardless of the type of vegetation because it is based on dry weights (Mannetje & Haydock 1963).

The Dry-weight Rank method is suitable for grassland and small shrubs types or understorey communities of large shrub or tree communities, however it does not work well on large shrubs and trees. An advantage of this method is that a large number of samples can be collected quickly. It is useful because it deals with estimates of production, which allows for better interpretation of the data to make management decisions. It is also easier to rank the top three species in a quadrat and easier to apply them similarly by individual observers, resulting in less observer bias.

However, the disadvantage with this technique is that, by itself, it will not give a reliable estimate of plant standing crop, and it assumes there are few empty quadrats. In many large shrub or sparse desert communities, a high percentage of quadrats are empty or have only one species present. The quadrat size required to address these concerns is often impractical. Sufficient training for evaluators performing this method is required.

3. RESEARCH METHODOLOGY

3.1 Study area

The study was conducted in the years 2012 to 2014 at the United Kingdom’s Silvopastoral National Network Experiment (SNNE), Henfaes in North Wales, which is one of six National Network Experiments established across the country with trees planted at different arrangements and densities to investigate the potential of silvopastoral agroforestry on UK farms (Sibbald and Sinclair, 1990). The site was established in 1992 on 14.47 ha of agricultural land at the Bangor University’s Henfaes Silvopastoral Systems Experimental Farm (SSEF) (53°14′N 4°01′W), Abergwyngregyn, Gwynedd, Wales.

The local climate in Henfaes is hyperoceanic, cool and temperate. Mean monthly temperature over the course of this study period was 10.6 °C, and temperatures of the warmest and coldest month was
20.0 °C in July and 3.4 °C in January, respectively. Average monthly precipitation ranged from a minimum of 25 mm in April to a maximum of 114 mm in December. Soil is a fine loamy brown earth over gravel (Rheidol series) classified as a Dystric Cambisol (Teklehaimanot and Mmolotsi, 2007). The parent material consists of postglacial alluvial deposits from the Aber River with a water table that is between 1 and 6 metres deep (Teklehaimanot and Sinclair, 1993). Further details of the site topography, climatic conditions, soil geology and hydrology etc. can be found in Teklehaimanot et al. 2002 and Sibbald & Sinclair, 1990.

Sycamore (Acer pseudoplatanus) and red alder (Alnus rubra) were planted on the site at establishment in 1992 at different configurations to investigate their use in agroforestry systems (Sibbald et al., 2001). The blocks were 4,225 m² (0.42 ha) each and sown to a mixture of perennial ryegrass (Lolium perenne L.) and white clover (Trifolium repens L.) at establishment of the farm. The experimental area was rotationally grazed by sheep through the period of the study at average stocking rate of 0.5 to 1.0 AU per ha (Teklehaimanot et al., 2002). All treatments and controls are replicated three times in a complete randomised block design. For the purpose of this study, due to limited time and resources, only the three-red alder (Alnus rubra) blocks were studied. A detailed description of the experimental design and site characteristics is given on the Henfaes agroforestry website, which can be found in the reference (Henfaes website, 2009).

3.2 Experimental design and data collection

The study was structured to systematically measure pasture species composition and diversity in red alder blocks and in adjacent open pastures (agricultural control blocks). A sample area of 60 m x 60 m in size was demarcated in each of the three red alder blocks as well as in the open pastures adjacent to each alder block to allow greater area within the study area to have an equal chance to be sampled. The experiment assessed the short-term (1 year) changes in pasture species composition and diversity under red alder trees and in the open before and after thinning using the Dry-Weight Rank method, which involved rapid estimation of the percentage dry weight of the three most dominant pasture species that are present in a quadrat (Mannetje and Haydock, 1963). Botanical surveys were conducted in June 2013, before the three 200 stem ha⁻¹ alder blocks were thinned to 100 stems ha⁻¹, and in June 2014 after the thinning.

Three parallel transect lines, 60 metres long and 20 metres apart, were established within each red alder block, and pasture sampling was conducted by systematically placing 12 quadrats (0.25 m²) along each transect line at 5-metre intervals and estimating pasture species composition within the quadrats using the dry-weight rank method of Mannetje and Haydock (1963) as modified by Jones and Hargreaves (1979). A total of 108 quadrats were sampled along 9 transects in the three blocks.

Each quadrat was visually observed and the three most dominant species were ranked depending on their relative weight (Mannetje and Haydock, 1963). The first, second, and third most abundant species (on a dry weight basis) were identified to which the ranks of 1, 2, and 3, were respectively assigned. All other species present were ignored. At the end of the sampling, ranks were tallied for each species, and weighted by a set of multipliers provided by Jones and Hargreaves (1979). The result of the weighted values of the three ranks were then added together for each species to represent species percent composition. Recommended procedures for treating equal-ranked species, less than 3 species, and species which consistently formed a high proportion of the biomass were followed. The details of the method are available in Mannetje and Haydock (1963), and Jones and Hargreaves (1979).

The distance between a quadrat and the closest tree was no less than 2.5 metres (Figure 1). For effective measurement of changes in the pasture species composition in both understorey and open pasture, the same transect lines and quadrat points were used for measurements before and after thinning. Each sampling area was set in a grid pattern and transect lines and midpoints of quadrat were marked with labelled pegs the first year for easy identification. Transects were oriented north to south, and sampling positions were geo-referenced using a GPS to an accuracy of ± 5 cm.
There was no estimation of the level of forage utilisation by livestock.

![Diagram of transects and quadrats in red alder blocks at Henfaes SNNE](image)

**Figure 1. Layout of transects and quadrats in red alder blocks at Henfaes SNNE**

### 3.3 Analysis of data

Species percent composition data from quadrats along the three parallel 60-metre transects were pooled for each block. A Chi Square analysis was used to determine if the frequency of each species in each rank tally group (1, 2, or 3) has changed from one sampling period to another (Coulloudon et al., 1999). Each species was analysed separately.

### 4. RESEARCH RESULT

Results of the dry-weight rank method of determining short-term changes in pasture species composition are presented in Table 1 and Figure 2. Generally, species richness was the same for the treatments. This approach generated eight most dominant pasture species in each of the three blocks and their adjacent control (open pasture) blocks across the treatments comprising of two sown species, four grass weeds, and two forbs weeds, respectively. However, there was a decline in the percentage composition by weight of the sown species (*L. perenne* and *T. repens*) and a slight increase in both grass weeds (*A. capillaris, H. lanatus, P. pratensis* and *F. pratensis*) and forb weeds (*U. dioica* and *C. arvense*) after thinning compared to the adjacent open pastures. *A. capillaris* dominated the pastures in all treatments. However, in the open pasture, *L. perenne* is as dominant as *A. capillaris* (Table 1 and Figure 2).

Specifically, the under-tree *L. perenne* (a sown species) declined from 17% by weight before thinning to 8% by weight one year after thinning compared to the same species in the open pasture (Table 1 and Figure 2). Similarly, the under-tree *T. repens* (a sown species) decreased from 8% by weight before thinning to 3% by weight one year after thinning compared to the same species in the open pasture. On the other hand, the under-tree *A. capillaris* (a grass weed) increased from 27% by weight before thinning to 30% by weight one year after thinning compared to the same species in the open pasture. Again, the under-tree *U. dioica* (a forb weed) increased from 13% by weight before thinning to 20% by weight one year after thinning compared to the same species in the open pasture.

These results indicate that there were changes in the percent composition by weight of each pasture species after thinning compared to the treeless open pasture, suggesting that thinning does have some effect on the composition of pasture species in the short-term. However, results of the Pearson Chi-Square analyses show that the observed changes in both under-tree and open pasture species composition by weight is not statistically significant $\chi^2(1) = 2.0, p = 0.157$. 

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**Table 1. Percent composition of pasture species by weight in the study system**

<table>
<thead>
<tr>
<th>Species</th>
<th>Open Pasture</th>
<th>Treeless Open Pasture</th>
<th>Thin 1</th>
<th>Thin 2</th>
<th>Thin 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>L. perenne</em></td>
<td>17</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td><em>T. repens</em></td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><em>A. capillaris</em></td>
<td>27</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><em>U. dioica</em></td>
<td>13</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

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**Figure 2. Percent composition of pasture species by weight in the study system**

**Key**

- **=} tree
- **=} quadrat
Table 1: Mean percent composition by weight of pasture species in pre- and post-thinned treatments at Henfaes SNNE using the DWR method of pasture assessment.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>Under tree</th>
<th>Open pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean % composition</td>
<td>Mean difference</td>
</tr>
<tr>
<td></td>
<td>Pre-thinning</td>
<td>Post-thinning</td>
</tr>
<tr>
<td>SOWN SPECIES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lolium perenne</td>
<td>17</td>
<td>8</td>
</tr>
<tr>
<td>Trifolium repens</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>GRASS WEEDS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrostis capillaris</td>
<td>27</td>
<td>30</td>
</tr>
<tr>
<td>Holcus lanatus</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Poa pratensis</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Festuca pratensis</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>FORB WEEDS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urtica dioica</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Cirsium arvense</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 2: Relative percent composition by weight of pasture species from quadrat data before and after thinning (June 2013 – June 2014) at the Henfaes SNNE in North Wales, UK.
5. DISCUSSION

The results of this study indicate some inconsistencies in the short-term effects of thinning on understory pasture species composition and diversity. Results suggest that thinning had some effect on pasture species composition by weight between 2013 and 2014, though the change was not statistically significant. Thus, the hypothesis that thinning will not change the understory pasture species composition, abundance and diversity in the short-term (up to 1 year) was therefore not corroborated in this study. As expected, the percent pasture species composition by weight of the open pastures were similar before and after the thinning treatments compared to the under-tree pastures. These results clearly demonstrate the degree of variability which can occur in the short-term following thinning. This is to be expected as it is well known that pruning and thinning debris and tree foliage litter can shade/cover available pasture area or crush and smother understory flora and interfere with grazing (Kellas et al., 1995; Thomas et al., 1999; Benavides et al., 2009).

Thinning trees did not improve species composition and diversity of under-tree pasture in the short-term in this study even though previous research studies suggested it would. Enhanced species richness and diversity in response to thinning was observed in previous studies more than 3 years following treatment (Bailey et al., 1998, Thomas et al., 1999; Thysell and Carey 2001; Brockway et al., 2002; Ducherer et al., 2013).

Though species richness remained the same for the treatments in the present study, there was a decline in the percent composition by weight of the sown species and a slight increase in both grass weeds and forb weeds one year after thinning compared to the adjacent open pastures. The increase in percent composition by weight of grass weeds and forb weeds after thinning was expected, which agrees with the Thysell and Carey (2001) who reported that exotic species were more abundant within 1- and 3-years following thinning in Douglas-fir forests.

The most consistent difference in species composition was a greater content of Agrostis capillaris and Urtica dioica in the under-tree pasture. The change may be short-term disturbance impacts due to removal of trees, which agrees with previous research studies by Ducherer et al. (2013) who reported that thinning had little effect on the understory species richness and diversity of ponderosa pine and Douglas-fir tree compared to the pasture control. Thomas et al. (1999) observed that thinning could crush and smother understory flora, while other research has upheld that extensive site preparation for tree cutting can have detrimental effect on the amount of surface, organic matter (Jurgensen et al., 1997). Tree in-growth have also been reported to have damaging effects on many understory species (Page, 2002).

On the other hand, disturbance occasioned by thinning can increase the availability of new microsites for plant establishment and growth, possibly leading to increased species richness (Brockway et al., 2002). It is common for understorey pasture species to respond to increases in light following thinning. Since understory vegetation responds to increased light, the greatest response to the increases in light following thinning are expected within the first several years (Thomas et al., 1999).

Citing previous studies by Bailey et al. (1998) and Thomas et al. (1999), Ducherer et al. (2013) reported that thinning trees enhances understorey species diversity, but that the increase usually occurs more than 10 years after thinning. Thinning had little effect on the understory species richness and diversity of ponderosa pine and Douglas-fir tree the first 4 years after treatment compared to the pasture control (Ducherer et al., 2013). Species richness improved within three years in a repeatedly thinned Douglas-fir forests in the Pacific Northwest of the U.S after early decline one year after thinning (Thysell and Carey 2000; Ducherer et al. 2013). Species richness was also reported to have improved two years after thinning in pinyon–juniper forests in central Mexico (Brockway et al. 2002; Ducherer et al. 2013). Bailey and Tappeiner (1998) reported similar improvement in shrub cover 10 to 25 years following thinning in Douglas-fir forests. Short term increase in species richness has been linked with exotic species and high treatment intensity (Griffis et al. 2001). Metlen et al. (2004) suggested that the short-term effect of thinning could be as a result of adaptation of the environments to minor disturbances.

Thinning disturbances and tree in-growth have been reported to have deleterious effects on many understory species as both can reduce the composition and abundance of many understory species,
depending on whether the species is a pioneer, a light demander, or a shade tolerant species. (Page, 2002; Ducherer et al, 2013). Therefore, thinning treatments should be applied with care.

Therefore, short impact of tree removal on understory pasture species composition, along with cold winter season, minimum disturbance to the soil during thinning using chainsaw, and relatively low tree density before thinning in this study at the Silvopastoral Network Experiment may have contributed to the observed changes in understorey species composition by weight one year after thinning treatment. The knowledge of the dynamics of pastures in response to thinning treatments is critically important for grazing enterprises as it can help livestock managers adopt sound pasture management strategies for adjusting stocking rate, increasing carrying capacity and pasture productivity.

6. CONCLUSION

The responses of pasture species to thinning in this study was variable. The percentage composition by weight of the sown species declined, while that of the grass weeds and the forb weeds increased slightly one year after thinning compared to the adjacent open pastures. Again, the greatest composition of the weeds was observed in the open pasture. The hypothesis that thinning will not influence understory pasture species composition, abundance and diversity in the short-term was therefore rejected in this study. It is evident from the results that there were little changes in pasture species composition one year after thinning compared to the open pastures, suggesting that minimum disturbance to the soil during thinning using chainsaw, together with cold winter condition and relatively low tree density before thinning in the study area, may have contributed to the minor change. Consequently, it is expected that the availability of new microsites essential for plant development as well as the response of the understorey to increased light, as a result of more open canopy (less shade), would eventually lead to increased species diversity and abundance within the first few years. These results indicate that there were changes in the composition by weight of the pasture species after thinning compared to the treeless open pasture, suggesting that thinning does have some effect on the composition of pasture species in the short-term.

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8. REFERENCES