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ESTABLISHMENT AND PRODUCTION FROM THINNED MATURE DECIDUOUS-FOREST SILVOPASTURES IN APPALACHIA

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Abstract: Past research has not adequately addressed effective management and utilization of silvopastures developed from the ubiquitous mature woodlots which comprise 40-50% of small Appalachian farm acreage. While some grazing in woodlots is common, a set of guidelines for optimal utilization of these areas is not. We thinned a white oak dominated mature second growth forested area establishing two 0.5 ha, eight-paddock, orchardgrass-perennial ryegrass-white clover silvopasture replications for comparison with two nearby open pasture replications. After thinning trees, silvopastures were limed, fertilized and seeded. Sheep were fed hay and corn scattered across the area to facilitate removal of residual understory and incorporation of applied materials into surface soil. We measured soil moisture in the top 15 cm using TDR and photosynthetically active radiation (PAR) using a system of 16, 1 m line Quantum Sensors during the subsequent growing seasons of 2004, 2005, and 2006. Paddocks were rotationally grazed by sheep with two 1 m^2 herbage mass samples taken prior to animal grazing. There was no significant difference in soil moisture between silvopastures and open pastures however, there was adequate rainfall to prevent drought all three years. The two silvopasture replications had residual tree stands of 14.1 and 15.6 m^2 ha^{-1} diameter breast height allowing 42 and 51% of total daily incident PAR compared to measurements in the open field. Total forage mass yield from open pasture for 2004, 2005 and 2006 was 9.9, 10.5 and 10.2 t ha^{-1} respectively and for silvopasture 8.5, 6.7 and 6.7 t ha^{-1}. Silvopastures received 47% of open pasture incident PAR yet yielded an average of 72% as much herbage mass as the open pastures. The silvopasture soils were managed for forage production only a few years unlike the open pastures which received roughly a century of better management. Soil limitations may have contributed to decreased forage yield in silvopastures in addition to reduced PAR.

Kew Words: C_3 forage, PAR, rotational grazing, sheep, woodlot

INTRODUCTION

In recent decades there is an emerging interest within the Eastern U.S. in developing deciduous-tree based silvopastoral systems to increase and diversify the income of small farms. These systems also provide potential environmental services such as microclimate modification for forages and livestock, improved wildlife habitat, and capture and recycling of nutrients leaching below the forage root zone. A number of research projects have developed silvopastures in the last three decades by planting trees such as

black walnut (*Juglans nigra* L.), black locust (*Robinia pseudoacacia* L.), or honey locust (*Gleditsia triacanthos* L.) into existing pastures as one strategy for studying optimal management.

Little has been done to develop silvopastures from existing forest because throughout the 20th century forest management increasingly emphasized wood production at the expense of other traditional products (Garrett et al. 2004). Animals are frequently allowed access to deciduous woodlots although little is done to manage these for forage production. In fact, Chandler (1940) states "It is widely recognized that the grazing of farm woodlands in the eastern United States is an undesirable practice". However, there are many small farms in Appalachia with woodlots that are little utilized and farm income could be increased if guidelines were available for conversion of a portion of these lands into productive silvopastures.

MATERIALS AND METHODS

The research site was on a small hill-farm in southern West Virginia, USA (37°46'W 81°00'N 860 m.a.s.l.). The soil was a Dekalb (fine sandy loam, mixed, mesic Typic Hapludult). Two 0.5 ha silvopastures were established within a white oak (*Quercus alba* L.) dominated mature second growth forested area using a method described in detail by Neel et al. (2007) for a conifer forested area.

In summary, the forested area was thinned to the desired stand density, fenced, and mob grazed by sheep to remove the understory vegetation and break up the litter layer. Additional hay and corn was scatter over the area to ensure uniform site preparation by animals. The sheep were removed and the area limed, fertilized, and seeded with a mixture of orchardgrass (*Dactylis glomerata* L) white clover (*Trifolium repens* L.) and perennial ryegrass (*Lolium perenne* L.). The area was again scattered with hay and corn and sheep introduced to trample in the forage seed. Rep one (S1) was established in 2002 and rep two (S2) in 2003.

Both sites were fenced into eight grazing sub-paddocks along with two nearby open pasture sites (O1 and O2) for comparison. All four sites were rotationally grazed by sheep during 2004, 2005, and 2006 with two 1 m^2 herbage mass samples taken from each sub-paddock prior to animal grazing. Tree diameter at breast height (DBH) was measured for all trees within the silvopasture paddocks during the summer of 2006.

Soil moisture was measured for the top 15 cm in a 24 point grid in all four sites whenever more than a week passed without precipitation using a TRIME-FM portable TDR soil moisture meter (MESA Instruments, Medfield, MA). Photosynthetically active radiation (PAR) was measured for a week period several times during the summers of the study period using a system of 16 LI-COR LI-191-SB line quantum sensors (LI-COR, Lincoln, NE) and 21X data loggers (Campbell Scientific Logan, UT).

During an overcast summer day with full tree foliage expansion, upward hemispherical images were photographed in the center of each grazing sub-paddock using a Nikon Coolpix 995 digital camera with a Nikon FC-E8 Fisheye Converter and a self-leveling mount. Images were analyzed for open sky percent field-of-view and potential direct-beam transmitted solar radiation through the tree canopy as a function of day-of-year (DOY) using WinSCANOPY software (Regent Instruments Inc., Quebec Canada).

RESULTS

There was adequate precipitation to prevent drought all three years resulting in only 6 measurement dates where there had been no precipitation for over a week. One open field and one silvopasture had a slight north facing slope and one of each had a slight south facing slope. The data from all years were pooled and an analysis of variance showed no significant difference between silvopastures and pastures (Table 1). However, there was a slight but significant difference between north and south slopes.

Table 1. Average soil moisture for periods without rainfall for over a week comparing north (S1 and O2) with south (S2 and O1) sites and silvopasture (S1 and S2) with open (O1 and O2) pasture.

Soil Moisture (% by vol.)		
North	South	(p)
25.9	23.2	.05
Silvopasture	Open Pasture	(p)
25.0	24.1	.53

The S1 paddock had a slightly smaller total tree DBH than the S2 paddock and correspondingly had a slightly greater percent open sky in the above ground field-of-view (Table 2). Measurements of PAR were not done on the same days for the two silvopasture reps. Measurement of PAR in the open from an automated weather station showed the days when S1 paddocks were measured PAR was attenuated to 64 % of maximum possible but on days when S2 were measured the attenuation by clouds resulted in 55% of maximum possible. The actual PAR received is influenced both by differences in shading and differences in weather between measurement periods. Comparing differences in forage response to shading for different regions is therefore confounded by climate differences on a long and short term basis.

Table 2. Silvopasture tree basal area, resulting percent open sky in the field of view above forages, measured PAR in an open field as a percent of theoretically possible (With Clouds), percent of actual incident PAR received by forages (Under Trees), and percent of maximum possible PAR received by forages (Actual).

			Photosynthetically Active Radiation (PAR)		
Treatment	Basal Area (m^2 ha^{-1})	Open Sky (%)	With Clouds (%)	Under Trees (%)	Actual (%)
O1	0	100	64	100	64
O1	0	100	55	100	55
S1	14.1	22.4	64	42	27
S2	15.6	21.0	55	51	28

Measurement under the trees showed the forage on the northern slope (S1) received 42 % as much PAR as the open while the southern slope site (S2) received more, 52% of the open, even though there was slightly less open sky in the forage field of view for the southern. This difference is partially due to the existence of an open lane to the south of the southern slope while there was only forest to the south of the northern slope.

The reason PAR under trees is much higher than the percent open sky is that trees cast the most shadow early and late in the day when solar radiation levels are much lower than midday. Gaps in the canopy nearly overhead make a disproportionate contribution to the amount of PAR received since the solar intensity is highest midday (Figure 1).

The yield from the silvopastures decreased relative to the open pasture in 2005 and 2006 more than in 2004 (Table 3). Over the three years, however, forage yield in the silvopastures was 72% of open pasture yield in spite of only receiving 47% as much daily PAR. This is consistent with the finding of Feldhake and Belesky (2009) that partially shaded forages utilize PAR much more efficiently than open-pasture grown. In open fields, C_3 forages do not efficiently utilize the high solar radiation levels found on cloudless days which opens the possibility of economic gain by capturing it with a tree-based crop.

Table 3. Season yield for the silvopasture compared to open pasture treatments.

	Yield (t ha^{-1})	
Year	Silvopasture	Open Pasture
2004	8.5	9.9
2005	6.7	10.5
2006	6.7	10.2

Figure 1. Photograph from a sub paddock at silvopasture rep 2 (S2) using a hemispheric lens showing how overhead gaps dominate the percent open sky at a given site. This site is 21% open sky overhead.

CONCLUSIONS

Dense maturing regrowth deciduous forests thinned to obstruct 78% of open sky in the field of view allowed 47% penetration of daily incident PAR and reduced forage production only 29% compared to open pasture. However, the pasture sites with which they were compared had soils managed for forage production for about a century and the sites left in forest were considered inferior for pasture. The silvopasture soils had only been limed and fertilized for a few years. Incident PAR for C_3 forage production may not have been the only limiting resource.

Disclaimer: Mention of equipment does not imply endorsement by USDA-ARS but is supplied to inform readers of how data was acquired.

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