

ABSTRACT

WYMORE, TEISHA LIANNE. Use of Goats for Vegetation Control in Young, Pine Plantations. (Under the direction of Dr. Frederick Cabbage).

Agroforestry presents an opportunity to increase land productivity and improve cash flow by combining variable income streams from agriculture, forestry, and animal production on the same piece of land. The specific objectives of this integrated research were to assess and demonstrate sustainable operational protocols in goat and forestry management, to measure how browsing affects desired and undesired forest vegetation and economically valued tree species, identify browse preference, and integrate sustainable agricultural practices and promote best management practices for woodlot owners.

The research site was located in Bahama, North Carolina, an area adjacent to an urban population of Durham County (N 36° 11' 57" W78° 53' 43"). The research area is a 6.9 hectare loblolly pine (*Pinus taeda*) forest that was planted in 2000. Half of the site was treated once with herbicide and the other half (untreated) represents a mixed-planted pine forest with a large hardwood natural regeneration component. Pre-treatment measurements included understory species identification, diameter of crop tree by species, biomass clip samples, and cover density sampling. Sampling occurred between July and August 2009.

Sixteen yearling *Boer* goat (*Caprus hircus*) wethers were used, eight goats per treatment. Pre-trial FAMACHA, body weights, and FEC measurements were taken on each subject. For each treatment, four equal-sized plots (0.10 ha) were hand-cut to reduce damage to tree crops and were tagged and fenced with portable solar-charged electric net-fencing. Post-treatment measurements included vegetation cover-density screening and goat health checks.

The findings indicate that goats effectively removed unwanted brush to an acceptable level (< 50%) up to a height of 1m to 1.5m without damage to the residual crop trees. When given a variety of forage, goats preferred browsing fruiting or flowering shrubs such as blackberry cane or sumac. They chose hardwood tree saplings, vines, and grasses before selecting pine trees. The larger trees, greater than 2 cm in diameter, were largely undamaged due to strict animal management and forage availability preferences.

The mature goats remained healthy and actually enjoyed the forest environment, and maintained similar weights during the 60 day experimental period. The role of goats as biological control agents may become more important due to environmental concerns and elevated costs of other control methods such as mechanical cutting and herbicide application. They also can provide food and income as well for farm producers.

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Use of Goats for Vegetation Control in Young, Pine Plantations

by
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DEDICATION

This work has been a long journey. Many months of blood, sweat and, most of all, tears were poured into the work that resulted in these pages, and for that, I want to dedicate this work to the goats who gave their lives to research, who were my friends and confidantes, and who gave me so much more than a research paper or a degree by just being goats. I love them all.

I was so fortunate because my family has supported me through the entire process; thus, I dedicate the end result, my degree, to them. My Dad, who patiently accepted my frantic phone calls and answered all of my emails without making me feel like an idiot; my mom, who listened to my crying and moaning, and who cheered me through the emotions, and sometimes even cross-country visits that accompanied this work; and finally, I would owe any academic verve passed onto me to my grandfather, Dr. A. Wayne Wymore. Thank you for being a role model and a scholar, and for providing me with courage and just enough guilt to get me to go through this all over again!

BIOGRAPHY

Ms. T. Lianne Wymore lives with her two dogs, Griffon and Dolly (who at this time are just 1-year old), in Durham, North Carolina. Teisha, a west-coast native, came to live in North Carolina with her (ex) husband Robert Murray to escape the high cost of living in San Francisco, where the two had met and lived together with Teisha's dog, Sasha. It was Sasha who was the common thread through most of Teisha's adult life. Having lived with her in over 10 different locations in just over a decade, Sasha and Teisha were as close as a badger and a frog! They had a love-hate relationship that was a true testament to the unconditional bond that humans and canines share. Ms. Wymore was born in Tucson, Arizona, to teenaged parents, Farrell and Georgiana Wymore. Farrell, a young musician, and Georgiana, a high school junior, were forever bonded by the unexpected birth of their first child, Teisha-Lianne.

Upon getting his Master's degree, Farrell and family moved east to follow the blooming high-tech industry in the early 1970s. It was then that Teisha experienced living in North Carolina as a child, playing with her younger brother Bryan (who later played a significant role in her life in the city of San Francisco) and feeling that wonderment of the natural beauty of the region was never forgotten. Having lived in most tech-hubs across the USA, Teisha has a broad experience in adaptation. She attended high school in Austin, Texas, and then moved to San Francisco, following her father's path to Silicon Valley. Ms. Wymore attended and graduated from San Francisco State University, then, after taking a year off to travel and explore the world, sow oats, and experience life, she began a career as a consultant at Andersen Consulting.

Working as a low-level grunt, she quickly understood how businesses like that thrived, and while she continued on to more traveling, she plotted her next move into the world where she would feel most at home through her love of food. While working for various software start-ups and wealth management companies, Ms. Wymore rubbed shoulders with the hardest working people in the fast-paced, high-tech world of Silicon Valley until she finally pursued her dream of owning her own business. She opened a catering company and worked with her boyfriend to create a successful restaurant and catering business—Picnic Dining. It was here where Sasha entered the picture and the pair were inseparable.

While the dot.com crash was taking prisoners, Ms. Wymore managed to stay afloat using her earlier marketing skills to support herself once again in the high-tech world, but this time, at the front line of a huge corporate business headed for Chapter 11. She spent several years as a personal assistant and liaison to the Chairman of the Board of this company and learned the intricacies and delicate, highly-guarded nature of being at the top of a large, multinational organization. And there she met Mr. Murray, her soon-to-be husband. Rob was a laid-back guy who wasn't swimming in the circles she was used to; he was a surfer from Canada—just what was missing from the tight-laced life she had in corporate American culture. The two quickly fell in love and moved in together after Sasha put Rob through rigorous testing and trials of commitment. The three were inseparable. As time went on, the little family found life in the city to be too much for what they sought out. Water, space, nature, and the long-remembered memory of North Carolina came calling. Rob got a job at the top software company in the Research Triangle and they moved—never looking back.

Teisha began graduate school after realizing that if she ever wanted to reinvent herself, the time was right! There was no doubt that NC State was the choice because it was exactly the atmosphere she sought. Big school, lots of energy and most of all, it was an agriculture school, and that was her first love—animals. It was through a mutual friend that her work with the goats at NCSU changed her life forever. Up to this point, she'd only dreamt of being on a farm and this experience was, indeed, a dream come true. During graduate school, she started working on Food Systems programming with the Center for Environmental Farming Systems where she found her niche, and her career change was made.

She is now leading a statewide consumer marketing program that encourages local food procurement, consumption, community awareness and economic development through sustainable agriculture in North Carolina. This program is a model for increasing local foods' market expansion in procurement in institutional and corporate settings and is being transferred to other states—a huge win for CEFS, and Ms. Wymore couldn't be more proud.

ACKNOWLEDGMENTS

Some may call it an anchor, and others may call it an albatross; for 5 long years I called it the weight-of-the-world. The education of obtaining a Master's Degree for me, at this stage in my life, is not just of the discipline of academic learning, course work and research, but also in large part, it was a life's lesson and each person I'd like to acknowledge here played a role in giving me something that made a life-long impact.

First, I acknowledge the goats that gave their lives to further our understanding of them through academic research like mine—truly, the best experience of my life was being in their company in the silent woods someplace in my mind that was far, far away from North Carolina; I will never know a more peaceful feeling. They taught me so much, and I am grateful for that every day.

I have to acknowledge two people who were directly responsible for my research focus and for my ever growing love of goats; without them, I would not ever have known how wonderful goats are. Heather Glennon, I can't quite describe the impact you made on my life. Maybe it was the mountain of goat poop and blood we analyzed while “doing science” or the working-with-livestock education you patiently gave a city girl like me. Of course, my favorite part of our time together were the early mornings we spent with our girls in the pasture—physical labor was never so much fun. I'll never forget what you brought to my life, and I thank you.

Dr. Jean-Marie Luginbuhl has also been pivotal in my work with goats at NC State. I have learned a lot working with you at the SRU, and I appreciate your continued patience

and guidance through this whole experience. Your lovely wife Silvana has also been a big supporter of mine. Thank you both.

Because so many major life events occurred during this work, I feel as though I've lived a few completely different lives through its duration and many of my family at CEFS (Center for Environmental Farming Systems) have been there with me, in particular, my mentor and friend, Dr. Nancy Creamer. As the years went by, you went from gentle nudging to mom-like pushing me, and as difficult a time as it was for me, you were always willing to work with me through all of it—a true friend. A million “Thank yous” to you, Nancy, you've changed my life in more ways than you know. In General, CEFS is a family more than an organization. All of my work-family members there have supported me and I love them all.

During the hot months of summer when my field research began, we had our work cut out for us. Literally, working with machete and compass to cut through the forest, building what would be my “home” for the summer, there was one person that stands out as being the engine of that summer work—Charlie Lawrence, a guy from Goldsboro nearly 20 years my junior who could not have made a better pair with me. You taught me not to fear the spider but to power through and not worry about the spider! Thanks, CLAW, for showing me that power.

Despite going through the mental anguish and pain of a divorce during this degree program, I want to thank Rob Murray my (ex) husband, who was a big help and support to me emotionally and who reminded me daily that I can make this happen even through adversity. Thank you, Rob.

I also need to give a huge thank you to my dear, dear departed best friend Sasha, my husky dog, the love of my life, my companion, and my support system for over a decade.

I appreciate the mentorship and continued support of Dr. Fred Cabbage, my Committee Chair and advisor. Fred has been instrumental in my graduate work since day one and has never quit on me despite all of the incredible events and insurmountable odds of never finishing that I'll leave out here. Fred has been the first person to support me all the way and does it with a smile and that dry wit I admire. Thank you, Fred.

Dr. Bob Kellison joined my committee late but was crucial to helping me become a better writer! I appreciate your patience and kindness Bob. Thank you.

Finally, I want to thank my dad for helping me with this work. I am so happy to have you in my life, dad. You have always been my voice of reason.

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CHAPTER 1: INTRODUCTION

Agroforestry practices in agriculture present an opportunity to increase land productivity and diversify cash flow by combining variable income streams from agriculture, forestry, and animal production on the same piece of land (Clason & Sharrow, 2000; Hamilton, 2008). It combines agricultural practices and forestry techniques to create more diverse, productive and sustainable land-use systems. Practices focus on satisfying economic, environmental and social objectives held by landowners (Sharrow, 2000; Workman, Monroe & Long, 2005). Such systems like Silvopasture, for example, are deliberately designed and managed to produce a high-value timber product (such as sawtimber) in the long term while providing short-term economic benefit from a livestock component (Hamilton, 2008). By farming three-dimensionally using agroforestry techniques, landowners can increase useable acreage and benefit from a diversified system (USDA NAC, 2008).

The Southeastern United States contains the largest percentage of farm and private forest ownership in the country (NASS, 2001). The role of goats as biological control agents may become useful in plantation forestry settings in the future due to environmental concerns and elevated costs of traditional weed and forbs vegetation control methods such as mechanical cutting and herbicide application. The specific objectives of this integrated research project were to assess and demonstrate sustainable operational protocols in goat and forestry managements to measure how browsing affects desired and undesired forest vegetation and economically valued tree species; to optimize animal stocking rates in wooded areas; to measure goat health in a forest setting; to identify browse preference; and to

integrate sustainable agricultural practices as well as to promote best management practices for woodlot owners.

CHAPTER 2: LITERATURE REVIEW

The success of modern agricultural and forestry production can be largely attributed to monoculture systems using a few select species (Nair, 2009). In the drive for maximizing yield and profit, the age-old tradition of using combined farming systems was essentially avoided and, in some cases, this has resulted in environmental problems such as land and water degradation and increased land clearing (Clason & Sharrow, 2002; Nair, 2004; Sharrow, 1997). During the last 30 years, however, there is an emerging body of literature on the adoption of agroforestry based on two influences: economics and legislation in favor of incentives, specifically for small to mid-sized holders of diversified forest and farmland (Cubbage et al., 2012; Cutter, Hunt & Haywood, 1999a; Frey et al., 2007); and to manage and improve natural resources on their land (Beetz, 2002; Peters, 2000).

One central theme in agroforestry is that productivity is higher in agroforestry systems compared to monoculture systems (Clason & Sharrow, 2002). The positive benefits of agroforestry to the environment have also been increasingly recognized worldwide, and practitioners are positing that livestock and tree crops can not only co-exist, but if properly managed, can provide additional income from land formerly used for a single crop (USDA NAC, 2008). General strategies for designing sustainable agricultural systems include

- 1) Diversification of plant species to enhance farm biological and economic stability
- 2) Use of plants/animals well suited to farm soil and climate
- 3) Preference for farm-generated resources over purchased inputs
- 4) Tightening nutrient cycles
- 5) Livestock management: stocking rate appropriately scaled to parcel size

- 6) Soil conservation and improvement practices including cover crops
- 7) Rotations that include deep-rooted plants to utilize nutrients deep in the soil profile
- 8) Natural and sustainable methods for controlling weeds, pests, and diseases
- 9) Controlled use of livestock manure and nutrient positive legumes to replenish nutrient losses
- 10) Creation of an overall net-positive effect on the environment

These strategies, based on naturally occurring ecosystems, are intended to be economically viable, socially acceptable, and biologically sound (Sharrow, 1997). Key characteristics that distinguish agroforestry systems from agriculture and forestry include greater structural and functional complexity, an emphasis on multipurpose trees, and the production of multiple outputs (Nair and Graetz, 2004).

Environmental Benefits

The role of agroforestry in protecting the environment and providing a number of ecosystem services are promoted as key benefits of integrating trees into farming systems (Nair, 2007). As traditionally employed, these benefits were intuitive to the farmers and landowners that managed agroforestry systems, although the scientific evidence to support these benefits is only now coming to light through research on environmental benefits and ecosystem services such as carbon sequestration (Nair & Graetz 2004; Nair 2007).

Soil

Soil management is a key feature of agroforestry systems, and in both tropical and temperate climates, agroforestry systems are designed and implemented to counter soil

erosion and degradation, and improve soil quality and health (Cutter et al., 1999a; McAdam, Sibbald, Teklehaimanot & Eason, 2007).

Evidence exists of accelerated erosion and increased run-off in many agricultural areas where replacement of natural forest and grasslands by croplands has been implemented (Nair, 2007). As well as increasing structural stability of the soil, tree roots can enhance water filtration and improve water storage by increasing the number of soil pores. In this way, the risk of soil erosion is reduced through tree roots acting as physical barriers to reduce surface flow of water and sediment (Pollock, 2008). By promoting a closed system with internal recycling of nutrients, where nutrients are accessed from multiple soil horizons by tree roots and returned to the soil through leaf fall and organic matter, agroforestry systems enhance soil nutrients and reduce reliance on external inputs (Pollock, 2008; Sharrow 2007).

In a meta-analysis on the adoption of agroforestry practices worldwide, Pattanayak, Mercer, Sills and Yang (2003) concluded that there are five categories that determine the adoption of agroforestry. The first category is preferences, or farmer-specific influences including risk tolerance, attitudes toward conservation, and characteristics of a household (including age, gender, education and social status). Other categories that determine adoption include resource leverages (assets like land, labor, livestock); market incentives (prices, availability and access to markets, transportation, and potential income loss or gains); biophysical factors (soil quality, slope of farmland, plot size); and risk and uncertainty (short-term risks like fluctuating commodity prices and long-term risks like land tenure).

In many parts of the world, the system offers farmers and small landowners the advantage of crop diversification, fuelwood and fodder production, erosion control, and

increased soil fertility (Bazill, 1987). In developing countries, agroforestry offers alleviation from poverty by providing food security and arresting degradation of marginal lands that affect over one billion hectares and over 800 million people (Nair, 2007). In the United States, a nationwide survey of Natural Resource Professionals was administered in 1995 and determined that 20 of 50 states offered legislation related to Agroforestry practices, including tax incentives like cost-sharing (Cutter et al., 1999b). This suggests that landowner adoption may be related to policy. Frey et al. (2007) examined silvopasture adoption in Argentina where large scale agroforestry is widespread among large landowners and found that a significant number of farmers said their adoption of the practices was influenced by cost-sharing and subsidies programs available from the government.

Silvopasture Systems

Silvopastoralism intentionally integrates trees, forage crops, and livestock into a structural practice of planned interactions (Clason & Sharrow, 2000). This system represents an integrated land use that combines elements of agriculture and forestry in a sustainable production system (Sharrow, 1997). The emphasis is on managing rather than reducing complexity.

Silvopasture systems are deliberately designed and managed to produce a high-value timber product in the long-term while providing short-term annual economic benefit from a livestock component through management of forage or annual crop component (Nair, 2004). Well-managed silvopasture systems may provide many additional benefits including the following: improvement of overall economic performance through diversification and maintaining biodiversity; maintenance or increase crop tree growth; improvement of cool

season grass production; provision of shade and shelter for livestock; production of short term revenue through non-timber forest products such as pine straw and mulch; an increase wildlife population; and improved water quality and reduce run-off (Nair, 2004, 2009; Sharrow, 2007; USDA NAC, 2008).

In the southern United States, controlled grazing studies have been underway for over 30 years examining various management scenarios (Pearson et al. 1995, as cited in Zinkahn & Mercer, 1997). However, in many areas, the practice of forest grazing is slow to become common practice (Cutter et al., 1999a).

Loblolly Pine in Silvopasture

In the Southeastern United States, there are four major pine species grown for production including slash pine (*Pinus elliotii*), longleaf pine (*P. palustris*), shortleaf pine (*P. echinata*) and loblolly pine (*P. taeda L.*) (Clason, 1999; USDA, 2008). Loblolly pine has the second largest range of the southern pines, growing naturally on the coastal plain from New Jersey to Florida and west to Texas, throughout the Piedmont, and into Tennessee, Arkansas, and Oklahoma. The main uses of loblolly pine are for softwood lumber and chips for pulping, depending on the size of the tree harvested (Clason, 1999). Because of its site adaptability, high yields and ease of seed production, it is the most widely-planted and utilized pine in the South. During the first five to ten years, height growth may average 0.7 meters per year (Sharrow, 1997). Typically, loblolly pine has the fastest growth of the production pine species and is suitable to plant in a variety of soil types including well-drained upland areas or clay soils. Loblolly pine has more branches and produces more shade than the other southern pine species, making it ideal for agroforestry application.

During the first three years after planting, competition from hardwoods often reduces height growth and kills young pine trees. For this reason, intentional spacing for optimal growth and root clustering is important when developing a silvopasture system (USDA, 2008). Closely-spaced trees restrict equipment accessibility and sunlight to forage growing beneath trees while a double-row spacing 2.5-3.0 m (8-10 ft.) within rows and an alleyway of 6.1-12.2 m (20-40 ft..) can improve both forage production and offer optimal tree growth. A typical silvopasture system will have trees planted in a 3.7x3.7 m (12x12 ft) or 4.6x4.6 m (15x15 ft.) spacing (USDA, 2008).

Animal Welfare

Approximately 25% of all US forest land, primarily in the western states, is grazed by livestock (Sharrow, 1997). Trees are multifunctional in their provision of resources for animals; they provide shelter from rain and wind, shade from the sun, cover from predators, and a diversity of foraging resources (Beetz, 2002; McAdam et al., 2007). Shade is particularly beneficial to reduce high temperatures and humidity conditions that put severe stress on livestock, which can adversely affect weight gain, health and also contribute to increased death in newborn calves (Clason & Sharrow, 2000). Shade can improve animal condition, milk production, breeding efficiency, feed intake, and weight gain (Clason, 1995). Intense and controlled system management can be particularly valuable and can lead to significant savings in feed costs, survival, and milk production. For smaller livestock, wildlife and farm animals such as poultry, trees offer protection from aerial predators, in particular, and can provide an escape from aggressive behavior within the flock as well as reduce visual stimulation that can provoke aggression (Hart, 2001; Kijlstra & Eijck, 2006).

Economics

Integrating trees into the agricultural landscape has the potential to impact the local economy through increasing economic stability, diversification of local products and opportunity for increased labor and skills; improved food and fuel security; and improvements to the environment (Clason, 1995).

Economic research in agroforestry systems has shown that financial benefits are correlated to increasing the diversity and productivity of the systems, which are influenced by market and price fluctuations of timber, livestock and crops (Grado & Husak, 2004). In addition to higher yield potential of agroforestry, product diversification increases the potential for economic gain by providing annual and periodic revenues from multiple outputs throughout the rotation, thereby reducing the risks associated with farming single commodity crops (Clason, 1995; Cubbage et al., 2012). Several studies in the southern United States suggest that silvopasture can lead to moderate rates of returns comparable to alternative production systems (Clason 1999; Grado & Husak, 2004). Compared with exclusive forestry land use, agroforestry practices are able to recoup initial costs more quickly due to the income generated from the agricultural component, and, more specifically, as technological advances in maintenance and implementation of silvopasture systems are made, widespread adoption will become a more common practice for landowners (Grado & Husak, 2004).

Vegetation Control in Agroforestry Systems

Traditionally, landowners have only a few options available for vegetation management. These include fire, which may be an effective pretreatment for goats, but it can also be physically dangerous to surrounding land, people and wildlife. Other options for

control include mechanical, chemical and animal browsing (Hart 2001, Sharrow 1997). Mechanical methods of vegetation management include rollerchopping, root plowing, bulldozing, chaining or cabling, and mowing, all of which are quickly and dramatically effective, even if it is costly to maintain equipment and not suitable for areas where machinery cannot access terrain, such as steep mountain hillsides or swampy areas. Nevertheless, most of these methods are too expensive for small to medium sized landowners (USDA NAC, 2008). Chemical control of weeds has been effective in the past, but increased expense and risk of killing desired species can negate the practice (Hart, 2001; Lewis et al., 1983).

The Role of Goats as Biological Control Agents

Goats have been used for vegetation management in the United States for over one hundred years (Hart, 2008; Nair, 2004). Their use for this purpose is expected to expand dramatically in the future due to increased vegetation management problems resulting as a consequence of environmental degradation created by past systems of farming and grazing, and the increased expense of using conventional methods (Clason & Sharrow, 1997).

In the United States during the 1980s, a dramatic influx of goat production further increased the number of states with significant numbers of goats and goat producers, especially in the South. There is a need to further develop the technology of using goats to manage vegetation in the many different ecosystems common to the area (Hart, 2008).

Characteristics that Make Goats Desirable for Vegetation Control

Goats are especially adaptable to diversity in diet; many studies have observed that goats consume a wide variety of plants and selected browse that other livestock will not

utilize (Hart, 2008; Luginbuhl, 1999; Sharrow, 2007). Goats are resistant to many plant toxins and can digest plant matter with high levels of tannins. Research suggests that Condensed Tannins (CT) are effective in mitigation of parasites in ruminants (Luginbuhl & Mueller, 2000; Waghorn, 2008). Vegetation high in tannic properties that are often non-palatable to cattle are utilized by goats. This fact presents an economic advantage for using goats in an agroforestry system as a reduction not only in feed cost, but also in parasite control. Studies focused on intensive agroforestry production suggest that goats consume a predominance of browse (60-70%) and lesser grasses (20-30%) and forbs (Torrano & Valderrábano, 2005), although that proportion varies with availability, season, and management intensity. Sharrow (2007) suggested that sheep and goats prefer hardwood over conifer browse in research using Douglas Fir (*Pseudotsuga menziesii*) and Western Red Cedar (*Thuja plicata*) plantations, noting that season and tree age also affect browse preference.

Case studies summarized by Luginbuhl and Pietrosemoli (2007) provide evidence for hardwood browsing by kid goats in rotational grazing research in an upland hardwood forest conducted during a grazing period from July through December. During summer months, goats selected vines, primarily *L. japonica*, *Smilax sp.* and *Berchemia scandens*, but as the season changed and as vines became less available, the proportion of other browse increased. Forbs (broadleaf weeds) decreased significantly from the diet after three months, whereas grasses increased as the season progressed, suggesting that mature broadleaf weeds are less desirable. Goats selected acorns, dead leaves and pine needles as the increasing severity of the fall and winter changed the environment. Excessive damage to pine trees did not occur

until other forage was consumed during the fall and winter months when green forage was scarce. Further, they argue that while it was common for goats to eat the bark of some tree species, they will browse to vary their diet with little effect on the targeted plant population. Conversely, some plants may only be grazed when goats are forced onto them as a sole diet, which suggests management as a factor in controlling vegetation damage (Luginbuhl & Pietrosevoli, 2007). Luginbuhl et al. (1999, 2007) concluded that due to a strong preference for browse, some woody plant species may prove to be an important component of goats' forage systems. Goats readily consumed immature grasses but switched to browse when forage quality decreased with advanced maturity, selecting for optimum nutrient benefit.

There has been an accumulation of literature over the years on the use of goats for controlling various plant species such as invasive weeds and as an effective alternative to herbicides for clearing and maintaining firebreaks (Hart 2008; Luginbuhl & Pietrosevoli, 2007). This alternative has application for reducing fire fuel hazards on public lands and in urban areas where controlled burning or chemical application is prohibited (Hart, 2008). There are several innovative uses of goats for vegetation management including socio-economic benefit that promotes goats as useful to suppress brush that is too overgrown for wildlife such as whitetail deer (Hart, 2001).

In the southeastern United States, both farmers and forestland owners have introduced silvopasture onto their land. While there are no size limitations for production, typical operations are at least 16 ha (40 acres) in size due to economies of scale required for cattle especially, although small tracts are sometimes used with goats (Frey et al., 2007).

Research by Cornell University (Smallbridge et al., 2004) suggested the ideal stocking rate for optimization of brush control in a mature hardwood stand was 20 adult goats in a 0.10 ha paddock for 3 to 4 days. In this study, the objective was to observe the dietary preferences and health of goats in a woodland setting. Recommendations from the Cornell research include stocking adult goats in hardwood stands where the average tree diameter is >2.5cm to avoid girdling of the dominant stems (Smallbridge et al., 2003). Further, the research asserted that adoption of the practice for controlling unwanted vegetation was largely due to the goat herd owners' hesitation and lack of knowledge on how to manage for the objective of financial gain for this service. Results offering an example for intense goat management in agroforestry systems suggest that grazing in the pre-growing season has more of a negative effect on the saplings than grazing in post growing season, resulting in the reduction in stem diameter increase in both oak and ash saplings observed in a study by Sharrow et al. (1992). This research also found radial growth to be more sensitive to browsing than tree height in Douglas fir. This would also appear to be the case for hardwoods like oak (*Quercus spp.*) and ash (*Fraxinus spp.*) as concluded by McEvoy, and McAdam (2008).

Much of the literature suggests that the primary limitation for adoption of using goats as biological control for vegetation is the lack of an infrastructure that includes animal markets, a consistent source of quality animals, and goat producer experience (Hart, 2001). The knowledge base to support and increase inclusion of goat enterprises is a serious constraint that can be overcome as the goat industry expands (Hart, 2001). Echoing this rationale, studies in the Southeastern United States contend that adoption, and-or inclusion of

goats into an agroforestry system may simply be lack of resources and knowledge needed to effectively manage goats (Hart 2001; Smallbridge., 2004).

CHAPTER 3: MATERIALS AND METHODS

The project design was based on using limited resources for goat management and working with existing field conditions. The day-to-day field management was carried out by a single individual with occasional help from additional persons to replicate a real-life scenario for a woodlot owner as well as to provide enough management for tree crop growth and goat herd management.

The research site was located in a 6.88 hectare (17 acre) loblolly pine plantation within the G.W. Hill Forest located near Bahama, North Carolina, Durham County (N 36° 11' 57" W78° 53' 43"). The G.W. Hill Demonstration forest is a 991 hectare (2,450 acre) research forest established in 1929 and owned by North Carolina State University and managed by the Department of Forestry and Environmental Resources. This self-sustaining forest sells recreational permits for public hunting, hiking, bicycling, horseback riding, and fishing in addition to creating revenue through timber sales. Figure 1 shows the geographic location of the treatment site within the research forest. The inset map in Figure 1 depicts the loblolly plantation stand used in the research. Durham County, North Carolina, has a climate ranging from humid subtropical during summer months to a temperate climate in spring and fall. It has an annual average of 110 days of precipitation, accumulating an average of 121.92 centimeters (48 inches) per year (NOAA, 2011).

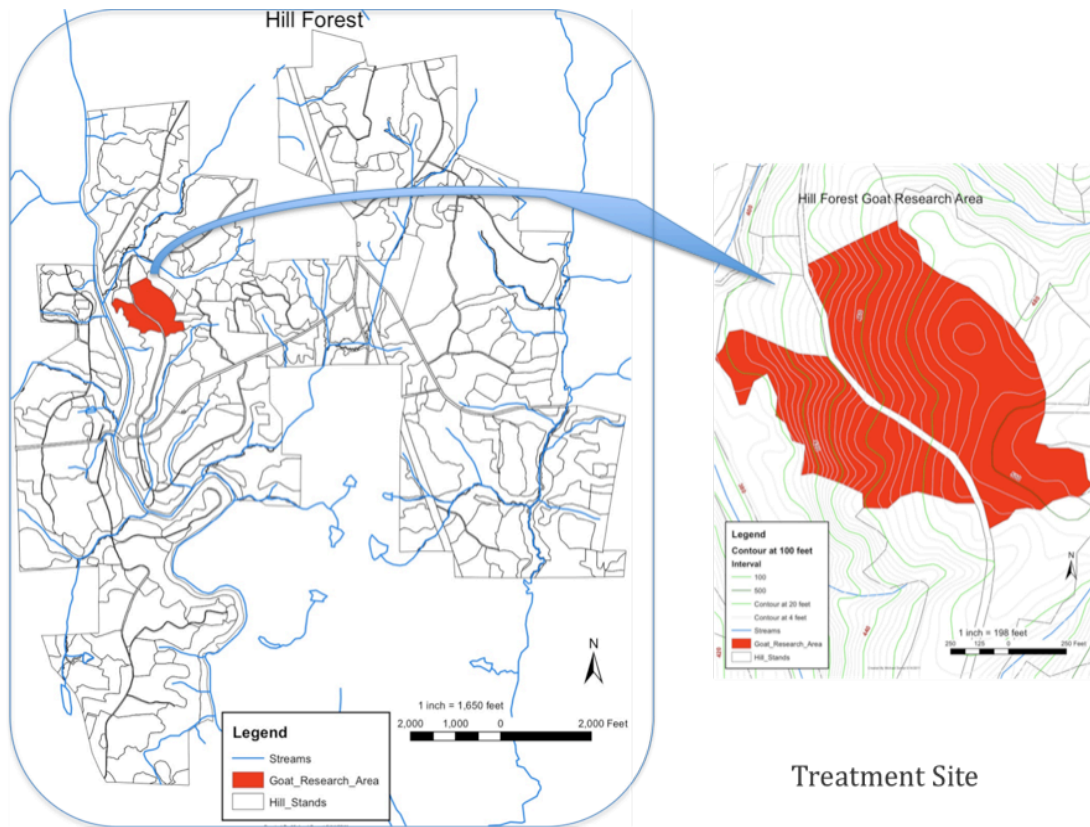


Figure 1: Hill Forest topographical map; Inset research location

Site Description

The treatment area within the 6.9 hectare (17-acre) research site were chosen based on stand age, proximity to road access, and previous herbicide treatment. Plantation crop trees, loblolly pine, were planted in 2000 and pre-commercially thinned. In 2004, about half of the 6.9 hectare (17-acre) stand was treated with Arsenal™ herbicide while the other half of the stand was left untreated. According to the product label, Arsenal™ may be used for

the control of undesirable vegetation in order to achieve one or more of the following vegetation management objectives:

1. The control of undesirable and noxious plant species.
2. The control of undesirable vegetation to aid in establishment of desirable plant species.
3. The control of undesirable vegetation for purposes of wildfire fuel reduction.
4. The release of existing desirable plant communities from the competitive pressure of undesirable plant species.

The stand is divided by an access road between the “Herbicide” and “Natural” areas we’ve designated as our “treatment area” for this research. The land contour has a slight slope facing west, which runs into a stream running in a north/south direction along the western edge of the herbicide-treated area. We established plots for the experiment that were approximately 182.3 m (200-yards) from the bottomland adjacent to the stream.

Experimental Design

The established pair plots study design (Figure 2) was based on the following criteria: proximity to the access road and a consistent topographical grade for ease of fencing. The access road bisected the treatment areas for ease of access to the animals and a nearby water source. Exact plot location was scouted to find the best area within the treatment site. We determined animal stocking rate based on the number of resources available to manage the herd in the remote location as well as through a process of equalizing the combined weight of the animals on each treatment. A total of 16 yearling Boer goat wethers were used in this field trial with eight goats placed in each treatment plot. Due to the number of animals used

and the length of the net fencing needed, we determined that a square was the optimal shape for each of the treatment plots.

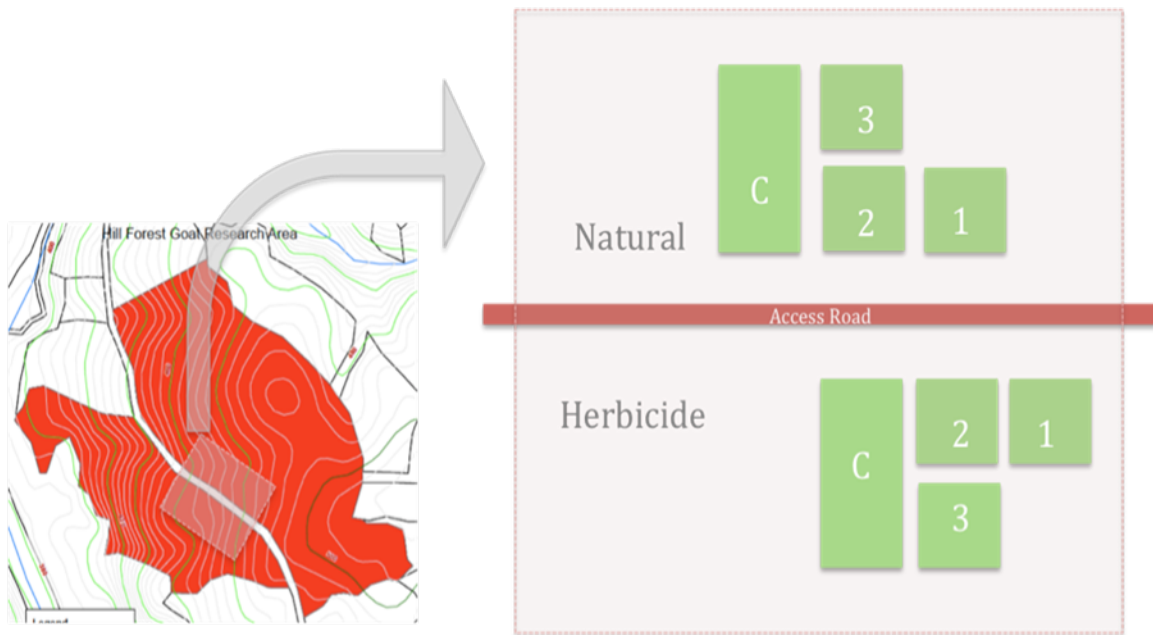


Figure 2: Treatment Plots Diagram

Research plots were measured and fenced at a 0.10 ha (0.25 ac) size, which were established for each treatment. The vegetation on the sides of the plots was hand cut at distances of 31.62 m x 31.62 m (103.7 ft. x103.7ft.) long. This plot size gave us ample room in the study area to do as many replications as necessary during the study timeframe. Because of limited access through the thick brush found onsite, we established three matched treatment plots and a control area for each on either side of the access road (Figure 2). These

were fenced with portable livestock electro-net fences: two measuring 45.72 m (150-ft) and one measuring 5.24 m (50-ft). A control plot adjacent to each treatment was measured and flagged but not fenced.

A 208 liter (55-gallon) plastic water barrel was used as a catchment tank, outfitted with a mesh top and a spigot on the bottom to fill water buckets. A barrel was placed along the access road adjacent to each treatment area (two tanks total). Water buckets were filled and hand-carried from the catchment tank to the goat plots. Drinking water troughs inside each plot were moved periodically to keep the goats from rooting and girdling nearby trees. Mineral supplement was kept in a waterproof box onsite and was provided to both treatments weekly. The supplements were moved periodically to encourage the goats to move around and not overgraze at one location.

Site Establishment

Prior to animals moving onto treatments, vegetation on each plot was cut by hand using machetes to avoid damage to the tree crops and to reduce cost of machinery typically necessary build a fence in the thick undergrowth of a forest. Ground preparation for each plot included fence line clearing using a machete, neon rolled flagging, and a compass; the next step was weed-eating with a brush saw to cut a three-foot-wide pathway for the electrified net fence placement. Brush and trees were cut in a straight line using a compass, and flagging was placed at 3.3 m (10.83 ft.) intervals to indicate the areas inside the plot where vegetation samples and measurements would occur.

Next, a portable net fence was unrolled and staked along the fence trail, creating the portable animal enclosure after cutting, clearing and flagging. A combination of two 45.72

m (150-ft.) and a single 15.24 m (50-ft.) livestock electro-net fence were used for each treatment plot. A 12-volt solar charger was used to electrify each plot enclosure. Pre-treatment vegetation measurements were taken immediately after the fencing was laid.

Water troughs for the goats were placed in the closest road access corner of the plot. Fence perimeters were walked and tested for any breach or potential failure. After the animals were moved on to the site and were acclimated, a portable solar-powered charger was situated on the ground facing the most southern part of the subplot fence line and was attached to the net fence and charged. A total of three same-sized subplots (.10 ha) were established on each treatment site, and the goats were rotated through the plots as subsequently described.

Vegetation Measurements

Field measurements of the vegetation were taken in each treatment and control plots. The measurements can be described as pre- and post-treatment measurements. An analysis of variance (ANOVA) was conducted using JMP software by SAS. Confidence intervals were estimated at 95% ($\alpha=0.05$). A consultant with the NC State University Department of Forestry and Environmental Resources provided statistical assistance. Analysis of variance was performed on all dry weight samples taken. Table 2 provides a descriptive statistical overview of the overall sample mean, standard deviation, standard error, and upper and lower percentiles for the dry weight samples taken across both treatments.

Pre-Treatment Measurements

Forage, cover density, and tree samples and measurements were taken prior to animals moving into a treatment plot. Using the fence-line flagging, sampling points were

determined by dividing each 0.10 ha (0.25 ac) plot into a quadrant. A transect was made within each quadrant to determine the center. This point was flagged in the branches of a plantation pine tree and exact compass coordinates of the center point were recorded.

Different plot measurements were established for tree, brush, and grass sampling, as well as for goat grazing density measurements.

Tree Sampling

For trees, a radius from the plot (quadrant) center point was measured at 5.63 m (18.5 ft.) in the Herbicide treatment and 3.51 m (11.5 ft.) in the Natural treatment. The radius was larger in the Herbicide stand, which had more well-distributed loblolly pine trees and not many other trees. The Natural stand had far more hardwood tree in-growth and many trees, so we used a smaller radius. Trees within this sample area measuring 2.5cm (1 in.) or greater diameter at 1.83m (6 ft.) were measured by species and recorded.

Vegetation Density Sampling

In each quadrant area within the sub-plot, a Cover Density measurement was taken from the center of the sample area. This technique is adapted from an NC State Wildlife Management study using a Vegetation Profile Board (Nudds, 1977) to determine the percentage of vegetation present. To do this, a vertical cover density cloth-screen was used for portability. The portable screen measures 2.5 m vertically by 1 m in width. The face of the screen had visible 10 cm (3.9 in) by 10 cm squares in an alternating black and white pattern. Height indicators were marked by a horizontal, orange line at half meter intervals within the screen for easy visual guidance; 0-0.5 m, 0.5 m-1.0, 1.0 m-1.5 m, 1.5 m-2.5 m. The screen was framed with 1.27 cm (½-inch) PVC pipes sewn into pockets along the edge

of the screen that when erected, allow it to be held up to its full height. Figure 2 shows a photograph of the Cover Density Screen that was used in the field.



Figure 3: Vegetation Density Screen

To take this measurement accurately, two people were required. When held upright, the screen was used to calculate and estimate of the percentage of vegetation cover density in front of the screen. One person stood at the transect center point holding the erect screen in front of them, facing one of four cardinal directions; North, South, East, or West. The second

person measures 9 m (30 ft.) in the same cardinal direction away from the screen, turned and faced the screen. A visual measurement was taken by counting the black and white squares visible from the 9 m distance. This count provides a visual estimation of the percentage of 'cover' vegetation obscuring the screen. Four measurements (representing each cardinal direction) are taken from each transect center point of each sub-plot. The resulting measurement used for each sample is the sum of the number of visible squares (black and white) on the screen representing a percentage of non-vegetation cover between the ground and 2.5 m (8.2021 ft.) vertically. The four values per sample were recorded for each plot and the mean was taken. Samples were taken from each plot over the three replications providing both pre-treatment and post treatment sample values.

Biomass Samples

An equal number of samples were taken from both Herbicide and Natural treatment plots. Biomass categories of forbs, tree, grasses and dead-matter samples were clipped using garden shears, separated by vegetation category, bagged, labeled, dried at 200 degrees Fahrenheit (93 degrees C), and weighed in grams.

Using the 3.1 m (10 ft.) interval flagging along the plot fence-line as a guide, sample sites were taken at nine areas within each plot. For this sampling, hedge trimmers, a 50ft measuring tape, a 6ft measuring tape, a 12-inch metal spike, (used as a center point for the measurement) and paper grocery bags were used. Each area sampled was represented as the reach and grab capacity of a goat browsing. Sample locations were taken at 9.14 m (30 ft.) by 9.14 m (30 ft.), 18.28 m (60 ft.) by 9.14 m (30 ft.), and 27.43 m (90 ft.) by 9.14 m (30 ft.) along all sides of the fence-lines and then at 15.85 m (52 ft.) by 15.85 m (52 ft.) in the center of the

plot within each of the 0.10 ha treatment plots. Control plots in both treatments were sampled in the same manner. We sampled three locations along the adjacent border from the treatment plots at a distance of 3.1 m (10 ft.) from the fence-line. No samples were taken along the access road side of a control treatment plot. A diagram of the plot sampling scheme for each replication-plot is shown in Figure 3.

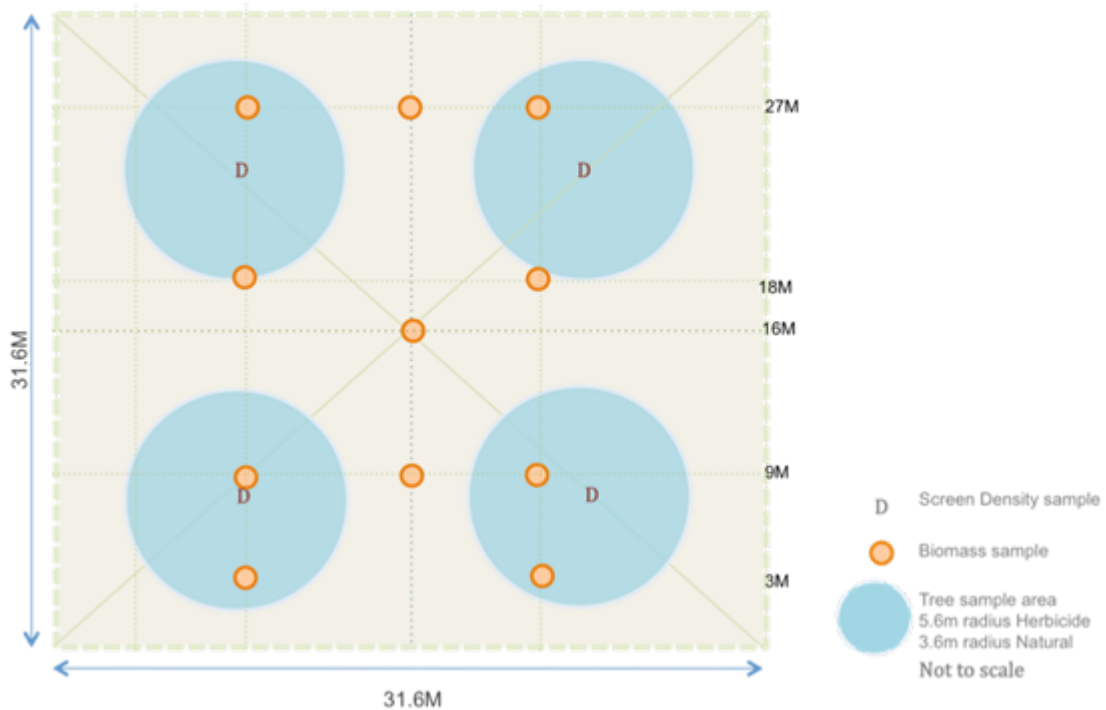


Figure 4: Plot sampling scheme

At each sample area, a radius was made using a 0.3 m metal stake and 2 m measuring tape. From the center point stake, a 55.8 cm (22 in.) radius was measured and a 9809.8 cm² cylindrical circular sample of vegetation was clipped at ground level. Then this radius was measured vertically, 121.92 cm (48 inches) from the ground. All vegetation in each sample area, 1196017.7 cubic centimeter cylindrical volume, was clipped and saved. ($\pi * (55.88 ** 2) * 121.92 = 1196017.7\text{cm}^3$ or 1.196m³).

All vegetation material within that cylindrical area was clipped using hedge trimming shears and placed in a paper bag. If a tree stem was centered within the sample area, the branches and leaves were taken but not the terminal stem. Following collection, paper collection bags were labeled using an identification code indicating the following information: Treatment type, Replication Cycle Number and Sample Location. Location ID is based on flagging locations along each plot perimeter (Appendix 1). Herbicide Treatment has an ID designation of (H) and the Natural Treatment ID, (N). The Replication Cycle ID is 1, 2, or 3. Sample Orientation ID is based on location within plot as oriented from the access road. Top (T), Bottom (B), Right (R), Left (L), and Center (C). Each sample collected included a location based on perimeter flagging set at intervals around the fence line.

Following animals moving off of a plot, a second Cover Density measure was taken in the same four locations within each plot as were used in the pre-treatment measurement.

Animal Measurements

Sixteen yearling Boer goat wethers with an initial mean weight of 41.1 kilograms were used in this field experiment. Animals were chosen from a larger herd and had been dewormed and given a complete physical a week before moving onto the field site. Each

animal had PCV (Packed Cell Volume) and FEC (Fecal Egg Count) tests run to determine the fitness of each. Each goat was also tested for anemia in the field using the FAMACHA scoring system. This method is useful when dealing with the *Haemonchus contortus* parasite. Because of concern to pasture-based sheep and goat production, FAMACHA is used to monitor health and administer deworming as needed. Heavy infestation by the blood sucking parasite results in anemia, the symptoms of which show up in the color of the membrane of the eye. In the FAMACHA system, a goat's eyelid color is matched with a scorecard that ranks color on a 1 to 5 scale. A dark red eyelid membrane color is a 1 and indicates no significant anemia. A white color is a 5 and indicates severe anemia. The light red, pink and pinkish white colors in between indicated by scores 2 through 4 indicate increasing levels of anemia that generally correspond to the parasite load the animal is carrying.

Pre-treatment Measurements

Prior to treatment, animals were weighed and FAMACHA tested for anemia and evenly distributed by weight across both treatments at 8 goats per treatment.

Daily Measurements and Observations

Animals were observed and checked daily. An observation log was kept for each treatment group (Appendix 6). This log recorded information on behavior of individuals' browsing habits, social habits and physical health. FAMACHA and hoof checks were performed randomly on individuals on both treatment plots each day. Mineral supplement was provided to each treatment plot once weekly.

Post-treatment Measurements

To prevent damage to the site or to the crop trees, we established a criterion of 20 percent vegetation remaining as being the indicator for removing goats from a treatment plot. At that point, goats were taken off treatment and weighed. There was not significant change in weights at this age of goat and quality of forage. Visual observation and photographs were used to assess overall animal health post-treatment (Figure 5).



Natural Treatment



Herbicide Treatment

Figure 5: Goats from each treatment, post-rotation.

CHAPTER 4: RESULTS

This field trial lasted 60 continuous browsing days in July and August, 2009. Daily observation and measurements were taken from three replications on each treatment. The results for the research indicate that intense goat management can be a key to successful vegetation reduction in a young plantation forest. The results are described in two ways: with data analysis of samples of vegetation and trees on site; and through direct observation of goat browsing preferences and behavior. Analyses were performed on each of the dry weight sample categories measured within the field research area. The categories are represented as Trees, Forbs (shrubs and vines), Grasses, and Dead vegetation.

Pre-Treatment Dry Weight Sample Results

Categories of *forbs, tree, grasses and dead-matter* samples were clipped, separated by category, collection site, plot and rotation; they were then bagged, dried, and weighed. Table 1 describes the mean values. The overall mean sample weight was 75.5 grams for 288 vegetation samples. We did not, however, cut down the standing trees, so the weights were only for small vegetation and brush and lower limbs of the trees falling within the sample measurement area (1.196 m³). Table 1 shows the results of the vegetation samples by sample category. The total vegetation amounts were similar between treatment plots, with slightly more vegetation in the natural samples (305 vs. 299 grams). However, the plots that were treated with herbicide had much more broadleaf forbs, and the plots that were not treated had more grasses and tree/leaf biomass. Details of the statistical comparisons follow.

Table 1: Descriptive Statistics for all Dry Weight Means in Both Treatments (grams per sample).

Statistic by sample category	Herbicide	Natural
Trees	66.94	112.00
Broadleaf Forbs	142.15	80.00
Grasses	33.51	60.00
Dead matter	56.20	53.40
Total Mean by Treatment	74.70	76.35
Total Sample Weight	289.8	305.4
N	288	

Each vegetation category was then analyzed in the same manner by testing the difference with a 95% confidence level ($\alpha=0.05$). Dry weights are given by category and then were compared between treatments. We found a fairly significant difference in mean dry weights of *Forbs* samples and in *Tree* category samples as shown in Figure 6 and Figure 7.

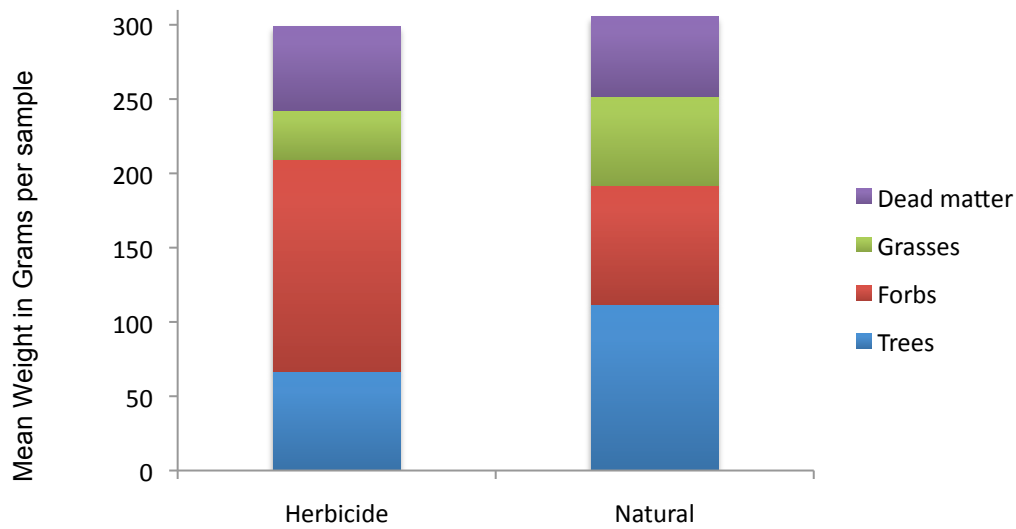


Figure 6: Comparison of mean dry weights for two treatments of all samples for three replications (grams per sample).

Pre-Treatment Dry Weight Tree Samples Statistical Analysis Results

Tree dry weight samples for both treatments were different from each other at probability value of 0.043 (Table 3). Natural plot samples had a mean value sample weight of 111.56g/m³ grams and Herbicide tree samples had a mean of 66.94 g/m³.

Table 2: Dry Weight Tree samples, measured in grams per sample meter cubed.

	Mean	Probability > F
Treatment		0.0435
Herbicide	66.94	
Natural	111.51	

The *tree samples'* dry weights in Table 2 clearly shows that the Natural plots samples had a higher mean weight than the Herbicide treatment at over 111 g/m³ mean sample weight versus approximately 67 g/m³ grams mean sample weight of the Herbicide *tree samples* at a probability of 0.0435. This is because there were more branches and limbs in the cylindrical sample area that we clipped for small brushy hardwoods in the natural stands compared to the pine stands.

Figure 7 shows a comparison of the mean dry weights of *tree samples* for three replications on each of the two (Herbicide and Natural) treatments. In the first replication, dry weight mean of the Natural treatment of 165 g/m³ was significantly greater than the dry weight mean for the Herbicide treatment at 75 grams.

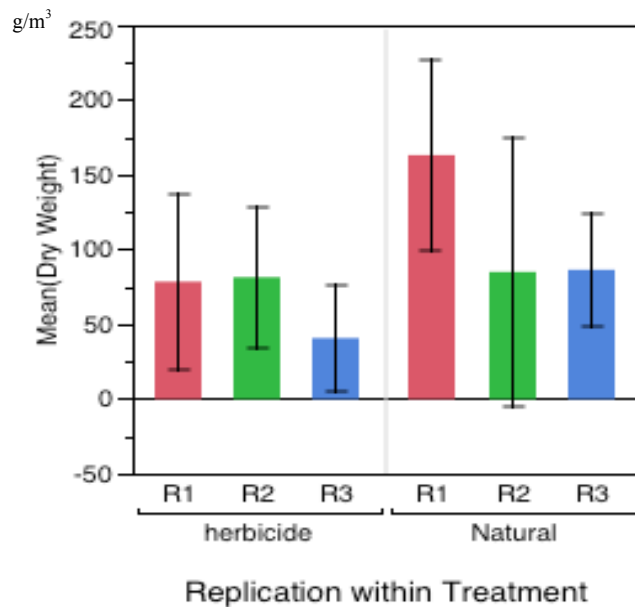


Figure 7: Comparison of mean dry weights for two treatments of tree samples for three replications g/m^3

As noted, the explanation for this could be that we didn't cut down an entire tree stem if it fell into our sample area because goats wouldn't eat the entire tree; instead, we clipped branches and leaves within the cylindrical shape of a sample measurement (1.196 cubic meter volume). In the case of the Natural treatment plots, there were many more small sapling hardwood trees available to sample versus the Herbicide treatment plots, where there were primarily plantation pines in the *tree samples* category, which, therefore, would not have been cut at the stem but only the branches.

Pre-Treatment Dry Weight *Forb* Samples Statistical Analysis Results

Table 3 describes the *forb sample* values for the least squares calculation of Herbicide treatment at 142.15 g/m³ and the Natural treatment mean value of 79.98 g/m³ with a standard error of 13.63 g/m³ and a probability of 0.0019. Forbs were much more prevalent in the herbicide-treated plots than in the natural plots.

Table 3: The least squares mean dry weights of Forbs samples of two treatments g/m³

Level	Least Sq Mean	Std Error	Probability > F 0.0019
Herbicide	142.15	13.64	
Natural	79.98		

Pre-Treatment Dry Weight Grass Samples Statistical Analysis Results

Grasses were found in both treatment sites, and analysis of dry weight samples collected are described in Table 4. Across two treatments (Natural and Herbicide), samples collected were significantly different from each other at probability value of 0.01. Analysis of the differences in weights of the Dead vegetation category yielded insignificant results and were not included here.

Table 4: Least Squares mean values for samples of dry weight grass samples in both treatments g/m³

Level	Least Sq Mean	Std Error	Probability > F 0.01
Herbicide	33.51	7.22	
Natural	60.16		



Figure 8: Before and after goats. Herbicide Treatment, Plot 2

The samples collected in the Grasses category suggest that there was significantly more abundance of grasses in the Natural treatment plots sampled across all three replications.

Figure 9 shows the dense vines and shrubbery present in the Herbicide plot, indicative of that treatment area. While Herbicide samples had a mean weight of 32g/m^3 , Natural treatment plots had a mean dry weight of 58g/m^3 , indicating more grasses present in samples on the Natural treatment plots. Figure 9 suggests that the overall Grass samples category were more predominant in replications 2 and 3 of the Natural treatment plots, showing significantly higher mean sample weights than those in all replications of the Herbicide treatment plots.

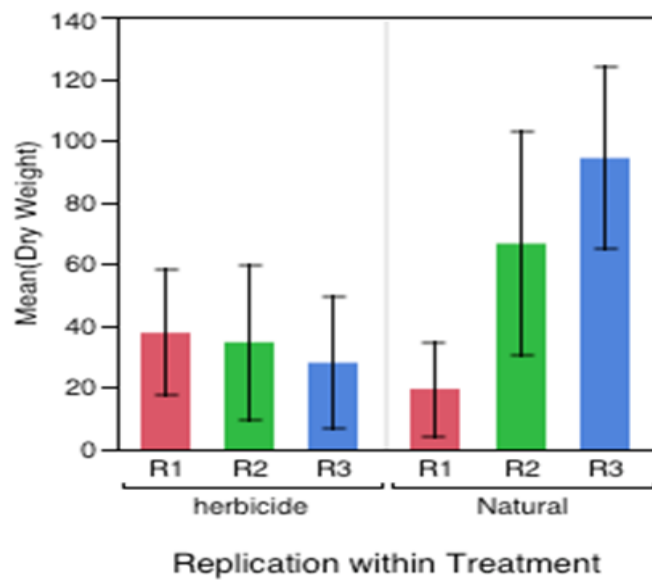


Figure 9: Replication within Treatment. Comparison of dry weight Grasses across two treatments (g/m^3)

Tree Samples

We sampled all trees of 2.5 cm (1 in.) or greater diameter in both treatments at 1.83 m (6 ft.) for consistency and to estimate the maximum forage available for goats (estimated browse level of 2 m high). These sample trees were identified, counted, measured and recorded. Figure 9 shows a bar chart of the mean diameter for Herbicide treatment plots of 6.73 cm (2.65 in.); the mean for the trees in the Natural plots was approximately 3.68 cm (1.45 in.). Table 6 provides a side-by-side comparison of the treatment tree sample means in the each of the sample areas. The radii size used for tree sample measurements in this research were different because there were many sapling trees to measure in the small Natural stands, and more, larger, crop trees in the Herbicide-treated pine stands. The samples taken in the Herbicide plots were in a sample radius of 5.6m, comprised mostly of the planted pine trees, and the Natural plots were measured using a smaller sample radius of 3.5m, with a mix of planted pines and some large, competing volunteer hardwoods. Each plot in both treatments had four tree sample areas as shown in the plot sampling scheme diagram in Figure 4.

Table 5: Comparison of Tree measurements of two treatments

Tree Measurements Per .01ha	Herbicide Treatment			Natural Treatment		
	R1	R2	R3	R1	R2	R3
Sample radius	5.64m			3.51m		
Sample area	99.93m ²			38.7m ²		
Mean volume of sample area	181.80 m ³			70.25 m ³		
Replication (.01ha)	R1	R2	R3	R1	R2	R3
Mean diameter (cm) at 1.83 m	6.71	6.99	6.53	3.87	3.72	4.09
Mean volume (m ³) Per plot	0.036	0.033	0.032	0.007	0.008	0.011
Mean Volume per treatment (m ³ per .10 ha)	0.033862			0.009018		
Expansion Factor	99.93m ² /38.7m ² = 2.58			2.58*0.009018		
Scaled Tree Volume (m ³ per .10 ha) Comparison	0.033862			0.023283		

The overall mean volume of trees in the Herbicide treatments was over twice as large as the mean volume of the Natural plot tree samples. One possible explanation for this difference might be that there were roughly twice as many plantation crop trees (101 Loblolly pines) counted in the Herbicide treatment plots than in the Natural treatment plots (54 Loblolly pines), although the total number of trees in each of the treatment types was similar. Table 6 illustrates a comparison of tree species counts between treatments. The

Herbicide treatment plots (which were about 1/100 ha) had a total sample count of 153 trees; 101 of those sampled were plantation pines. The Natural treatment tree sample plots (which were about 1/250 ha) count totaled 115 trees; 54 of those were plantation pines. This is an indication of smaller diameter hardwood saplings in the Natural plots crowding the plantation trees, thus producing less growth in plantation trees and more sapling hardwoods.

Table 6: Comparison of tree species counts between two treatments measured in *tree* samples ≥ 2.5 cm

Natural Treatment		Herbicide Treatment		Species Type	
Species	Count	Species	Count		
CH	3	CH	0	CH= <i>Prunus serotina</i>	Cherry
HI	14	HI	11	HI= <i>Carya cordiformis</i>	Hickory
NP	14	NP	33	NP= <i>Pinus taeda</i>	Nat. Pine
PO	9	PO	5	PO= <i>Populus deltoids</i>	Poplar
PP	54	PP	101	PP= <i>Pinus taeda</i>	Planted Pine
RB	2	RB	2	RB= <i>Cercis chingii</i>	Red Bud
RO	4	RO	0	RO= <i>Quercus rubra</i>	Red Oak
SG	15	SG	1	SG= <i>Liquidambar styraciflua</i>	Sweet Gum
Total	115		153	Samples from trees ≥ 2.5 cm diameter	

Cover Vegetation Density Screen Samples

Using a method adapted from techniques used in wildlife management (Nudds, 1977) for estimation of vegetation cover before and after treatment provided a visual indication of the goats' effectiveness at browsing areas to approximately 2.5 m in height. Figure 10 represents the overall pre-treatment results from vegetation cover screen density measurements. The Y-axis in Figure 10 is the mean percentage of vegetation cover density screen visible through the vegetation. The means from 1 meter height samples indicate that we could see only about 10 percent of the cover density screen through the Herbicide plot's vegetation pre-treatment, and slightly more (~ 16%) visible on the Natural plots, meaning that approximately 85-90% of the screen was obscured by vegetation.

Overall, pre-treatment results estimate that less than 25% of the cover density screen was visible on either treatment at a height of 2.5 m, meaning that greater than 75% was obscured by vegetation (tree cover).

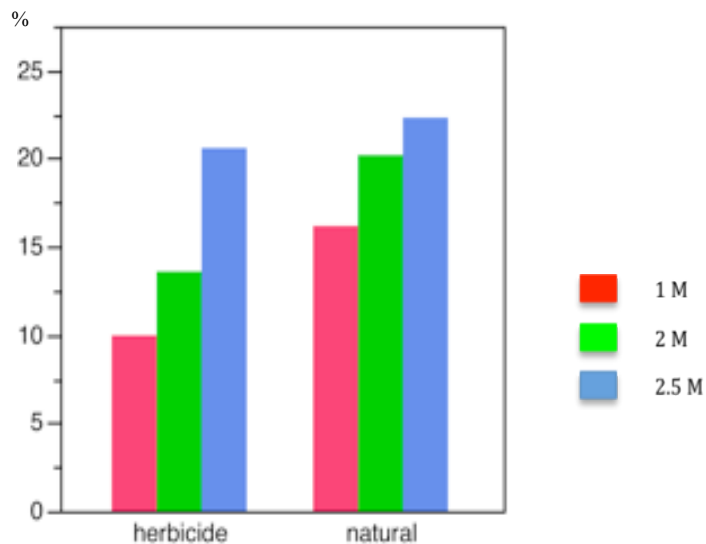


Figure 10: Percentage comparison of pre-treatment vegetation cover across both treatments

Immediately following goat treatment, each plot was sampled again; a mean was taken and combined over all replications within each treatment. The results are shown here in Figure 10. As is visible on both treatments, a significant reduction in cover density occurred post-goat browsing. In Figure 10, the Y-axis represents the percentage of screen visible through the vegetation. Our results suggest that a significant change is evident in the mean sample values at the 1 meter height range. The post-treatment sample means across both Herbicide and Natural plots estimated about 50% visible screen cover density. The difference is about 40% from our pre-treatment measure of the same area, which exceeded our target of about 20% reduction in vegetation before rotation.

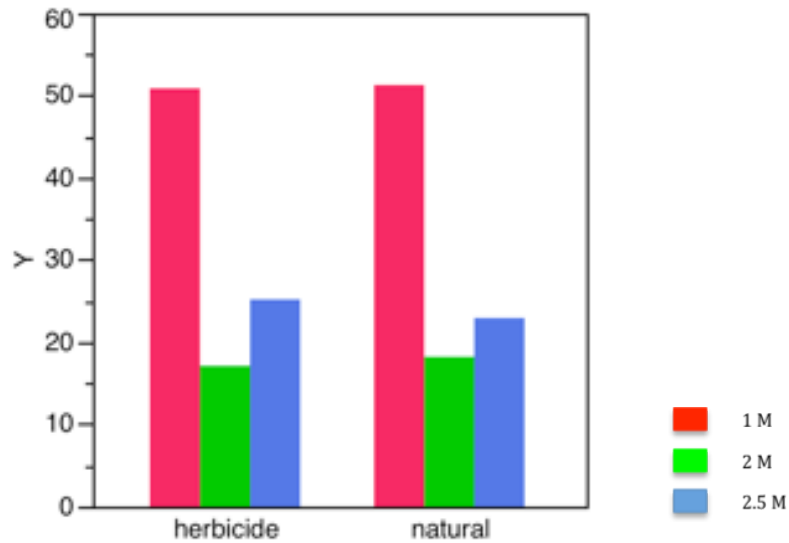


Figure 11: Post-Treatment vegetation Cover Density Screen visibility percentage comparison across both treatments

The mean vertical measurement from 2 to 2.5 m showed little difference between treatments, which suggests that the goats are efficient at browsing to about the 2 meter mark regardless of cover type. This might also suggest that intense management of goats is necessary to get desired results in a browse setting since the rotation times between treatments varied significantly based on the forage type available to the animals.

We analyzed the pre- and post-treatment percentage of vegetation reduction within both treatments and compared them with their respective control plots. Table 7 provides screen density measurements for the Herbicide treatment and Table 8 shows the same comparison for the Natural treatment.

Table 7: Comparison of pre-treatment and post-treatment vegetation cover density percentage reduction across Herbicide and Herbicide Control Treatment

Category	Height M ²	Percent Visibility	Height M ²	Percent Visibility	Height t M ²	Percent Visibility
PRE TREATMENT Percent of vegetation cover	1.0	16.18 83.82	2.00	20.20 79.80	2.50	22.58 77.43
POST TREATMENT Percent of vegetation cover	1.0	51.72 48.28	2.00	52.11 47.89	2.50	22.96 77.04
GOAT EFFECTIVENESS Percentage of vegetation reduction	1.0	35.54	2.00	31.90	2.50	0.38
Control PRE TREATMENT Percent of vegetation cover	1.0	15.63 84.38	2.00	20.88 79.13	2.50	23.64 76.36
Control POST TREATMENT Percent of vegetation cover	1.0	11.75 88.25	2.00	19.38 80.63	2.50	22.07 77.93

The results suggest that the post-treatment reduction of vegetation at the 1 meter height yielded the most significant difference across treatment replications (Table 7). Pre-treatment vegetation cover on both Herbicide and Herbicide control plots was estimated at 90% at the 1 meter high mark, and post-treatment, the control plot had a 0.27% increase in cover density at that same height during the 60 days of the growing season, as compared to the percentage of vegetation reduction by the goats to 40.92%. At a height of 2 meters vegetation cover before goats had a mean percentage of 86.7% and goats in the Herbicide

plots reduced vegetation by 33.21% while the post-treatment control vegetation had a cover density of 87.5%.

Table 8: Comparison of pre-treatment and post-treatment vegetation cover density percentage reduction across Natural and Natural Control Treatment

Category	Height M ²	Percent Visibility	Height M ²	Percent Visibility	Height M ²	Percent Visibility
PRE TREATMENT	1.0	9.97	2.0	13.22	2.5	19.94
Percent of vegetation cover		90.03		86.78		80.06
POST TREATMENT	1.0	50.90	2.0	46.43	2.5	25.22
Percent of vegetation cover		49.10		53.57		74.78
GOAT EFFECTIVENESS						
Percent of vegetation reduction	1.0	40.92	2.0	33.21	2.5	5.28
Control PRE TREATMENT	1.0	9.63	2.0	12.44	2.5	17.73
Percent of vegetation cover		90.37		87.56		82.27
Control POST TREATMENT	1.0	9.36	2.0	12.45	2.5	14.19
Percent of vegetation cover		90.64		87.55		85.81

Table 8 shows that the reduction of vegetation at the 1-meter height yielded the most significant difference across treatment replications in the Natural treatment plots (Table 8).

Pre-treatment vegetation cover on both Natural treatment and Natural control plots was

estimated at a mean of 85% at the 1-meter high mark; post-treatment, the control plot had a 3.88% increase in cover density during the research period. Goats effectively reduced vegetation at the 1-meter height by 35.5%. At a height of 2 meters, vegetation cover before goats had a mean cover density percentage of 80%; goats in the Natural treatment plots reduced vegetation at 2 meters by 32% while the post-treatment control plot had a cover density increase by 1.5% during the research period, indicating over 80% vegetation cover.

The resulting vegetation reduction estimation for the 2.5-meter cover density samples was less significant in both treatments, as indicated in Tables 7 and 8 with exception of the Herbicide treatment control plot that showed an increase in cover density of 3%. This change indicates that there was denser crown cover in the Herbicide treatment trees. The pre-treatment results in both treatments suggest that there was a range between 77-85% vegetation cover at the 2.5-meter height, with the Herbicide treatment slightly more densely covered pre-treatment. Post-treatment vegetation cover density samples in both treatments also indicate only a slight change (~5%) in vegetation density.

Goat Activity Measurements

Animals were given health checks prior to participation in the research. This included hoof trimming, FAMACHA testing, and de-worming with a 10 cc drench of cydectin per goat. The day the goats were put on to the plots, each was weighed using a livestock scale and color coded for plot assignment; goats were then distributed randomly into plots for even weights in each treatment. Goat performance was measured by daily health checks that included random FAMACHA testing for anemia, physical observation, photographs, hoof checks for lameness, and effectiveness measured through pre-and post-treatment screen-

density measurements. Appendix 5 provides the pre-treatment health check data taken prior to putting goats into treatment plots, thereby indicating the weight distribution on both treatments was equalized and the overall fitness of the goats was excellent.

The daily management regime consisted of an early-morning check on each treatment. Due to the remoteness of the plot location, goats were counted and inspected for any injury or sickness daily in case of predation from wild animals or inclement weather. Appendix 5 provides a chronology of observed goat behavior, health, and forage preference information that was recorded in a daily activity log. Each morning, goats were checked, given water, and forage levels were assessed. Additionally, health information was recorded and observations in diet and behavior were also made.

CHAPTER 5: DISCUSSION

Support from a wide body of literature suggests that agroforestry practices are useful and provide economic, environmental and sustainable benefits to landowners. While the use of goats as vegetation control mechanisms isn't a novel concept, we were impressed with the goats' performance in a mixed hardwood setting.

Differences in Forest Treatments

Working in a plantation forest with two different vegetation management treatments, Herbicide treated loblolly pine plantation trees and Naturally grown loblolly plantation pine, provided a look at how competition and spacing play an important role when planting for optimum tree crop growth. In general, the total volume of biomass in the samples of Herbicide treated plots and Natural plots was quite similar, at about 300 grams per sample. However, the distribution of that biomass among components of trees, forbs, grasses, and dead mater was quite different. The herbicide treated plots had more biomass in the broadleaf forbs, followed by the trees branches and leaves (but recall that weight of the the tree trunks were not counted). The Natural plots had a wide variety of trees and branches and leaves, which comprised the largest component of the stands, followed by broadleaf forbs.

Trees in the Herbicide treatment were visibly larger and evenly-spaced. Although understory vegetation was significantly thicker in that treatment, the tree competition was less of a factor in the plantation tree growth. Another factor we consider is the use of Arsenal™ herbicide in this stand. This compound is commonly used in suppression of grasses and our treatment plots had very little grasses as compared to the Natural, or non-

herbicide plots, giving an opportunity for growth of other, broadleaf species such as Blackberry (*Rubus L.*) that dominated the undergrowth in the herbicide area.

Dry weights in the Herbicide treatments were higher than in the Natural treatment plot samples. In this case – it is not intuitive to think about an herbicide treated area to have “more” forbs matter than that of an untreated stand, but this particular tree stand was predominately populated with a dense blackberry cover that was about 4 years old. Figure 8 shows before and after treatment effects on blackberry canes. The canes were thick and weighty and that could account for this finding. In the Natural treatment plots there were no predominant shrubs like blackberry cane and so there was a less significant presence of shrubs within our samples.

As Table 2 indicates, there was a significant difference between treatment mean tree sample dry weights. Natural samples had a mean value sample weight of 111.56g/m³ grams and Herbicide tree samples had a mean of 66.95 g/m³, making an argument for more browse sampled in the Natural plots than in Herbicide plots. In the Natural treatment plots there was a range of forage variety for goats, although the sampled plantation trees were not as large as those in the Herbicide plots due to the sapling hardwoods competing for space, and nutrients, and in some cases were dominating the crop trees in size. Additionally, the Natural plots were less evenly spaced, providing much more light for grasses to grow between crop rows. These results might indicate that herbicide treatment affect carbon partitioning as desired – putting more volume and biomass on large crop trees. However, the sites still supported similar amounts of biomass in total, reaching a similar carrying capacity, but distributing the biomass much differently.

The Cover Screen Density technique is adapted from a wildlife scientist (Nudds 1977) who used a similar methodology to estimate the nesting cover density for deer. Adapted as a useful field technique, NC State Wildlife Biologist Aimee Rockhill developed the Density Screen technique further by creating a portable, accurately sized (with equal sized squares) screen with visual measurements that were easy to see through the thick forest brush. The technique described by Rockhill (personal communication, unpublished research) was used to measure brush density for Bobcat hunting cover. Further adapted for this research experiment, Rockhill's technique provides an accurate and easily-calculated method for fieldwork in thick brush given a fairly level terrain. The Cover-Density screen is adaptable in terms of height and worked well for goats in this browsing situation as they have a maximum browse level that was easily captured with this method.

Another success in terms of vegetation sampling is the use of a 3-dimensional sample or a cylindrical vegetation removal technique. In this research, we used an adaptation of a grab-sample technique that mimics what a goat will forage from a stationary position. This sample takes into account the vegetation within a sample radius that closely resembles that of the reach of a goat, as well as the height a goat is most likely to browse. While not an exact replication; this measure was accurate to determine effective vegetation reduction with variable botanical composition within treatments. In future experiments, the mean goat browse height might be recorded to ensure that a more accurate sample volume is determined.

Challenges

Using different sized radii for tree sampling of larger trees within the treatments became a complex challenge to accurately compare trees and vegetation. Most of the trees in the Natural Plots were smaller than 2.5cm, our sample measurement size for trees, and therefore were not computed in the tree volume measurements but instead were weighed and calculated as tree “dry weights” leaving out some of the actual ‘volume’ of tree vegetation available in the sample plots. Future research might account for these differences by taking measurements of all trees within the sample in the same manner.

Goat Effectiveness

Animal performance in this experiment exceeded our expectations for vegetation reduction and in particular in terms of leaving no damage to the crop trees. Goats in this experiment were effective at vegetation control in a mixed hardwood stand to a level of 2 m and with trees and brush with a diameter of 2.5 cm or less. Table 9 compares the rotation length and the predominant forage type available to the goats in each treatment. The criterion for rotation was based on approximately 20% vegetation change and was based on observation of browsing behavior within each plot and was variable in time due to differences in botanical composition both within and between treatments.

Goats were observed each day and their behavior indicated when the palatable vegetation within a plot had been eaten. Within the Herbicide treatment plots, the forage was dominated by blackberry cane and goats would rotate through the available forage quickly (7-10 days). The goats on the Natural treatment plots browsed a variety of hardwood tree saplings and grasses and could sustain a much longer rotation time (15-22 days).

This was interesting that the Herbicide treated plots did place more volume on the crop trees, and had about the same total volume as the Natural stands, but the forbs on those plots actually did not provide as much food for the goats to subsist on. Thus Natural, untreated stands actually would be better for goats, and cost less than having both goats and herbicides. The goats did, however, enjoy eating the blackberries, honeysuckle, briars and forbs on the Herbicide plots, but goat happiness probably is not a forest owner or goat producer goal. In practice though, goats and as a means to thin competition below planted pines did seem to be an ideal mix of moderate competition control and goat health, without having to move the goats as often.

Table 9: Rotational management and understory vegetation type comparison

	Natural Treatment	Herbicide Treatment
Rotation length	15-22 days	7-10 days
Prominent forage type	Hardwood saplings, grasses (hickory, oak, poplar)	Shrubs and vines (blackberry, grape, sumac)

Notable behavior included use of teamwork to retrieve browse that was too high to reach from bipedal posture. Many goats would stand or pounce repeatedly on a sapling tree to pull it down so that others could browse. Knowledge of the goats' history of having no prior experience with browsing (completely pasture-based) provided a look into behavioral changes that happened over the course of the experiment, such as immediately looking up for available browse upon moving to a new plot. Also observed was communal dirt bathing and sun bathing casually, suggesting a non-stressful environment.

Dietary preferences were observed and most important to this research are the goats' distinct resistance to consumption of the plantation pine tree needles, branches or bark, even in trees less than 2.5 cm diameter until there was little choice, suggesting a positive interaction with loblolly pine trees used for crops. Goats in the Natural treatment (no herbicide pine tree crop) were observed eating charred tree stump bark on a few occasions while the Herbicide treatment goats were not observed doing this although the same opportunity was given on both treatments. Goats in both treatments seemed to prefer to eat fruit bearing browse over non-fruit bearing browse when possible and specifically enjoyed eating Sumac (*Rhus aromatica*) berries and leaves, often until they were bloated and lethargic.

Also noted, goats in the Herbicide plots tended to select the immature blackberry canes and fruit but would not eat mature canes, which could suggest that their effectiveness for reduction of this vegetation type would need to be early in the growing season and also in plants that are not mature. Of the variety of sapling hardwood browse available, goats did not choose black cherry, (*Prunus serotina*) a known toxin to goats nor sweetgum (*Liquidambar*

styraciflua). On two occasions, it was noted goats were eating yellow crown beard, (*Verbesima Occintalis*) where in other, pasture settings the same goats would not eat this plant.

Methods and Management

The screen density measurement technique was a good tool for goat browse measurement. For example, we looked at the pre-treatment results in both treatment types and the control plots, where overall, there was more than 77% vegetation cover at the 2.5 meter height, with the Herbicide treatment slightly more densely covered pre-treatment. Post-treatment vegetation cover density samples in both treatments also indicate only a slight change (~5 percent) in vegetation density. A few factors can be attributed here. The age of the tree stand is one possible reason for less defoliation above the 2.5 meter height. The canopy for the 9-year old plantation trees in our research stand is fairly open at 3 m. Also, some of this might be potentially, due to the loss of some sapling trees as the goats browsed through during treatment.

Yearling wethers are considered adult weight and were not expected to show significant weight gain, or experience significant changes during the research and were chosen because of this factor as opposed to pregnant does or kids that will require a much different management regime in this browse setting. Pregnant goats do require a higher protein diet and would need to be supplemented and moved more frequently to meet their nutritional needs. And pre-market weight kid goats would likely require a significantly more intense management regime that focuses on maintaining a healthy level of nutrition for growth as well as protection from potential wildlife predation.

Working with a prey animal such as goats in a forest setting, protection is an important consideration. We chose to use an electrified net fence to keep the goats confined but to also keep out potential predation from coyotes. The electric fencing components are important as there is potential for the fence to lose charge for a variety of reasons including vegetation touching the fence, missed or loose connections between fences or accidental disconnect from the charger due to weather, or animals. In our research we used a 12-volt solar charger with a grounding wire, inserted into the soil next to the charger. This was a portable system, allowing the charger to be moved for optimal solar collection and maximum effectiveness at keeping the fence continuously charged through the grounding system.

CHAPTER 6: CONCLUSION

The specific objectives of this research project were to assess and demonstrate sustainable operational protocols in goat and forestry management, to measure how browsing affects desired and undesired forest vegetation and economically valued tree species, measure goat health in a forest setting, identify browse preference, and to integrate sustainable agricultural practices and promote best management practices for woodlot owners.

In a study by Luginbuhl et al. (1999), goats were an effective tool in reclamation of pastureland in an orchard setting in the Appalachian region of the United States. The research provides an example of an environment similar to our research in that there are crop trees and undesirable vegetation beneath. Goats grazing for eight-week periods over four years beginning in May resulted in 21% mortality by the beginning of the second year, 78% by the third year and 94% by the beginning of the fourth season. Additionally noted in this study, due to goats' versatile grazing/browsing behavior, they are able to successfully control unwanted vegetation while at the same time selecting a diet that meets their nutritional requirements in situations where other domestic ruminant species would be at a disadvantage. This indicates that there is reduced pressure on the landowner to keep the weight, and nutrition of the animals as priority in a browse setting.

Goats in this forest setting required daily management and as such are most beneficial for situations where landowners are on-site or nearby. When properly managed, goats will thrive and tree crops will benefit from decreased competition from saplings, vines, and unwanted vegetation that could fuel forest fires and mitigate plantation tree growth. When effectively managed, goats are a complementary, multi-use crop for a farm or forest owner.



Figure 12: Goats browsing in a natural mixed pine-hardwood stand

While the use of goats as vegetation control mechanisms isn't a novel concept, we were impressed with goat performance in a mixed pine-hardwood setting in reducing vegetation by about 50%. It is worth noting that we aimed to reduce vegetation to a 20% level, but this seemed to be too low a target. The goats became too hungry before that and started working together to pull down larger trees, which could damage crop trees as well. So the 50% level ended being more practical in actual operations.

Overall, the goats performed well in the forest plantation crop setting as they clearly reduced unwanted vegetation when managed effectively. Goats preferred a variety of browse

and grasses choosing hardwood saplings, and broadleaf brush while leaving the pine trees as a last alternative. Stocking rate for optimal vegetation control is an important consideration, as well as plot size, botanical composition. Future research could include these factors along with testing various fencing and exclusion options for goats.

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APPENDICES

Appendix 1: Example Vegetation Sample Coding Scheme

Herbicide (H) Natural (N) Treatment	Replication cycle	Sample orientation (Left, Right, Top, Bottom, Center)	Sample flagging location (In Ft)
H	2	R	60x30
N	1	L	90x30
H	3	C	52x52

Appendix 2: Analysis of Variance for Dry Weights of Tree Samples in Two Treatments/m³

Source	DF	Sum of Squares	Mean Squares	F Ratio	Probability > F
Treatment	1	35825.39	25475.8	4.23	0.0435
Replication	2	40601.99	8461.3	2.39	0.0984
Samples	68	575369.42			

Appendix 3: Analysis of Variance for Dry Weight Samples of Forbs samples in Two Treatments g/m³

Source	DF	Sum of Squares	Mean squares	F Ratio	Probability > F
Treatment	1	69576.93	69576.9	10.39	0.0019
Replication	2	12112.63	6694.9	0.90	0.4095
Samples	68	455253.40			

Appendix 4: Analysis of Variance for Dry Weight Grass (Biomass) Samples in Two Treatments g/m³

Source	DF	Sum of Squares	Mean Squares	F Ratio	Probability > F
Treatment	1	12789.34	8673.63	6.82	0.01
Replication	2	13231.55	1874.68	3.52	0.03
Samples	68	127478.10			

Appendix 5: Pre-treatment Animal Health Data

**Hill Forest Research
Goats on the Hill 2009**

Dewormed 04.01.09
07.22.09//08.05.09
Feet Trimmed 06.25.09
FAMACHA 06.22.09

GOAT ID	WEIGHT 07.21.09		PLOT ID	PET NAME	Notes
	lbs.	Kg.			
8021	94.6	42.9	H1	Flip	
8042	99.8	45.26	N1	Peabody	
8047	103.5	46.94	N1	Floyd	
8048	78.2	35.47	N1	Chestnut	
8054	103	46.72	N1	54	
8069	89.4	40.55	H1	buddy	
8078	83	37.64	H1	Timmy (timid)	
8080	85	38.55	N1	The Joker	diarrhea
8081	74	33.56	N1		
8087	79.2	35.92	H1		
8102	93.2	42.27	H1	My spy	
8103	91.2	41.36	H1	tallboy Donkey	
8107	91.2	41.36	N1	Child/guido	
8119	93.4	42.36	H1	Dollface	
8123	103	46.72	H1	brutus	FAMACH A=3-4
8132	88.6	40.18	N1	Maurice	
Total		657.84			
Weight	1450.3	5			
H1 Weight	724.8	328.76			
N1 Weight	725.5	329.08			

Appendix 6: Field Observations and Activities

Date	Plot ID	Activity	Random FAMACHA Goat ID & Score	Notes
07.22.09	H1	Fence test, Filled H2O	8123 2+	visual all ok
	N1	Fence test, Filled H2O	8080 2+	visual all ok
7.23.09	H1	Mineral, H2O, Goat Health Check	8021 2+	goats slept in center of plot surrounded by blackberry "fence"
	N1	Mineral, H2O, Goat Health Check	8048 2+	checked animals for ticks; found 2 Still sleeping upon arrival - evidence of deer outside fence; observed goats(8132) eating burnt pine stump goats eating dead sweet gum leaves?
07.24.09	N1	Fence test, Filled H2O	8080 3 // 8123 3	goats eating forbs, excellent condition, happy, playful=no stress
	H1	Fence test, Filled H2O	8081 3	eating dead blackberry cane+leaves/heavy rain/#178 alone
07.25.09	N1	Filled H2O	8054 2+	eating dead blackberry cane+leaves/heavy rain/#178 alone
	H1	Moved H2O barrel/checked perimeter	8178 3	
07.26.09	N1	walked perimeter/Hoof checks	8103 2	#8042 lays in dirt bath;checked for ticks/none
	H1	walked perimeter/Hoof checks	8107 2+	rain and mud- took photos/no hoof problems
07.27.09	H1	Fence test, cleaned buckets Filled H2O	8119 2 // 8132 -3	#8132 slow/droopy head/watch
	N1	Fence test, cleaned buckets Filled H2O	8048 2	teamwork browsing saplings took photos
07.28.09	H1	walked perimeter/Hoof checks	8119 2+	#8119 active
	N1	walked perimeter/Hoof checks	8054 2+	#8042 in dirt - sunning Assed plantation crop: no pine damage
07.29.09	H1	Moved H2O/walked plots	8069 3+	#8047 eye filmy
	N1	Moved H2O/walked plots	8047 -3	
07.30.09	H1	Moved solar charger/fence tested/H2O		Happy boys
	N1	Cleaned H2O Bucket/fence tested		Happy boys

Appendix 6 cont'd

Date	Plot ID	Activity	Random FAMACHA Goat ID & Score	Notes
07.31.09	H1	walked perimeter/cleaned buckets		observed tunnels in blackberry; saw deer inside fence
	N1	walked perimeter/cleaned buckets		slightly eroded hillside near water bucket
08.01.09	H1	Mineral/H20—rain	8123 2+	goats eating sumack/blackberry/grapevine
	N1	Mineral/H20—rain	8047 3+	took photos - observed bipedal browsing #048 extended browse line~ 2M
08.02.09	H1	Fence Tested/H20--heavy rain	8021 2+	goats seem thinner but have high energy
	N1	Fence Tested/H20--heavy rain	8042 2+	Less mud on this plot; goats ok.
08.03.09	H1	walked perimeter/FAMACHA/Hoof checks	all goats FAMACHA	all goats FAMACHA #8078 and #8119 3.5=pale
	N1	walked perimeter/FAMACHA/Hoof checks	all goats FAMACHA	FAMACHA #8048/8054/8047 3.5=pale
08.04.09	H1	Fence tested/H20/cleaned buckets	8119 3.75	random eye check no change ----HEAVY RAIN
	N1	Fence tested/H20/cleaned buckets	8047 4	Heavy rain - fixed fences from trees falling on them
08.05.09	H1	Heather onsite/walked perimeter	all goats dewormed	gave 10cc cydectin to both treatment groups
	N1	Heather onsite/walked perimeter	all goats dewormed	goats eating yellow crown beard
08.06.09	H1	Walked site/H20/filled mineral		repaired fences as needed from heavy rain
	N1	Walked site/H20/filled mineral		observed bipedal browsing for maple and oak
08.07.09	H1	H20/tested fence	8087 2+	photo day. Goats love sumac - ate until couldn't stand up, sleeping happily and bloated!
	N1	H20/tested fence	8080 2+	observed team browsing on sapling oaks

Appendix 6 cont'd

Date	Plot ID	Activity	Random FAMACHA Goat ID & Score	Notes
08.08.09	H1	walked plot/H2O	8078 3	Forage is low; observed eating dead grass/tree stump/large cane, mature blackberry is only left sat with goats in middle of plot; observed sun bathing=no stress
	N1	tested fence/Filled H2O barrel	8042 2	
08.09.09	H1	moving day	visual	tested fences/filled water/goat check - all ok-went right for sumac! happy goats - observed browsing wars between teams using saplings as ladders to reach higher browse
	N1	hot water - cleaned bucket H2O	visual	
08.10.09	H2	tested fences/H2O	8102 2+	thriving on dense blackberry and forb cover lots to browse in plot-goats are learning to look up and stand to browse goats still sleeping under blackberry shelter - got under with them--RAIN
	N1	tested fences/H2O	8107 3	
08.11.09	H2	H2O/Mineral		all-ok moved buckets to other side of plot goats ok - #119 outside of plot crying - no fence break?? Put him back in and he's happy
	N1	H2O/Mineral		
08.12.09	H2	cleaned H2O buckets	8119 2+	working hard to browse - visible browseline
	N1	cleaned H2O buckets	8081 3	
08.13.09	H2	H2O/FAMACHA	all goats FAMACHA	#48 thin/eyes ok #54 very thin/FAMACHA =3
	N1	H2O/FAMACHA	all goats FAMACHA	
08.14.09	H2	walked perimeter/tested fence		RAIN:muddy areas
	N1	walked perimeter/tested fence		RAIN-goats clustered under plantation tree
08.15.09	H2	H2O		all-ok
	N2	Moved goats/changed H2O/tested fences	8080 3 // 8048 3	Goats happy to move and followed me to new plot #103 stomped my ft and tried to butt me to get to grass

Appendix 6 cont'd

Date	Plot ID	Activity	Random FAMACHA Goat ID & Score	Notes
08.16.09	H2	walked perimeter/checked fences		goats running through grasses quickly; more shade in this plot
	N2	walked perimeter/checked fences		Fat gorging goats! More grasses in this plot than plot 1 - more grazing goats
08.17.09	H2	H20/tested fences	8021 +3	all ok
	N2	H20/tested fences	8047 3	out of H20 upon arrival - eating well-FAT
08.18.09	H2	H20/walked perimeter	8042 2	photo day-great change observed from control plot
	N2	H20/walked perimeter	8021 3	photo day-friendly goats enjoy my company
08.19.09	H2	H20/moved solar/Mineral	8103 +3	observed team browsing to take down sumak
	N2	H20/moved solar/Mineral		mineral day=fighting goats! Lots of playful fights
08.20.09	H2	H20/cleaned buckets	8087 3	tick checks - found infected tick on buddy #8069-behind ear
	N2	H20/cleaned buckets	8102 2+	# 102 friendly-follows me around plot
08.21.09	H2	filled barrels/visual goat checks	hoof checks	all ok #8085 crying-browsing grapevine no signs of pale eyes or hoof issues
	N2	filled barrels/visual goat checks	hoof checks	Rain - moved water to other side of plot - goats rooting near buckets
08.22.09	H2	H20/tested fences	8119 3	prepare new plot - found turtle shell/old burnt stumps of mature plantation trees
	N2	H20/tested fences	8132 3	goats happy! Lots of forage
08.23.09	H3	moved goats/tested fences/walked perimeter		all-ok - eating dense blackberry/followed me around fence
	N2	H2O dirty-rain leaves removed		all ok-heavy rain
08.24.09	H3	H20/random hoof check - all ok		Observation: seem to not want to eat pine/perfer dead grass/blackberry cane
	N2	walked plot perimeter/H20		assessed when to move - rotation, goats destroyed saplings, eating and playing
08.25.09	H3	H20/walked perimeter/tested fence	8078 +3	rain is heavy - goats living with deer in plot saw them today

Appendix 6 cont'd

Date	Plot ID	Activity	Random FAMACHA Goat ID & Score	Notes
	N2	H20/walked perimeter/tested fence	8081 3	rain knocked out power - goats roaming more - following me Observation: #8107 hiding in 'nest' while others browse- 8084 and 8047 are outcasts and sleep alone
08.26.09	H3	H20/Mineral		checked fences/weedeat around solar
	N3	moved goats/Mineral/H20		
08.27.09	H3	H20/visual inspection		all-ok Observation: fat and happy - more grass in this plot - goats eat first because it's visible and available rather than looking "up"?
	N3	H20/visual inspection all goats		
08.28.09	H3	H20/	8103 -3	RAIN - #103 bloated - lying down - eyes ok Rain - Observation: boys are not nesting together - laying together in 3 groups. Observed later taking down saplings in teams (same as "friend" group?) Observed: large spiders/goats creating corridors in plot/low browsing in blackberry canes
	N3	H20/		
08.29.09	H3	H20 and fence walk		
	N3	moved H20 to opposite side/less trees		photos - all happy
08.30.09	H3	H20/all goats FAMACHA		visual inspection - all ok. #103 ok +3 and 8047 hiding
	N3	H20/ALL GOATS FAMACHA		walked perimeter - fence down/nobody out

Appendix 7: Trees Found on Research Site

American Beech (*Fagus grandifolia*)
Black cherry (*Prunus serotina*)
Black Gum (*Nyssa sylvatica*)
Dogwood (*Cornus Spp. L.*)
Elm (*Ulmus Americana*)
Hickory (*Carya cordiformis*)
Loblolly Pine (*Pinus taeda*)
Long Leaf Pine (*Pinus palustris*)
Oak (*Quercus stellata*)
Oak (*Quercus rubra*)
Oak (*Quercus alba*)
Poplar (*Populus deltoids*)
Redbud (*Cercis chingii*)
Red Maple (*Acer rubrum*)
Sweetgum (*Liquidambar styraciflua*)
Sumac (*Rhus typhina*)
Tulip Tree (*Liriodendron chinense*)
Winged elm (*Ulmus alata*)

Appendix 8: Forbs Vegetation Found on Treatment Plots

Blackberry (*Rubus L.*)
Broom Sedge (*Andropogon virginicus*)
Chickweed (*Stellaria Spp. L.*)
Common Rag Weed (*Ambrosia artemisiifolia*)
Desmodium (*Desmodium canescens*)
Diacanthelium (*Dicanthelium Panicum*)
Fennel (*Foeniculum vulgare*)
Golden Rod (*Solidago Spp. L.*)
Grapevine (*Vitis spp.*)
Ironweed (*Veronic Noveboracensis*)
Lespedeza (*Lespedeza cuneata*)
Prairie Grass (*Asclepias syriaca*)
Plume Grass (*Saccharum alopecuroides*)
Milk Weed (*Asclepias syriaca*)
Nut Sedge (*Campsis radicans*)
Partridge Pea (*Chamaecrista fasciculate*)
Poison Ivy (*Toxicodendron radicans*)
Raspberry (*Rubus idaeus*)
Trumpet Vine (*Campsis radicans*)
Verbena (*Verbena rigida*)
Virginia Creeper (*Parthenocissus quinquefolia*)
Wild Strawberry (*Duchesna Spp.*)
Yellow Crown Beard (*Verbesima Occintalis*)