AGROFORESTRY: A PROFITABLE LAND USE

Proceedings of the 12th North American Agroforestry Conference

June 4-9, 2011

Athens, GA

COMPARING SILVOPASTORAL SYSTEMS AND PROSPECTS IN SIX REGIONS OF THE WORLD

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Abstract: Silvopasture systems combine trees, forage and livestock in a variety of different species and management regimes, depending on the biophysical, economic, and social factors in a region. In some regions, culture and tradition cause producers to primarily focus on management of either the livestock and forage or the trees, while in other regions, the focus is on joint production. We describe and compare silvopastoral systems in six regions within five countries of the world: Misiones and Corrientes provinces, Argentina, La Pampa province, Argentina, the Southeast United States, the North Island of New Zealand, Paraguay and Uruguay. This summarizes the biological and social factors that have led to their adoption by farmers and the current status of these systems in each country.

Keywords: silvopasture, adoption, South America, USA, New Zealand

SELECTED SILVOPASTORAL REGIONS

Silvopastoral systems represent a form of land use where tree, forage, and livestock components occupy the same plot of land. They form a varied class of production practices. Silvopastoral systems can have different objectives, management practices, and strengths and weaknesses. A systematic review of different practices around the world is one important way that farmers, extension agents, and researchers in one region can learn from the practices in other regions.

The objective of this paper is to present a brief comparison of silvopastoral systems in six regions of the world, based on our research and experience in those regions. We have performed research, worked with various silvopasture parcels, and interviewed the managers and researchers and extension agents of silvopasture systems in each country. The overview for this conference draws from previous research by Frey et al. (2009), and will hopefully provide the basis for a thorough synthesis in subsequent review article.

The location and climate of the researched regions appears in Table 1. Most of the regions we review have warm temperate (subtropical) humid climates, which are denoted by Cf (Cfa and Cfb) in the Köppen-Geiger climate classification system (Kottek et al. 2006). Only the Western Region of Paraguay and the province of La Pampa, Argentina have semi-arid climates.

Table 1. Location and Climate of the Selected Regions and Silvicultural Systems

Region	Location	Area (km^2)	Topo-graphy	Climate Köppen-Geiger classification	Mean annual precip. (mm)	Mean Jan. temp. (˚C)	Mean July temp. (˚C)
Misiones & Corr-ientes, Argentina	25-30˚ S, 53-60˚ W	118,000	North: hilly South: rolling plain	Humid sub-tropical (Cfa)	1,800	27	15
La Pampa, Argentina	35-39˚ S, 63-68˚ W	143,000	Rolling plain	Mid-latitude steppe (BSk)	500	24	8
Southeast USA	26-39˚ N, 75-96˚ W	1,500,000	Flat to mountain-ous	Humid sub-tropical (Cfa)	1,200	2-16	28
North Island, New Zea-land	34-42˚ S, 172-179˚ E	114,000	Mountain-ous with volcanic peaks	Temperate maritime (Cfb)	1,200	18	10
Paraguay	19-27˚ S, 54-63˚ W	407,000	Flat with some hill ranges	Tropical savan-nah (Aw) & humid sub-tropical (Cfa)	400 – 1,700	28	17
Uruguay	30-35˚ S, 53-58˚ W	176,000	Rolling plain	Humid sub-tropical (Cfa)	1,100	24	12

MANAGEMENT REGIMES AND FARM CHARACTERISTICS

Typical silvopastoral system management regimes for each region are summarized in Table 2. These are the systems that farmers utilize, which sometimes may not coincide with recommendations made by research and extension. In addition, some farmers have systems with other species, higher or lower density of planting, and more or fewer thinnings and prunings, but these are the most typical regimes in each region.

Misiones and Northern Corrientes, Argentina

Silvopastoral systems in Misiones and Corrientes generally involve exotic tree species planted in natural grasslands, or with exotic pasture species. The Argentine northeastern provinces of Misiones and northern Corrientes have experienced moderate adoption of silvopasture systems in recent years among farms of all scales. Silvopasture implementation had reached an extent of approximately 20,000 hectares by 2007, and by 2010, 28,500 hectares in Misiones and nearly 40,000 hectares in Corrientes, or 10% of the tree plantation surface. In general, these systems integrate a tree component (mainly *Pinus* spp., and in lesser degree, *Eucalyptus* spp. and other exotics such as *Grevillea robusta*, or the native *Araucaria angustifolia*) with a forage component (mainly the native *Axonopus compressus and Hypoginium vigatum* or exotic *Brachiaria* spp. and *Axonopus catarinensis* and secondarily *Cynodon* spp. and *Pennisetum purpureum*) as forage species, and usually cattle cross-breeds of Braford and Brangus.

A diversity of farm types exist in Misiones and Corrientes. Silvopastoral systems are common, but not pervasive. Northern Corrientes and southern Misiones are relatively flat prairie land, where the larger ranches often include a cattle component, stemming from the grazing heritage in the region. Central and northern Misiones consists of the Upper Parana Atlantic Forest eco-region, which has been settled for agriculture, with some of the more remote areas still relatively undisturbed. This area is utilized mostly by small and medium-scale cash-crop farmers (PyMES) and micro and small enterprises (MYPEs), some of whom include silvopastoral systems in their management, with primarily focus on *Pinus* spp. Larger forest-product firms exist, who also plant mainly *Pinus* spp.

The benefits that farmers report from silvopastoral systems include: higher profit because the tree and livestock components each produce a comparable level of output to what they would produce in a single component system; improved microclimate for cattle and pasture such as protection from frost and sun; favorable cash flow including a long-term investment and short-term returns; reduced risk of forest fire; and fewer weeds, pests, and pathogens. Farmers' chief perceived disadvantages of the silvopastoral system are the competition between the tree and forage component, and the complex management that this creates.

La Pampa, Argentina

The mesquite, or caldén, woodlands, commonly known as the Caldenal, stretch to the west of the provincial capital, Santa Rosa. Low intensity wildfires are a natural part of this ecosystem. Cattle were introduced into the Caldenal over 100 years ago, as in many of Argentina's forests. Typically, livestock are managed in a relatively extensive manner on large properties, allowing cattle to roam through the woodland grazing the understory and occasionally consuming tree leaves and seed pods. Trees also provide much-needed shade in the hot summer months. However, cattle can create a problem by spreading mesquite seeds during browsing, leading to a proliferation of small brush instead of larger trees and pasture.

The Caldenal/cattle system provides ecosystem benefits, but is at risk of conversion to crop lands with continued high soybean and wheat prices. The tree component is generally not managed for timber production, although caldén and other species are often used for firewood and posts and the

dense wood has potential for flooring and furniture. In fact, part of the streets of Buenos Aires in the 19th and early 20th century were cobbled with the hard wood of the caldén.

Southeast United States

Silvopastoral systems in the Southeast USA generally include pines with a combination of warm-season and cool-season grasses and cattle. Trees are planted in groups of two or three rows, commonly leaving an "alley" of about 40 ft (12 m) between the row groups to allow greater light penetration. Native *Pinus* spp. are the most common trees, but natural hardwood stands may be used for unplanned or planned agroforestry systems.

While there are a few long-term practitioners, silvopastoral systems in the southeastern United States as an intensive land use practice has not seen widespread adoption thus far. 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 used with goats at times. Several studies that have been undertaken in the South reveal that silvopasture can lead to moderate rates of returns relative to alternative production systems.

Southern silvopastoral systems can also include intentional grazing under hardwoods and nut orchards. Pecan (*Carya illinoinensis*) plantations in the southern coastal plains and river floodplains of Alabama, Arkansas, Georgia, Louisiana, and Mississippi often integrate cattle grazing. However, timber production is not the objective with growers using this system.

North Island, New Zealand

Farmers on the North Island of New Zealand practice what they refer to as "farm forestry", which include livestock and tree components managed on the same farm. The North Island has the challenge of continuous winter rains in an area with highly erodible volcanic soils.

Although both livestock and timber production are managed on the same farms, the systems generally are kept separated, with livestock fenced in certain areas and the plantation timber of *Pinus radiata* grown on sites too steep for livestock. There are, however, a few exceptions. Occasionally, farmers allow sheep to find shelter in the timber stands when they were freshly shorn, or if strong storms arise. Some landowners allow sheep in timber plantations to mow down the grass beneath the trees. Also, tree species such as *Cryptomeria japonica* are utilized as shelterbelts to protect pasture and livestock.

Paraguay

Silvopasture is not commonly practiced in any region of Paraguay, but there are some systems combining cattle and trees that may have potential. In the Upper Paraná Atlantic Forest of Paraguay's Eastern Region, some landowners have thinned out existing native forest stands and planted exotic pastures underneath. This system, called "parquizado", is practiced in other regions, such as Misiones, but is not common. The initial timber thinning can provide income, but the tree component would generally not be managed for any other forest product from that point forward. Trees help to prevent frost from killing back the grass; however, other warm-season grasses may

perform better in the summer in full sun. This system has the disadvantage of a relatively high likelihood of falling trees which can crush fences or even livestock, because the trees originally grew in a dense stand.

The Humid Chaco eco-region consists of native grassland interspersed with woodlands of palms and other species. Cattle-raising on native grasses has been a traditional source of income in this region, on relatively extensive ranches. Some large-scale landowners have begun planting exotic tree species of *Pinus* spp. and *Eucalyptus* spp., mostly to access a cost-share payment that was enacted as law, but was never fully funded. Cattle are maintained, primarily to reduce the likelihood of forest fire and to provide some short-term returns.

Table 2. Typical Silvopastoral System Farmer Profile and Typical Management Regimes by Country and Region

Region	Typical silvopastoral system farmer profile	Typical tree species	Regeneration	Plant-ing density (trees/ha)	Final density (trees/ha)	Pruning	Typical forage species	Grazing Typical
Misiones and Corrientes, Argen-tina	Corrientes & south Misiones: extensive cattle-ranchers (>1000 ha). Central and north Misiones: farmers (<200 ha) and forest owners (>100)	*Pinus taeda*, *P. elliottii*, *P. elliottii* x *caribaea*; *Euclyptus* spp., *Araucaria angustifolia*	Plantation	700-1,600	150-400 (recommend fewer: 80-225)	Yes: 3-4 time to 6.5m	Natives (*Axonopus compressus*, *Hypoginium vigatum*) or exotics (*A. catarinensis*, *Brachiaria* spp., *Cynodon* spp., *Pennisetum purpureum*)	Cattle Bra-ford & Brangus crosses
La Pampa, Argen-tina	Extensive cattle-ranchers.	*Prosopis caldenia y P. flexuosa; Schinus fasciculatus*; *Condalia microphylla*	Natural	n.a.	n.a.	No	*Piptochaetium napostaense*, *Digitaria califórnica*, and other annuals	Cattle
South-east, USA	Farmers and forest owners. Large-scale innovators who own larger tracts of both timber and pastureland (total >50 ha). Limited-resource farmers (<20 ha) are less common.	*Pinus elliottii* & *P. taeda* have a shorter rotation, but timber from *P. palustris* is viewed as more valuable and there is interest in its restoration. Sometimes nut orchards of *Carya illinoinesis* or hardwoods.	Plantation	Pines: 370-1,000 in groups of 2 or 3 rows. Nut orchards: 45	No data	Sometimes	Warm-season: *Paspalum* spp. y *Cynodon* spp. Cool-season: *Secale cereale*, *Trifolium* spp., *Festuca* spp. y *Lolium* spp., between tree rows. Because of seasonal temperature variability, warm and cool season forage choices are important	Cattle, occasional sheep or goats

Table 2. Typical Silvopastoral System Farmer Profile and Typical Management Regimes by Country and Region, Continued

Region	Typical silvopastoral system farmer profile	Typical tree species	Regeneration	Planting density (trees/ha)	Final density (trees/ha)	Pruning	Typical forage species	Grazing Typical
New Zealand	Experienced farmers as well as the children of farmers who were carrying on the family farm. Average about 500 ha.	*Pinus radiata; Cryptomeria japonica; Eucalyptus* spp.; *Acacia* spp.; *Populus alba*	Plantation	1,600	300-350	Yes (3 times)	*Lolium* spp., with N fertilization de N and herbicide	Sheep
Para-guay	East – parquizado Farmers of various scales.	*Tabebuia* spp. & *Cedrela* spp.	Natural	50-100		No	*Brachiaria* spp.	Cattle
	Humid Chaco Farmers of various scales	*Pinus* spp.; *Eucalyptus grandis* & *E. camaldulensis*, others	Plantation	1,333	530	No	Natives (*Axonopus compressus*, *Hypoginium vigatum*)	Cattle
	Western Central Dry Chaco Farmers of various scales	*Prosopis alba* & *P. nigra*; *Leucaena leucocephala*	Natural	45	45	Yes	Natives	Cattle
Uruguay	Large-scale forest industry in conjunction with local cattle-ranchers.	*Pinus taeda*; *Eucalyptus grandis* & *E. globulus*	Plantation	1,000-1,100	150-250	Yes	*Paspalum notatum, Paspalum plicatulum , Paspalum dilatatum, Stipa* sp, *Briza* sp, *Adesmia muricata, Axonopus affinis,* *Bromus auleticus, Bromus unioloides, Poa lanigera*	Hereford (mainly), Aberdeen, Angus. Some Sheep

There also some small-scale landowners experimenting with silvopastoral systems, with support from nongovernmental organizations.

In the western Central Chaco, INTTAS (Sustainable Agricultural Technology Research and Extension Initiative) has been working with several local landowners with silvopastoral systems. The *Prosopis* spp. would be allowed to naturally regenerate on previously deforested cattle pastures. The goal of these systems would be to maintain the productive life of the pastures, generate high-quality timber and fuelwood, and possibly to sequester carbon. Potentially *Prosopis* spp. could generate seed pods for sale as on the local market or as feed for the livestock in winter months. It has been shown that grass growth below the canopy of *Prosopis* spp. in open stands can be greater than farther from trees.

Uruguay

More than 70% of Uruguay's land is covered with natural grasslands, which is used mostly for cattle raising, and sheep to a lesser extent. Silvopasture systems in Uruguay are extremely common, and are practiced on most of the lands with forest plantations, as well as many pasture lands that have isolated woodlots or trees on fence lines. Some history helps explain these systems. Traditional Uruguayan pasture practices focused on grazing cattle and sheep, and the country had few trees except in stream and river drains and corridors. Land owners might have up to 1000 ha, but could see most of their holdings in one day by riding throughout them on horseback, with an un-obscured viewshed. About 80 to 50 years ago, farmers began to plant trees—usually exotic *Eucalyptus tereticornis and E. camaldulensis*—in small blocks or on fence rows, which were use-

ful to provide shade for livestock, especially cattle, and fuelwood. They also provided good wood for rural use, such as posts and slats for fences.

Uruguay offered incentives that attracted many major foreign forest industry investors beginning in the late 1980s and 1990s. Uruguay now has about 970,000 ha of exotic forest plantations of mostly *Pinus* spp. and *Eucalyptus* spp. These plantations usually include grazing by cattle as part of the system. Although pasture production between trees is limited, the system allows moderate grass production because usually about 30% to 40% of land is not forested, mainly due to soil restrictions (lowlands and natural drainages) as well as roads and requirements of distance from fences and electric lines. The roads also serve as firebreaks.

Forestry companies usually lease their plantations for grazing to local Uruguayans, who manage the livestock on the land. This provides lease income and better local relations for the companies, and cattle forage and income for local Uruguayan producers. More recently forest companies are trying to promote joint venture with cattle producers holders of the land and the company brings the genetically improved planting stock, site preparation, plantation and harvest operations. This can include from annual payments to share the profits at the final cutting and other combinations. The main advantage for the cattle farmer is to provide shade and shelter for livestock.

CONCLUSIONS

While they have many common characteristics, silvopasture systems in Misiones and Corrientes, Argentina; La Pampa, Argentina; the US Southeast; North Island, New Zealand; Paraguay and Uruguay are variable. First, it is obvious that there are differences in (1) the use of native forest species (La Pampa, USA, sometimes in Paraguay and Misiones) versus exotic trees (Uruguay, New Zealand, commonly in Misiones/Corrientes), and (2) plantation forests (Misiones/Corrientes, USA, N. Zealand, Uruguay) versus natural regeneration (La Pampa, western Paraguay). In some regions, native or naturally regenerated grasses are used (La Pampa, Corrientes and southern Misiones, western Paraguay, Uruguay) while in other regions pastures are planted (northern Misiones, eastern Paraguay, USA).

More profound than the differences in species are the differences in the driving motivation behind the silvopastoral systems. In Uruguay, the principal reasons for keeping cattle in the forests is to reduce the risk of wildfire and to maintain good relationships with local farmers. In La Pampa, landowners release livestock into the caldén forest because it is a low-cost means to generate livestock returns. In New Zealand, farmers use forestry and agroforestry systems mostly to have productive systems in steep land that reduce erosion. In the USA, some farmers use silvopastoral systems to diversify their income, and in Argentina many are seeking profit maximization.

Increased silvopasture systems will require some changes in thinking and culture about whether trees help or hurt the animals and forage. Low intensity forest plantations affect viewsheds and traditional ranching cultures, but may offer grazing and financial advantages that can provide diverse benefits. Forests and shade often provide shelter, reduce frost damage, foster good warm season grass growth, provide timber income, and reduce erosion.

In summary, while we only observed six distinct regions, we note some differences between silvopasture systems worldwide. We hope that gaining knowledge about the differences and similarities between the systems helps improve the understanding and application of different technologies and extension in these and other countries.

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