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Paraiso (*Melia azedarach* var. "Gigante") woodlots: an agroforestry alternative for the small farmer in Paraguay

P.T. EVANS and J.S. ROMBOLD

Peace Corps, C/O U.S. Embassy, Asuncion, Paraguay

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Abstract. This paper describes the salient aspects and analyses the potential of the 'Paraiso Woodlot' System, which is becoming popular as an agroforestry alternative to land use in the degraded acid sandy soils of the humid sub-tropical Guayaybi area of Paraguay. The system consists of a combination of paraiso (*Melia azedarach* var 'gigante') with other trees, especially *Leucaena leucocephala*, and annual crops.

The fast growth habit, deep root system, addition of large quantities of organic matter through leaf and litter fall, compatibility with agricultural crops, high value of the sawlogs and production of substantial quantities of poles and firewood make paraiso an excellent species for agroforestry combination. Preliminary results of the trials indicate that the 'woodlots' are successful and with increasing efforts of the extension agencies, they are being accepted as a viable alternative to traditional agricultural systems.

Besides discussing the potential of these 'woodlots' based on initial results, the paper identifies the constraints of the system and highlights the priority research areas.

1. Introduction

The Paraguayan Agroforestry Extension Project is a cooperative effort between Paraguayan national agencies and international technical assistance organizations. Initiated in June 1981, the project aims to better address the problems of rural farmers in Paraguay, by introducing new, more sustainable systems of land culture.

The most promising system developed by the project is a mix of 'paraiso' (*Melia azedarach* var. 'gigante') with other trees and annual crops and is popularly known as 'paraiso woodlots'. Where well-tended, the paraiso woodlots have performed with excellent results. With increasing popular acceptance through the efforts of the extension agencies, the woodlots seem to be establishing themselves as a viable alternative to traditional agricultural practices. This paper describes the salient aspects and projects the potential of paraiso woodlots as an agroforestry alternative to land use in Paraguay.

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2. General description of the area

2.1 *Geographical location*

The longest established paraiso woodlots are located in the Department of San Pedro, in the locality of the town of Guayaybi (24° S latitude, 56° W longitude). This area was first settled 20 years ago by small farmers moving from older, more crowded regions. With no electricity, running water or paved roads, Guayaybi remains a simple, undeveloped area.

2.2 *Biophysical environment*

Guayaybi lies within the Paraguay River watershed. The topography is gently rolling, with almost flat valleys drained by slow-moving rivers. The average elevation ranges between 200 and 250 m.

2.2.1 *Climate.* Guayaybi has a humid, sub-tropical climate. The annual rainfall averages 1500 mm and is well-distributed throughout the year. Much of the precipitation occurs as intense downpours. The yearly temperatures in the area average 24 °C. Frosts are variable; some years are frost-free and others have several or more light freezes, the average being two frosts a year.

2.2.2 *Soils.* The soils in the area are sandy red-yellow podzols derived from Triassic and upper Permian red sandstones. Most of the soils are acidic sandy loams with a variable clay fraction and pH in the range of 4.2 to 6.5. Soils of the areas that have been cleared for agriculture are more acidic, have a lower percent organic matter content and are more extensively leached than corresponding soils under forest cover. Bedrock is encountered at depths of 15–25 m.

2.2.3 *Vegetation.* A tall, humid, semi-deciduous forest forms the climax vegetation of the Guayaybi area. This forest contains many hardwoods highly valued for their quality lumber. Scattered emergent trees, such as tajy (*Tabebuia ipe*), yvyra-pyta (*Peltophorum dubium*) and kurupay-kuru (*Anadenanthera macrocarpa*) rise above a layer of co-dominant species, characterized by guatambu (*Balfourdendron riedelianum*), laurel (*Ocotea* spp.) and yvyrapepe (*Holocalyx balansae*). The understory is dense and woody.

2.3 *Landuse systems*

2.3.1 *Agriculture.* The lands around Guayaybi are owned by small farmers. Most of the farms in the area are 10–20 ha in size. The farmers practice agriculture at a rudimentary level. They cultivate maize (*Zea mays*), groundnut or peanuts (*Arachis hypogea*), cassava (*Manihot escultenta*), beans (*Phaseolus vulgaris*) and bananas (*Musa* spp.) for their own consumption or to sell locally. In addition, cotton and tobacco are planted as cash crops for export.

The families depend greatly, but not entirely, upon their farms for subsistence. Sour orange (*Citrus aurantium*) is grown in plantations for a fragrant oil used in perfumery.

Typically a form of slash-and-burn agriculture is used. To start, forested land is divided into lots. Each farmer periodically clears a portion of his lot and plants cotton or tobacco as the first crop on the new land. These crops grow well for 2–4 years; thereafter their yields decline sharply. Subsistence crops are then planted on such 'old land' and more forest is cleared to plant cash crops. Eventually when the cash crops will have to be planted on the leached, nutrient-depleted soils which had long since had their forest cover removed, the farmer either sells his land at a low price and moves to a new area, or stays faced with the prospect of steadily dwindling crop yields.

Each family has a small number of pigs, cattle and chickens. Pigs are fed table scraps and allowed to root in the fields. Cattle are crowded on small over-used pastures. They gain weight slowly on forages high in roughage, low in protein and insufficient in quantity. Milk yields are low. Chickens yield small amounts of meat and eggs. They graze around the houses and occasionally are thrown some corn, but are otherwise left uncared for.

2.3.2 *Forestry.* Thirty percent of the Guayaybi area is covered with natural forests, the rest having been cleared for agriculture. In the 1960's this forest was selectively cut. The valuable species, such as tajy (*Tabebuia ipe*), peterevy (*Cordia trichotoma*), yvyra ro (*Pterogyne nitens*) and cedro (*Cedrela tubiflora*) were removed. The remaining forest contains species for which there is little or no market outside local use. For this reason the cut-over forest is not valued. There are few industries based on wood products from the natural forest in Guayaybi.

3. Structure of the paraiso woodlot system

Drops in productivity to as little as a half to a third of what was harvested previously indicate agriculture, as currently practised in the area, is not sustainable in the long term. This drop in productivity is primarily due to soil and climatic conditions that predispose the land to fertility loss after deforestation:

- the sandy soil is readily leached;
- organic matter, abundant in the natural forest soils, diminishes rapidly after forest clearing;
- intense, erosion-causing rains are common; erosion losses range from 30 to 100 t ha^{-1} of soil or even more.

In an effort to rebuild soil fertility and use their degraded lands farmers are turning towards agroforestry (paraiso woodlots) as a land use alternative.

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3.1 *Components*

3.1.1 *Crops.* Common subsistence crops grown in the woodlots include bananas (*Musa* spp.), beans (*Phaseolus vulgaris*), cassava (*Manihot esculenta*), maize (*Zea mays*) and groundnut (*Arachis hypogea*). Vegetable crops for urban markets are also sometimes grown, such as onion (*Allium cepa*), bell pepper (*Capsicum annum*), tomato (*Lycopersicon esculentum*) and watermelon (*Citrullus vulgaris*).

Crop management consists primarily of weeding with a hoe. Two crops are grown each year: one in early summer and another in the fall. Groundnut, pepper, tomato, onion and watermelon are early crops. Maize, beans and cassava are grown year-round except in the cold months (June–August). Beans are often grown in combination with cassava and/or maize.

3.1.2 *Trees.* Paraiso (*Melia azedarach* var. 'gigante') is the main tree component of the system. It is a fast-growing exotic with an erect growth form. Little shade is cast by the crown. Paraiso produces an attractive wood that can be used in furniture making, plywood, veneers and interior carpentry.

– *Planting.* Paraiso is planted as a bare-root stump. The planting site should be freshly ploughed. A crop is planted between the tree rows and the trees are kept weed-free through the periodic weedings done for the crop.

– *Pruning.* The tree requires pruning for the first two years, enough time to develop a limb-free 6 m bole.

– *Thinning.* Paraiso is shade-intolerant and should be maintained at low densities for fast growth. At a 4 x 3 m spacing at least two thinnings will be required: first in year 3, and next in year 6, 50% of the trees being removed with each thinning.

– *Harvest.* In 12 years, 200 trees will be ready for harvest, with an average DBH of 40 cm. All the trees may be harvested at this time, or 50% may be removed and the remaining trees harvested in year 15, with an average DBH of 50 cm.

Leucaena (*Leucaena leucocephala* var. K-67, K-28 and Cunningham) is also planted to produce forage, firewood, posts and poles. Leucaena has failed to nodulate in the Guayaybi area, probably due to high soil acidity. Nonetheless, it grows well.

– *Planting.* Leucaena is planted as a bare-root stump, either inter-mixed with paraiso or in separate rows.

– *Pruning.* If the Leucaena is to be used as posts or poles it is pruned for the first 4 years. If it is to be used as forage the top is cut-off periodically at 1.5 m.

– *Harvest.* The Leucaena is harvested on an as-needed basis for firewood, posts and poles.

Peterevy (*Cordia trichotoma*), timbó (*Enterolobium contortisiliquum*), yvyraro (*Pterogyne nitens*) and yvyra pyta (*Peltophorum dubium*) are native hardwoods valued for their high quality lumber. Timbó and yvyra pyta fix nitrogen

and are good soil improvers. All produce posts and firewood as secondary products.

– *Planting.* Plant as bare-root stumps, either intermixed with the paraiso or in separate rows.

– *Pruning.* The native species (with the exception of peterevy) grow with poor form. Constant pruning is required to insure the formation of a single trunk. The paraiso overstory, once formed, will shade the native hardwoods, inducing superior growth form (but slower growth).

– *Thinning.* Trees with poor form or slow growth should be thinned out.

– *Harvest.* The native species should be of harvestable size (40 cm) in 25–35 years.

Yerba maté (*Ilex paraguariensis*) is a small, shade-tolerant evergreen tree. The leaves and small branches are dried, ground-up and used to make a mildly stimulating tea (terreré, the national drink).

– *Planting.* Yerba maté should be raised in containers and planted during winter one year after the paraiso has been established.

– *Harvest.* After 5 years of growth yerba maté is ready for its first harvest. The foliage and twigs are cut, leaving the trunk and larger branches. Trees are harvested once every two years and harvest continues for about 30 years.

3.1.3 *Animals.* On average, each farm supports an average of six heads of cattle. Of these, two are oxen used to work the fields and haul the produce to market; two are milk cows; and the remaining two are young animals. The cattle – unimproved crosses between zebu-type and European breeds – are not good producers of meat or milk, but are resistant to the diseases and are adaptable to the local climate.

3.2 *Arrangement of components*

The arrangement of the woodlot components is flexible; it varies according to the needs of the farmer. Two combinations will be explained in detail:

3.2.1 *Paraiso with yerba maté and bananas*

– *Year 1.* Paraiso is planted at 4 x 3 m spacing. At the same time 4 rows of groundnut are planted between the paraiso rows, to be followed by beans.

– *Years 2–4.* Yerba maté is planted in the paraiso rows in the second year at 3 m spacing. Maize, beans and cassava are planted between the tree rows.

– *Years 5–14.* One row of bananas is planted in the fifth year with 3 m between each banana plant. Paraiso can be cut in year 12.

– *Year 15.* Final harvest of paraiso for sawlogs.

Schematic presentations of this arrangement in years 1 and 7 are given in Figure 1.

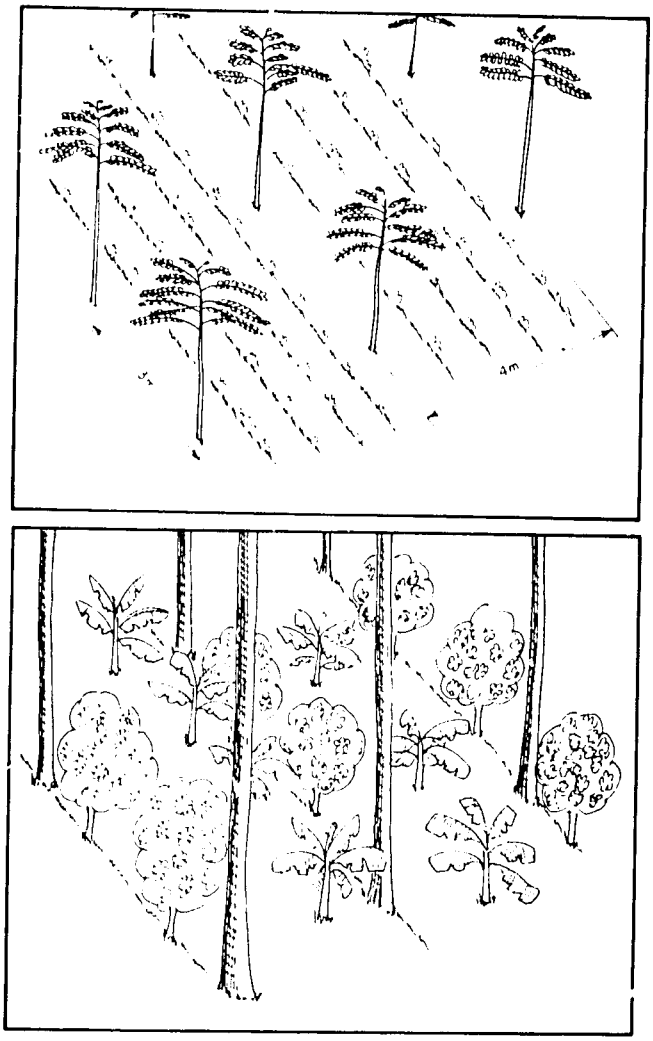


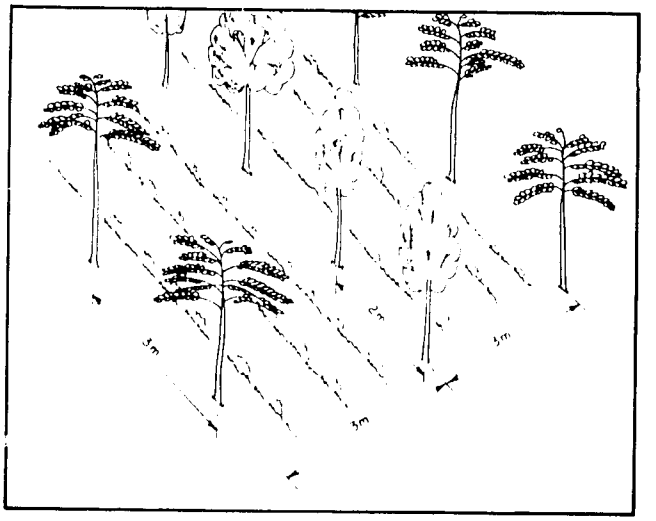
Figure 1. (top) Schematic presentation of planting arrangement of Paraiso (*Melia azedarach* var. 'Gigante') with yerba maté (*Ilex paraguariensis*) and bananas; year 1. (bottom) Same combination as in Figure 1 (top); year 7.

3.2.2 *Paraiso with Leucaena and Timbó*

– *Year 1.* Rows of paraiso are planted 3 m apart from rows of Leucaena (var. K-67) mixed with timbo. Trees within the paraiso rows are spaced 3 m apart, trees in the Leucaena rows are spaced 2 m apart. Three rows of groundnut are planted between the trees, to be followed by beans.

– *Years 2–3.* Maize, beans and cassava are planted between the trees.

– *Years 4–14.* Grass is planted and 2 heads of cattle/ha are allowed to graze the woodlot. The Leucaena is harvested as needed for forage, posts,



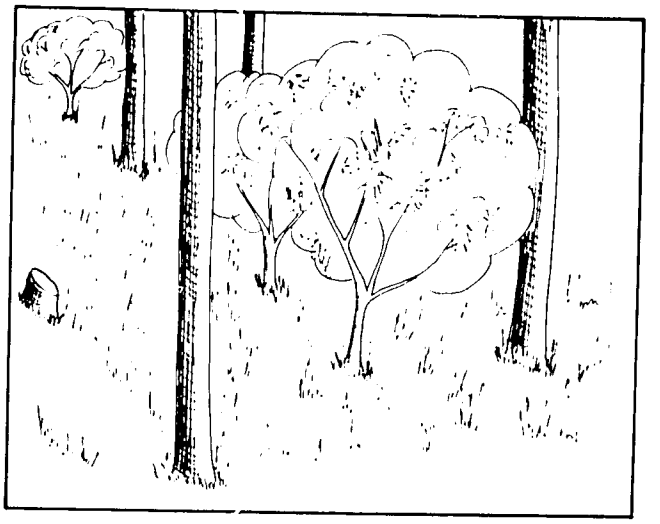


Figure 2. (top) Schematic presentation of planting arrangement of Paraiso (*Melia azedarach* var. 'Gigante') with Leucaena (*Leucaena leucocephala*) and Timbó (*Enterolobium contortisiliquum*); year 1. (bottom) Same combination as in Figure 1 (top); year 7.

firewood and poles. Harvest of paraiso for sawlogs can be started in year 12.

– *Year 15.* Final harvest of paraiso for sawlogs. The primary component of the woodlot is now timbó.

Figure 2 shows the schematic pattern of this combination in years 1 and 7.

3.3 *Interaction of components*

The most readily observable interaction is competition for light between:

– *Trees and weeds.* Paraiso's growth is stunted when weed competition is intense. Growth is more than double when a crop is planted between the tree rows and the field is kept free of weeds.

– *Trees and crops.* In the first year, a tall, fast-growing crop such as maize will shade the paraiso and slow its growth. Later, when the trees are taller, the opposite occurs and it becomes no longer possible to plant sun-loving crops.

– *Trees and trees.* If allowed to become too dense, paraiso's growth is slowed. Likewise, without periodic thinnings of the paraiso overstory, little light reaches the intermediate layer of leucaena and native hardwoods (if these components were included).

Thus, it is important to carefully plan spacings and thinnings to optimize the performance of the system's components. Another important interaction is the amelioration of the environment by the tree overstory. Frosts, high winds and intense solar radiation are mitigated to some extent by the crowns:

– the partially shaded bananas have a lower incidence of sigatoka (*Cercospora musae*) disease;

– under shade, yerba maté grows better than when in full sunlight;

– cattle grazing beneath the overstory are less stressed by heat;

– crops (melon, tomato, pepper, etc.) interplanted with trees are protected from late frosts and can be planted earlier.

Other interactions include the production of forage for cattle and of nectar for bees (if a bee component is included).

4. System functioning

4.1 *Resource input and utilization*

4.1.1 *Land.* The size of the paraiso woodlots ranges between 0.25 and 2.0 hectares, with an average of about 1.0 ha. Thirty seven families in the Guayaybi area have planted woodlots in a land area of about 35 hectares. These families have bought lands from the government and are full owners of their farms. The average population density is 0.7 persons/ha. This population density is currently increasing, due to immigration from older areas and a high birthrate (4.1%). In the future it is expected there will be a diminution of farm size from the current average of 12 ha/family to about 7 ha/family as land holdings are subdivided.

4.1.2 *Capital.* Only a small capital expenditure is required. Trees are sold at 10 guaranies (100 guaranies = $0.30 U.S. dollars in March 1984) a piece. All technical assistance provided by the project is free.

4.1.3 *Labour.* The largest investment is the labour required to establish and

maintain the plantation. To plant one hectare, the following labour inputs (mandays) are required: ploughing – 2; tree planting – 2; sowing of crops – 1; weeding/hoeing (four times) – 16; pruning – 2 days the first year and 3 the second year.

4.2 *Pattern*

In Paraguay agroforestry activities are best undertaken during the cool months (May–September). During this period there is little work to be done in the fields. Also, during the winter, trees experience less stress after transplanting. From October to April the farmers are busy planting, tending and harvesting their cotton and tobacco crops.

Seeds are collected inside the country and are distributed free to the agroforestry extension nurseries. Trees from these nurseries are then sold at a low price to interested farmers. All traction power is supplied by oxen. Pesticides are sometimes used on vegetable crops intended for the market. Fertilizers are not used because of their high cost and limited availability.

4.3 *Production*

Though no accurate data is available on the yields of agricultural commodities from the paraiso woodlots, estimates indicate that a paraiso woodlot (4 x 3 m spacing), underplanted with bananas and yerba maté, will have produced 110 m^3 ha^{-1} of posts, poles and firewood and 176 m^3 ha^{-1} of sawlogs by year 15. A woodlot of paraiso (3 x 6 m spacing) mixed with Leucaena and native species, will have produced, by year 15, 75 m^3 ha^{-1} of posts, poles and firewood from Leucaena and native trees and 176 m^3 ha^{-1} of paraiso sawlogs. Preliminary data on the growth of paraiso and Leucaena in the Guayaybi area are given in Table 1. Photographs of the 6 month- and 12 month-old trees are given as Figures 3a and 3b.

Initially the primary output of the woodlots is food crops. As the trees grow taller the emphasis is shifted to shade tolerant crops (banana, cassava) and wood products. The sawlogs are grown for the local market and/or export. The other outputs are intended for home consumption.

4.4 *Protective and service aspects of the system*

One of the primary goals of the woodlots is the improvement and productive utilization of degraded soils. Most farms more than 10 years old (after first forest clearing) have fields that are either producing very little or have been taken out of production altogether. The paraiso woodlots have potential to improve soil in the following ways:

– organic matter is added to the soil through leaf drop and root decomposition;

– nitrogen is added to the soil by nitrogen-fixing trees included in the woodlot;

– aeration of the soil through the action of tree roots;

Figure 3A. Photograph of a 6 month-old Paraiso woodlot.

– retrieval by deep tree roots of nutrients leached below the root zone of annual crops;

– prevention of further soil erosion and subsequent fertility loss by the formation of a permanent protective vegetative covering. The paraiso woodlots are re-vegetating and utilizing formerly unproductive farmlands. The quantative effect of the woodlots on soil quality is not yet known. However, qualitatively it can be observed that humus layers are being rebuilt and that soil structure is becoming less compact and more porous where woodlots have been planted.

4.5 *Socio-economic description*

In rural Paraguay, incomes ebb and flow with the tobacco and cotton harvest. Little income is realized from the sale of other crops. From October until January farmers spend large amounts of capital on seed and pesticides. By harvest time most families owe money to local merchants for food, clothing, tools and agricultural products. If the price for cotton and tobacco is good,

Figure 3B. Photograph of a one year-old Paraiso + Leucaena (K. 67) stand.

the farmers earn enough profit (average harvest income from 2 ha of cotton = U.S. $800) to pay off their debts and buy needed items. Often though, the price of cotton is low and families have problems meeting their debt obligations. These are the times of greatest emigration out of the rural areas, as the less-successful farmers sell their lands and seek work in urban centers.

The paraiso woodlots add a long-term dimension to the economic outlook of the rural farmer. The system has a real potential to provide large amounts of income 10–15 years after planting. The value of the harvested sawlogs has not been established on the Paraguayan market. However, in Argentina paraiso is replacing cedro (*Cedrela tubiflora*) – one of the highest priced native hardwoods – on the market, largely because the supplies of cedro are almost exhausted. Based on this, the value of a mature paraiso woodlot is estimated to be U.S. $5100–6800 per hectare. The prospect of this long-term profit adds security to families' futures and encourages them to view agriculture as a long-term, sustainable enter prise.

4.6 *Overall performance assessment*

Paraiso has demonstrated its potential as a fast-growing reforestation species.

Table 1. Early growth of paraiso and leucaena woodlots in the Guayaybi area

Woodlot	age (months)	Paraiso mean height (m)	mean DBH (cm)	Leucaena mean height (m)	mean DBH (cm)
Casere	9	3.34			
Acosta	6	2.98			
Soria	8	2.93		3.08	
Ronan	8	2.24		2.25	
Ortiz	12	3.76	3.32	3.22	2.50
Ortiz	19	7.00	5.75		

When degraded land units with the woodlots are compared to similar land units without the trees, the advantages become obvious: formerly unproductive units of land are now supporting fast-growing trees and crops and are directly adding to the well-being of the families who work the land.

5. System dynamics

5.1 *Rate of growth*

The paraiso woodlots are a new landuse alternative and are expanding at an impressive rate. The demand for trees to plant woodlots is outstripping the production capabilities of the extension nurseries. According to an FAO study, Paraguay's wood products industry has 15 years of life left before it runs out of reserves of commercially valuable species. Paraguay's forests are being destroyed at the rate of 3.3% each year, the fastest deforestation rate in the Western Hemisphere. At the same time, the demand for Paraguayan wood products is projected to be 14 times greater in the year 2000 than its former level in 1970. On top of this, Paraguay has a high population growth rate and limited arable land. These factors add impetus to the push towards sustainable systems that produce both wood products and food, such as the paraiso woodlots.

5.2 *Degradation of the system*

The first two years of the woodlot are critical. The trees must be kept free of weed competition or their growth is stunted. This is the stage where the extensionist has a key role. Farmers who have been well-supported by a forest extensionist have confidence in the woodlot and are willing to work hard to keep the trees free of weeds. Other farmers who have had weak support often develop doubts, concentrate their labour elsewhere and let the weeds grow, choking out the trees. It has been observed many times that when a woodlot fails, it happened because the farmer believed it would fail and did not invest the necessary labour.

5.3 *System sustainability*

Since the paraiso woodlots are new, no data is available at this time on their sustainability.

6. Evaluation

6.1 *Merits*

1. Paraiso grows rapidly, quickly establishing a vegetative cover and producing wood products in a short time (see Table 1).
2. The woodlots effectively combine food crops and trees to provide products for home consumption and the market on priorly unproductive lands.

3. The system shows promise as a means of rehabilitating degraded soils and protecting against erosion.
4. A prospect for long term stability and security is gained by the farmers who plant the woodlots.

6.2 *Weaknesses*

1. *Biological.* In some plantations paraiso has been attacked by an unknown pest or disease. The attacked trees develop a horse-tail shaped brooming of the growing tip. Apical dominance is lost and the trees cease active height growth. Up to 10% of the trees in some plantations have been attacked. Leaf-cutter ants are another major pest, sometimes causing complete defoliation.
2. *Climatic.* In the sapling stage paraiso is susceptible to frost damage.
3. *Edaphic.* When used as a component of a woodlot, Leucaena has exhibited little tendency to nodulate on acid ($pH \leqslant 5.0$) soils. Nevertheless, it grows rapidly.
4. *Ecological.* Paraiso does not compete well with weeds.
5. *Technical support.* Paraiso woodlots are a new landuse method that farmers are unfamiliar with. To be successful, the farmers need strong technical support from well-trained extensionists. Due to institutional constraints, this support is often difficult to provide.

6.3 *Constraints*

The lack of strong governmental support for an agroforestry programme is the primary constraint limiting the success of the paraiso woodlots. Without this support, it is difficult to provide the minimal level of technical assistance necessary to manage the woodlots. The spread of the woodlots in the field is outgrowing the institutional capabilities to support them.

Another constraint is the uncertain market for paraiso sawlogs. In Misiones, Argentina, a province along the southern border of Paraguay, paraiso is the second major reforestation species (after eucalyptus), and there is an ample market for the sawlogs produced. A similar market could be developed for paraiso in Paraguay, but does not exist as yet.

6.4 *Potential*

With greater institutional support and a firm market, paraiso woodlots could become a common landuse in Paraguay. The woodots could be made more productive by:

– using improved strains of pasture grasses;
– including an apicultural component if nectar-producing trees are planted in the woodlot;
– including more shade-tolerant crops, such as coffee, papaya, etc.;
– incorporating more nitrogen-fixing, soil-building leguminous trees other than Leucaena;
– collecting paraiso seed from superior trees and initiating a tree improvement programme.

6.5 *Extrapolability*

In Paraguay and Argentina, paraiso is cultivated on acidic clay and sandy soils, in climates ranging from warm temperate to subtropical, with precipitation between 1400 mm--2000 mm. While extrapolable to areas with similar conditions, it is not known how the tree would grow in more tropical climates or at higher elevations.

6.6 *Research needs*

Through research, the paraiso woodlots and their management could be improved. Some research needs are:

- growth predictions for different site conditions;
- quantitative outputs of the crop component and how the tree component affects this yield;
- effects of *azedarachin*, a compound contained in paraiso leaves, on crop pests;
- growth rates of native species that could be used in the woodlots;
- effects of the woodlots on soil fertility over time;
- cost/benefit analysis of the woodlots;
- timing of thinning;
- pests and diseases of paraiso, focusing upon the horse-tail brooming and upon the relationship between root damage due to ploughing and root rot proliferation.

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Data/information base

The following persons may be contacted for more information regarding the paraiso woodlots:

Associate Director, Forestry
Peace Corps
c/o U.S. Embassy
Asunción, Paraguay

Director COSUDE Forestry Project
c/o Embassy of Switzerland
Asunción, Paraguay

Ing. Forestal Felix Riveros
Director de Investigaciones
Centro Forestal Alto Parana

Pte. Presidente Stroessner
Paraguay

Tec. Forestal Roque Martinez
Servicio Forestal Nacional
Asunción, Paraguay.

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