Alley Farming in the Humid and Subhumid Tropics

Proceedings of an international workshop held at Ibadan, Nigeria, 10–14 March 1986
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Alley Farming in the Humid and Subhumid Tropics

Proceedings of an international workshop held at Ibadan, Nigeria, 10–14 March 1986

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Abstract / Résumé / Resumen

Abstract — An urgent challenge facing scientists working on upland food-crop production in many parts of the humid and subhumid tropics is the need to find viable, sustainable, and environmentally sound alternatives to the ancient shifting cultivation and bush-fallow, slash-and-burn cultivation systems. As a food-cropping and livestock-production technology, alley farming requires a low level of inputs and helps conserve soil resources while sustaining long-term farm productivity. This publication presents the results of an international workshop on alley farming in the humid and subhumid tropics. Held in Ibadan, Nigeria, 10–14 March 1986, the workshop was attended by 100 participants from 21 countries. The theme of this workshop was the development of more productive, sustainable farming methods with low inputs in the humid and subhumid tropics using alley farming techniques. This book reviews the present state of alley farming research and its application, discusses the use of woody species in tropical farming systems, highlights training and research needs, and proposes the establishment of channels for collaborative research.

Résumé — Les scientifiques s'intéressant aux cultures vivrières en zones d'altitude dans de nombreuses régions des tropiques humides et sub-humides doivent répondre à un besoin urgent : trouver des solutions de rechange viables, soutenables et environnementalement saines aux anciennes méthodes de rotation des cultures et mise en jachère et de culture sur brûlis. A titre de technique de culture et d'élevage, l'agriculture en couloirs ne nécessite que peu d'intrants et contribue à conserver les sols, tout en favorisant la productivité agricole à long terme. Cette publication présente les résultats d'un atelier international sur l'agriculture en couloirs dans les tropiques humides et sub-humides qui s'est tenu à Ibadan, au Nigéria, du 10 au 14 mars 1986 et qui a réuni 100 participants de 21 pays. L'atelier portait sur la mise au point de méthodes culturales plus productives et plus durables ne nécessitant que peu d'intrants pour les régions des tropiques humides et sub-humides, grâce aux techniques de l'agriculture en couloirs. Le livre fait le point sur la recherche actuelle en matière d'agriculture en couloirs et ses applications, discute de l'utilisation des arbres dans les systèmes agricoles en milieu tropical, met en lumière les besoins en matière de formation et de recherche et propose l'établissement de canaux aux fins de la recherche en collaboration.

Resumen — Un reto urgente al que se enfrentan los científicos que realizan investigaciones sobre la explotación de cultivos de montaña en muchas zonas húmedas y subhúmedas de los trópicos, es la necesidad de encontrar alternativas viables, sustentables y correctas desde el punto de vista del medio ambiente, al antiguo método de cultivos migratorios y a los sistemas de cultivo en barbecho y de corte y quema. Como tecnología utilizada para cultivos alimentarios y la producción ganadera, la agricultura de pasillo o entreurcos necesita pocos medios y ayuda a conservar los recursos del suelo en tanto mantiene la productividad agrícola a largo plazo. Esta publicación presenta los resultados de un grupo de trabajo internacional sobre agricultura de pasillo o entreurco en las zonas húmedas y subhúmedas de los trópicos, celebrado en Ibadán, Nigeria, del 10 al 14 de marzo de 1986, y al que asistieron 100 participantes de 21 países. El tema de este grupo de trabajo fue el desarrollo de métodos de cultivo más productivos y sostenidos con pocos recursos en las zonas húmedas y subhúmedas de los trópicos, utilizando técnicas de agricultura de pasillo o entreurco. Este libro revisa la situación actual de la investigación sobre la agricultura de pasillo o de entreurco y su aplicación, discute el uso de especies maderables en sistemas de cultivo tropicales, subraya la necesidad de realizar investigaciones y dar cursos de capacitación y propone la creación de canales para la investigación conjunta.
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The role of *Leucaena leucocephala* in farming systems in Nusa Tenggara Timur, Indonesia

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Abstract — Nusa Tenggara Timur (NTT) is one of the driest provinces in Indonesia. Agriculture is seriously restricted by the long dry season, steep slopes, and low soil nutrient status. Shifting cultivation is still widely practiced, resulting in soil erosion and land degradation. Various programs introduced in the past by the Dutch colonial government to replace shifting cultivation (e.g., partial mechanization or intensive agriculture using high inputs) have failed. *Leucaena leucocephala* was introduced in NTT during the 1910s to improve traditional farming systems. Although it is widely grown in the region, a breakthrough in its use did not occur until the 1970s with the introduction of the Lamtoronisasi and the Paronisasi programs, and the Hawaiian Giant strain, known locally as lamtoro-gung. The local varieties (Hawaiian type) are being used successfully for soil-conservation programs on hilly land at Sikka on the Island of Flores and to fatten cattle at Amarasi in West Timor.

Introduction

The province of Nusa Tenggara Timur (NTT) occupies the eastern part of the Lesser Sunda Islands, which includes West Timor, Flores, Sumba, and many other small islands. The provincial administration is divided into 12 regions called Kabupaten. The total land area is about 50 000 km² with a population of about 3 million. The population density varies between regions. Kabupaten Sikka on the island of Flores is the most densely populated region with an average density of 150 people/km²; central Sikka has more than 400 people/km². Kabupaten Sumba Timur on the island of Sumba has the lowest population density (25 people/km²).

NTT occupies a special position in the Indonesian archipelago: it has the lowest average annual rainfall (1 000–2 000 mm), especially on the northern slopes, which have over 6 dry months. Agriculture, the predominant form of land use in this region, is seriously restricted by the long dry season with irregular amounts of rainfall, steep slopes, and low soil nutrient status. The intensity of the rains also causes severe erosion, floods, and landslides. Slash-and-burn agriculture is still widely practiced on about 43% of the total arable area of this region. Combined with other forms of upland farming, dryland agriculture makes up about 72% of all land cultivated each year. Slash-and-burn farming with no efforts at conserving...
soil, together with overgrazing, have resulted in extensive land degradation over about 48% of the province's land area. This is marked by extensive grass savannas and severely eroded hills, many of them covered with *Imperata cylindrica*.

The low average agricultural productivity, sometimes marked by crop failures, has resulted in a low per-capita income. This has prompted the government, even under Dutch rule, to introduce improvements in traditional agricultural practices and farming systems. At the end of the 1800s, coconut was introduced as a monocrop at sea level and on steep hills to an altitude of 600 m. This resulted in serious soil erosion and environmental degradation of the hilly lands.

Cattle was introduced from the islands of Java and Bali at the beginning of the 1900s with the intention of inducing the native population to switch to commercial stock keeping. Although large numbers of cattle can now be found on the islands of Timor and Sumba, this goal has not been achieved (Metzner 1977). The cattle adapted well to the local situation but did little to solve the problem of feeding the people (Piggin and Parera 1984). Moreover, the heavy concentration of free-grazing animals has led to overgrazing in many areas.

Many failures were also observed with several other projects, e.g., partial mechanization to help farmers farm larger areas (as in Sekon on the island of Timor) and resettlement schemes with intensive cultivation at lower altitudes for shifting cultivators who lived in scattered mountain settlements. Later, it was felt that the problems could only be overcome by a complete change in farming methods: the incorporation of *Leucaena*, a plant already known in the area (Metzner 1976).

**Introduction of *Leucaena leucocephala***

*Leucaena*, a promising forage and tree crop for the tropics, was introduced by Spanish merchants to Asia from Central America sometime between 1565 and 1825. A bushy, Hawaiian strain was brought to the Philippines by these merchants (NAS 1984). Dutch plantation owners imported *Leucaena* to the island of Java during the 1800s to be used as shade trees for plantation crops such as tea, cocoa, cinchona, coffee, and vanilla. It was later observed that *Leucaena* could be used as a support for climbing crops such as pepper and vanilla, as firewood and forage, for green manure, or for erosion control when planted in rows along the contour lines of hillsides. Because of its many functions, particularly erosion control, *Leucaena* was introduced to NTT during the 1910s as part of an effort to replace shifting cultivation. The species has adapted well to the dry, harsh conditions of the province; however, because of its rapid growth, farmers found it difficult to accept at first. Now, however, *Leucaena* plantations can be observed in various areas of NTT.

On the island of Flores, the first *Leucaena* introduction was made in the mountainous Lio area (about 1930). It has since expanded extensively. This vast expansion was due to the realization by the farmers that *Leucaena* was well suited to their traditional agricultural practices. Soil-fertility restoration under *Leucaena* took less time. From September to April, farmers clear small plots in the *Leucaena* forest for upland rice and maize production.
On the island of Timor in the 1930s, *Leucaena* was planted on abandoned fields around Baun as an experiment under the guidance of the Dutch administrator (Ormeling 1955; Metzner 1981). Since then, the plant has been established widely. A traditional ruling in 1932 obliged every farmer in Amarasi on the island of Timor to plant contour rows of *Leucaena* not more than 3 m apart in cropped areas before the land was abandoned. Failure to comply carried the threat of a fine or jail sentence. Planting expanded eastward to Oekabiti and Burain as the local decree was implemented in the early 1940s (Metzner 1981).

This local regulation was reinforced in 1948 by the government, which compelled all shifting cultivators to plant *Leucaena* along contour lines (Ormeling 1955). Today, *Leucaena* has formed such a solid cover that, in Amarasi, the contour lines are not evident. This is because the hedges were not trimmed and the plants quickly colonized the spaces between the hedgerows (Metzner 1981). According to Ormeling (1955), the total area under *Leucaena* in Kupang district on the island of Timor was 465 ha in 1948, with 437 ha located in Amarasi. A more recent estimate (Metzner 1981) shows that *Leucaena* covers about two-thirds of the Amarasi district. This has greatly helped in controlling the weed *Lantana*. Jones (1983) and Piggin and Parera (1984) reported that the area under *Leucaena* was spreading south and east of Amarasi.

The eastern and the driest part of Sumba is mostly hilly and barren. At the Isyak Daorivu garden close to Waingapu, an area of about 3 ha has been planted with *Leucaena* since 1936. This small *Leucaena* field provides a contrast to the surrounding barren area and illustrates the potential that trees can have on the environment.

### Lamtoronisasi

*Lamtoronisasi* is a term widely used, particularly in the Sikka region, in which the Hawaiian bushy type of *Leucaena* is used to create hedgerows of indirect terraces on sloping land to control erosion (Fig. 1). In 1978, when Hawaiian Giant was introduced, this term also encompassed the Salvador and Peruvian varieties (Parera 1980).

Efforts to control erosion in the Sikka region began in 1966 with the development of bench terraces. Because the hard work required had no immediate payoffs, however, the local population was reluctant to adopt this practice. Father H. Bollen, a German priest, was impressed with the potential of *Leucaena* for erosion control and rehabilitation of critical lands. He established a small trial plot by planting contoured rows. One year later, a local farmer also established a small garden. The stable yields in this garden over a 3-year period from 1969 to 1971 prompted the establishment of an indirect terracing demonstration plot using contoured rows of *Leucaena* planted at 5-m intervals.

A year after the establishment of the *Leucaena* hedgerows, clove trees were planted between the *Leucaena* rows. The success of this experiment is one of the best examples of *Leucaena*’s ability to grow in harsh conditions, with subsequent rehabilitation of the soil so that valuable crops can be planted.

Stimulated by these successes, the local administrator of Sikka district directed that these practices be expanded to other areas in the district. A Soil Erosion Control Team for Sikka district was set up in 1973. The team was charged with
Fig. 1. *Leucaena* hedgerows are used to stabilize hilly and steep lands in Sikka District, Flores, Indonesia.

training farmers and arranging for the purchase and distribution of tools such as hoes and water levels. The term *lamtoronisasi* (Parera 1980) was introduced to distinguish this technique from other forms of erosion control.

To promote *lamtoronisasi*, the national food crop intensification program (BIMAS), which has been operating in Sikka district since 1974, makes improved seeds, inputs, and credit facilities available only to farmers who have planted *Leucaena* on their land (Parera 1982). The same arrangements were made for those farmers wanting to buy seedlings of cocoa or cloves from the Agricultural Extension Service. The larger crop yields derived from the project made this exercise attractive to local farmers (upland rice yields increased from 500–700 kg/ha with the traditional system to 2–3 t/ha; maize yields more than doubled). The farmers also made more money by growing cloves, which fetch higher prices than the earlier-introduced coconut.

All these factors have led to more *Leucaena* being planted since 1974 to create indirect terraces and to support bench terraces that were already there (Fig. 1). By 1982, about 20 000 ha of hilly lands had been terraced and more than 2 million *lamtoro-gung* (Hawaiian Giant) had been planted in Sikka district.

The effectiveness of *Leucaena* hedgerows in reducing erosion and runoff largely depends on layout and timeliness; the hedgerows must be planted on the contour at the start of the short rainy season (±4 months). The seeds of the Hawaiian type are sown directly in raised beds in the fields; seeds of Hawaiian Giants are first grown in polyethylene bags and then transplanted. The contours, spaced 3–5 m apart, are determined using a water level or a simple A-frame, after which raised beds of
20 x 10 cm are constructed. Untreated seeds are sown in the beds at a seeding rate of 70–100 kg seeds/ha. The less vigorous Hawaiian type is more suitable for terrace hedgerow planting.

Periodic pruning of the hedgerows (at 75–80 cm height) prevents *Leucaena* from becoming a weed, a development that made it unacceptable to farmers in the past. Pruning is done after the plants are more than 1 year old. In many cases, poor performance of hedgerows can be traced to too early pruning. In burned-over areas, the regrowth of *Leucaena* can be stimulated by pruning.

Although not many farmers in the Sikka District intentionally use *Leucaena* prunings as green manure for their crops, the leaves drop around shrubs during pruning. The manuring effects are the same as in deliberate mulching, with the upper side of the terraces benefiting more from the practice (Metzner 1976).

The presence of *Leucaena* hedgerows also improves microclimate. Some farmers have recognized these changes and have begun cultivating crops, such as peppers and cocoyams, that could not be cultivated before (Parera 1983). Single *Leucaena* stems in the hedgerows spaced 3 m apart were sometimes left uncut and used as supports for climbing crops such as vanilla.

*Leucaena* prunings are also fed to chickens and pigs in Flores. Cattle have not traditionally formed a significant role in the livestock industry in Flores. Efforts to encourage cattle farming began in 1967 with the introduction of 100 head of Bali cattle under a government credit program. According to Cunha (1982), however, there were only 50 cattle in Sikka in 1970, owned mainly by the Department of Animal Husbandry and the Catholic Mission.

The cattle industry received another stimulus in 1978 with the introduction of the more productive Hawaiian Giant strain, which are planted widely in uncropped areas and are suitable as material for fodder banks. Further introductions of 1 500 head of Bali cattle over the next 2 years brought the cattle population to over 2 000 head by mid-1982 (Cunha 1982). It is anticipated that, in the future, the *Leucaena* farming systems in Sikka will also include intensive cattle production and fattening, using a cut-and-carry system. Farmers are familiar with tethered livestock, as horses are traditionally tied (Piggin and Parera 1984).

**Paronisasj**

Bali cattle was introduced to Nusa Tenggara Timur around 1912 to supplement periodic food shortages, usually the result of incorrect agricultural practices (Manny 1979). This objective was not wholly achieved, however, as the large increase in population and livestock was not accompanied by a corresponding intensification of cultivation methods (Metzner 1977). With more cattle to feed (about 440 000 in 1977), fodder supply became a problem (Huijema and Doormal 1946). The traditional practice of burning and overgrazing reduced not only the forage quality but also the carrying capacity of these grasslands. Abortion and death among calves are common in the dry season.

At Amarasi on the island of Timor, the condition was aggravated by the presence of *Lantana camara*, a woody shrub first observed in Timor around 1912. It was probably introduced as a potted plant or with cattle to Kupang. It spread rapidly
Fig. 2. Fattening cattle on Leucaena fodder.

eastward between 1915 and 1935. By 1949, about 80% of Amarasi District was covered by the weed (Ormeling 1955; Metzner 1981).

Livestock owners and food crop farmers have differing opinions about the plant. To livestock owners, the plant is a weed as it dominates the grassland and is not eaten by the livestock. Metzner (1981) suggested that the decline in livestock numbers (cattle, water buffalo, horses) in Amarasi from 6 000 in 1916 to 4 000 in 1948 was largely due to Lantana infestation. Ormeling (1955) reported lower livestock numbers in the early 1950s in Amarasi (60/km² and 50 per 1000 inhabitants) compared with the Timor island average (170 and 450, respectively). However, the shifting cultivator likes Lantana because it grows rapidly and can reduce fallow periods from 15 to 5 or 6 years. It provides a rapid soil cover, maintains good soil structure, and reduces the growth of other weeds. Thus, land-preparation time in subsequent crops is reduced (Ormeling 1955). Under the
influence of powerful cattle owners, attempts were made around 1955 to control Lantana biologically using Teleonemia lantanae and herbicides (Ormeling 1955; Metzner 1981). These methods had little effect, and control was ultimately achieved by replacing Lantana with Leucaena, an acceptable solution to both herders and farmers (Piggin and Parera 1984).

In 1971, cattle production in Timor was stimulated by the provincial government's successful introduction of paronisasi (Fig. 2). In this program, cooperating farmers are given a bull to feed on crop residues and plantation products. When the animal reaches export weight and is sold, the profit is shared by the government and the farmer. This program has become the basis of an extensive private program in which exporters and individuals with large herds provide animals for feeding and share the profits with the farmer doing the feeding (CIDA 1980).

Because Leucaena is available in abundance for use as fodder in Amarasi, that district benefits the most from this scheme. According to Metzner (1981) and Jones (1983), the average farmer in Amarasi supports a family of about six people and owns 2 ha of land on which Leucaena is established at a density of about 10,000 trees/ha. One-third of the farmer's land is used to plant maize and other food crops in a 3-year rotation scheme; the remaining two-thirds is used to provide fodder for the tethered cattle.

The cattle are fed 15–20 kg of Leucaena fodder and other legumes each morning and afternoon. Over 100 kg/day of browse is required for a family with three cattle. Leucaena, densely planted on 1 ha, can usually supply this requirement. Cattle and goats that were fed entirely on Leucaena for 6 months did not show any symptoms of mimosine toxicity. One-year-old cattle (Fig. 2) bought at the local markets for about IDR 75,000 (in 1985) are fattened for about 18 months and sold for about three times the purchase price (in December 1988, 1750 Indonesian rupiah [IDR] = 1 United States dollar [USD]).

Leucaena also benefited other crops such as banana, pawpaw, and coconut. These crops are now intercropped with Leucaena. Banana stem is fed to cattle as a source of water.

**Extending alley farming**

The impact of lamtoronisasi in Sikka and paronisasi in Amarasi has prompted government and private agencies in other districts to use Leucaena to promote soil fertility and increase agricultural production. The Provincial Development Programme is run by the Directorate of Regional Development, Ministry of Home Affairs, and the United States Agency for International Development. Together, the two agencies run three projects on the island of Timor, one on the island of Flores, and one on the island of Alor. One aim of these projects is to help resource-poor farmers raise their incomes and standard of living. Because agriculture predominates in these areas, incorporating Leucaena into the farming system is one of the main goals of the Provincial Development Programme (Prussner 1981).

In 1980, Hawaiian Giant seeds were brought from Sikka to be planted in backyard gardens and alley cropped fields. In alley-cropped fields, these seeds were planted in straight double rows, 45 m apart, on the flat areas, and in single,
contoured rows in hilly areas. In the hills, interrow spacings depend on slopes. Crop-yield trials using *Leucaena* as green manure were conducted at some of these locations and on farmers' fields.

The NTT Livestock Development Project aims to improve and stabilize farming systems in NTT through improved livestock management and stable cropping. A pilot project to determine the most appropriate technology is being conducted on 4 000 ha in south-central Timor by the Department of Animal Husbandry and the Australian Development Assistance Bureau.

The project began in March 1982. By January 1984, about 400 ha had been sown with contoured rows of *L. leucocephala* (cv. K-8, cv. K-28, cv. Cunningham), *Sesbania grandiflora*, *Macroptilium atropurpureum*, *Stylosanthes hamata*, *Stylosanthes scabra*, *Bothriochloa pertusa*, and *Chloris gayana* to demonstrate catchment stabilization and fodder production. Initial establishment was excellent.

*Leucaena* was also established in 1- to 3-ha demonstration areas at five locations in the four villages close to the project area to demonstrate stable cropping systems. Several research trials using *Leucaena* have been established. They investigate:

- the productivity of *Leucaena* (cv. K-8, cv. Cunningham, local) and *S. grandiflora* with and without phosphorous fertilizer,
- the nitrogen contribution of *Leucaena* and other crop/pasture rotation trials, and
- the best time of establishment of *Leucaena* and other pasture species, sowing methods, and seed treatments.

Once the appropriate technology is identified, the project will be extended to other areas within the district.

Initial results showed the following:

- giant varieties are more productive than the local variety;
- planting can be undertaken successfully months before the wet season;
- effective nodulation and establishment are encouraged by inoculation with soil from an established *Leucaena* field (Piggin and Parera 1984).

World Neighbors projects in East Sumba and in Ende (on the island of Flores) are attempting to improve water supply and agricultural production. They are particularly focusing on the dry district of East Sumba and the eroded, steep hills of southern Ende. The projects' goal is to stabilize the land and control erosion through the use of *Leucaena*.

On Sabu, a small, eroded, barren island halfway between Timor and Sumba, IRAE, a local organization, is introducing direct terraces with *Leucaena* hedgerows on small catchments. These have resulted in better maize and sorghum yields and have allowed the introduction of new crops such as onions, assorted vegetables, and lemon trees.

The Catholic Mission, either directly or in cooperation with the local government, is actively promoting the *lamtoronisasi* program in some districts. At Sikka, the Mission manages a Farmer's Training Institute at Waigete. The Institute trains young farmers from Sikka and other districts in dryland farming.
A large-scale lamtoronisasi program has existed in Ende since 1984. A large area of agricultural land was sown with *Leucaena* in the rainy season of 1984.

Lokomea, a small village in north central Timor, best illustrates the success of the giant *Leucaena* strain. Barren backyard gardens owned by smallholder families have been transformed into lush green areas following the introduction of *Leucaena*. Various crops such as papaya, bananas, pineapples, and vegetables can now be planted successfully. The paronisasi program in the area has already improved the villagers’ income. About 50 ha of the surrounding agricultural land has been terraced with *Leucaena* hedgerows intercropped with pineapple and forage grass (planted on the lower side of the hedgerows). New crops such as pepper and cocoa are also being introduced.

**Research issues and results**

The question of whether to use cv. Hawaiian Bushy or Hawaiian Giant *Leucaena* to create indirect terraces needs more research. In Sikka, the bushy Hawaiian type is used for indirect terraces and fencing backyard gardens. The Hawaiian Giant is planted as a shade tree or in open fields and grassland as a source of forage and wood. The slower growing, shorter, cv. Hawaiian Bushy is preferred where climbing crops such as pepper and vanilla are grown. In some of the villages of the Provincial Development Programme and the World Neighbors projects, however, the giant types are preferred for indirect terraces. More frequent hedgerow pruning of the giant types (once in every 4 weeks compared with every 7 weeks for the bushy type) is evidently advantageous to the farmer, as it provides more browse to feed cattle.

For partial shading when food crops were planted, some farmers in Sikka girdled the trees of the giant strain by cutting off a 20 cm wide ring of bark from the tree 1.5 m above ground. This provides partial shading until the first weeding. This microclimate is beneficial for the early growth of some food crops (especially upland rice and maize). It helps the crops overcome extreme drought. New growth that emerges below the girdle is pruned to allow only a single sprout to form a new tree. The dead part of the tree above the girdle is then cut for fuel after the food crops are harvested. Some owners of small plantations of coffee and other perennial crops who used the giant type as a shade tree have benefited from the trees’ windbreaking function. Sometimes, however, fallen branches and heavy concentration of raindrops can damage crops (Parera 1984a, b; NAS 1984).

The paronisasi program, which relies on a cut-and-carry system, does not support soil conservation: most of the cattle dung is left in backyard gardens. To take advantage of this manure, in 1985, the Provincial Development Programme began to construct simple, temporary stables in the field on one of the alley strips. In 1986, this alley strip, which had become more fertile, will be cultivated for food crops; stables will then be built on another alley strip (Parera 1985). This study also showed that *Leucaena* becomes well established when sown with maize; in this situation, maize yields are not reduced.
Conclusions

The successful introduction of *Leucaena* reflects its ability to adapt to the harsh and dry conditions of Nusa Tenggara Timur to meet the needs of local farmers. *Leucaena* improves soil conditions and the microclimate; improved agricultural techniques can then be introduced. The fast-growing Hawaiian Giant can also serve as a cash crop. The sale of *Leucaena* wood, leaves, and seeds has already provided good income for the farmers.

Despite these achievements, NTT still needs to do a lot more to improve the environment and quality of life through the use of woody species such as *Leucaena*. More research on the inclusion of other leguminous species in the system is required.

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