Chapter 25

Use of *Leucaena leucocephala* to Intensify Indigenous Fallow Rotations in Sulawesi, Indonesia

Fahmuddin Agus

Efforts to get farmers to adopt technological soil conservation packages often fail because the new technologies are frequently offered without any consideration of farmers' experiences and indigenous practices. Because they have a high-risk livelihood, subsistence farmers are resistant to drastic changes. They are more likely to respond favorably to simple modifications to their traditional practices.

In many parts of Asia Pacific, traditional practices include indigenous agroforestry and soil conservation techniques. For example, West Sumatran farmers value *Austroeupatorium inulaefolium* for its contribution to soil fertility, its provision of firewood, and its mechanical support for viny legumes (Cairns 1994, Chapter 15). In East Nusa Tenggara, the Amarasi fallow rotation system, using *Leucaena leucocephala,* has proven to sustain agricultural production. These systems, however, are only suitable when there is no scarcity of land, and pressure from increasing population has not only reduced the availability of land but has also led to shorter fallow durations and more intensive farming practices, particularly where there is improved access to agricultural inputs.

One modification of traditional crop and fallow rotation that may ease the transition from shifting cultivation to more intensive agricultural practices is the use of contour hedgerows, where shrubs or grasses are planted along the contours of sloping land and annual crops are planted in the alleys between the hedgerows. Instead of fallowing the entire land area, only about 10 to 20% of it is devoted to controlling erosion, producing organic matter, fixing atmospheric nitrogen, and, to a lesser extent, recycling nutrients (Agus et al. 1999).

Such contour hedgerow systems have been tested in several parts of the tropics (Lal 1991). They have proven to prevent downslope soil movement, so that they serve as vegetative "plugs" in areas prone to gully erosion. This chapter, therefore, proposes the modification of existing fallow rotation systems in South Sulawesi by converting them into contour hedgerow systems.

In already intensive farming systems, one disincentive to farmer adoption of a contour hedgerow system is that it takes scarce land out of food crop production. Therefore, in compensation for the sacrificed land, either food crop yields must become significantly higher or the hedgerows must provide byproducts such as nitrogen and firewood (Lal 1991). This problem is not an issue on the outer islands of Indonesia, where traditional shifting cultivation, with a fallow period equal to or

Fahmuddin Agus, Indonesian Soil Research Institute, Jl. Ir. H. Juanda 98, Bogor 16123, Indonesia.

longer than the cropping period, is being intensified by simple reduction of the fallow period. Under these circumstances, hedgerows that use only a relatively small portion of a farmer's land would simply replace what is currently in fallow and would not conflict with crop production levels.

Fallow rotation using *Leucaena leucocephala* has long been a traditional farming practice at Lilirilau, in Soppeng district, in the Indonesian province of South Sulawesi. Land is planted with both annual and perennial crops, but annual crops, including onions, corn, and tobacco, occupy more than half of the land. With little or no chemical fertilizers, soil productivity steadily declines and reaches an unacceptable level after three to five years of annual cropping. The land is then fallowed, and *Leucaena* trees sprout from the seeds of previous fallows. The *Leucaena* grows densely and reaches a height of three to eight meters after three to five years. It is then cut. The woody parts are used as firewood, while the green parts are used as mulch.

In this case, a hedgerow system could be established on land currently covered by *Leucaena* simply by cutting the *Leucaena* 30 cm above the surface of the soil to form hedgerows, and at the soil surface in areas to be used as cropping alleys. Farmers cultivating neighboring fields, and who wanted to change to the new system, could make similar adjustments to form continuous contour hedgerows. However, increased agricultural inputs such as fertilizers would be needed to support this relatively more intensive system and there could be unfavorable interactions between the food crops and the hedgerows. These might include competition for light, nutrients, and water; allelopathy; and pests and diseases harbored by the hedgerows (Kang et al. 1990; Lal 1991).

Leucaena leucocephala is not unique in its suitability as a hedgerow species. Several other suitable species have been reported, including *Gliricidia sepium* (Agus et al. 1999; Garrity and Agus 1999) and senna (*Cassia spectabilis*) (Maclean et al. 1992). In addition, several grass species have been used as hedgerow crops and have been received very positively by farmers owning ruminant livestock (Abdurachman and Prawiradiputra 1995). The most appropriate species for a particular area would be the one most adaptable and familiar to farmers. The introduction of exotic species should not be given priority unless they promise significantly greater benefits.

The Study Site

A notable example of a fallow rotation system that would benefit from modification to hedgerow cropping occurs at Tetewatu, a village 27 km east of Watan Soppeng, the capital town of Soppeng district, and about 200 km north-northeast of Ujung Pandang, the capital city of South Sulawesi. The land is undulating to hilly with dominant slopes ranging from 10 to 40%. The village is located 50 to 130 m above sea level (asl). Annual rainfall is 1,540 mm, with three consecutive months having rainfall exceeding 200 mm and two to three months having less than 100 mm (Agus et al. 1995). Mean monthly air temperatures range from 25.4 to 26.6°C.

The soil is classified as very fine, mixed, isohyperthermic, Vertic Ustropept (USDA Soil Survey Staff 1994). It was derived from limestone and has a mixture of 2:1 smectite and illite, and 1:1 kaolinite minerals. This mixture causes the vertic, or shrinking and swelling, property of the soil. Soil cation-exchange capacity is high to very high. However, the concentration of Olsen-P is very low (see Tables 25-1 and 25-2), although 25% HCl-extractable P ranged from 1,300 to 2,100 mg/kg of soil. This indicates that P may be fixed by Ca and Mg, and is therefore unavailable.

Table 25-3. Nutrient Content of *Leucaena* Leaves and Their Contribution to Fallow Fields

	Concentration in Leaves (g/kg)		*Contribution to Soil (kg/ha)*	
Element	*Mean*	*Standard Deviation*	*Mean*	*Standard Deviation*
N	49	6	254	34
P	2.5	0.7	12.5	4.5
K	41	8	171	35
Ca	49	9	251	47
Mg	8.0	1.0	38.2	4.2

Note: Means were from five samples of four-year-old *Leucaena*.

Source: Husen and Agus (1998).

Table 25-4. Parts of *Leucaena* Trees at the Fifth Year of Fallow

Plant Part	*Sun-Dried Volume (m^3/ha)*	*Value[a] (Rs/m^3)*	*Expected Revenue (Rs/ha)*
Stems for firewood	105	20,000	2,100,000
Branches	23	Not sold, for domestic use	—
Leaves and adjacent green parts	9.7	Not sold, for mulch on the same field	—

Note: Averaged from five fields. [a] US$1.00 = Rs8,500.

Conclusions and Recommendations

The farmers in the study area are not only receptive to new technologies, but they are also using an indigenous method for testing plant adaptability on the borders of their fields. Therefore, any innovation that holds promise of meaningful benefits will be adopted. *Leucaena leucocephala* fallow systems have also been practiced in the area for many years. They have sustained the productivity of annual crops and, to some extent, have reduced erosion. However, significant rill and gully erosion still exists between the fallow fields. The local farming systems would benefit from a continuous hedgerow system planted along contour lines. It is believed this would effectively reduce rill and gully formation, and because it represents only a minor modification to existing management practices, the chances of its adoption are very high.

References

Abdurachman, A., and B.R. Prawiradiputra. 1995. Tinjauan Penelitian dan Penerapan Teknologi Usahatani Konservasi di DAS Jratunseluna dan DAS Brantas: Pengalaman UACP-FSR. In: *Analisis Agroekosistem dan Pengelolaan DAS, Prosiding Lokakarya Pembahasan Hasil Penelitian 1994–1995 dan Rencana Penelitian 1995–1996*, February 15–17, 1995, Bogor, Indonesia: Pusat Penelitian tanah dan Agroklimat, 217–232.

Agus, F. 2001. Selection of Soil Conservation Measures in Indonesian Regreening Program. In *Sustaining the Global Farm: Selected Papers from the 10th International Soil Conservation Organization (ISCO) Meeting, May 24-29, Purdue University*, edited by D.E. Stott, R.H. Mohtar, and G.C. Steinhardt. Purdue, USA: Purdue University Press, 198–202.

———, D.P. Garrity, and D.K. Cassel. 1999. Soil Fertility in Contour Hedgerow Systems on Sloping Oxisols in Mindanao, Philippines. *Soil and Tillage Research* 50:159–167.

This study is limited by the fact that the length of fallow and cropping period was confounded by the original soil properties. Soil samples were taken from different fields at different levels of fallow management. Long-term research should seek to better understand the dynamics of soil properties under this fallow system.

Terracing

Bench terracing facilitated by extension workers was found on a few demonstration plots. The demonstration apparently had little or no impact. Farmers claimed that soil productivity declined after the formation of the terraces, especially near the terrace base, where the bangi soil layer was frequently exposed to the surface. Crop growth near the terrace bunds was reportedly fairly good but could not compensate for yield reductions near the terrace base. In addition, terrace risers were vulnerable to sliding in heavy rain, so the construction of bench terraces is not suitable on this soil, with its unstable structure (Agus 2001). To overcome the stability problem, extension agents planted mulberry (*Morus alba*) in hedgerows on the terrace bunds. This was effective on slopes under 15%, but less so on steeper slopes.

The "Tetewatu System"

This system is very specific to Tetewatu village. The land is divided into two parts, a central part that is planted to annual crops such as corn, onion, and tobacco, and a border with widths ranging from two to five meters that is planted to perennial crops such as banana, papaya, cacao, coconut, and jackfruit (Figure 25-1). The spacing of the perennial plants follows the farmers' estimate of canopy diameters. As well as being a means to distinguish land ownership and to generate additional farm products, the border area is used by farmers to trial alternative marketable tree crops. If the crop eventually proves to be either nonadaptive or nonbeneficial, the farmers slash the trees and return to mixes of perennials on the field borders. Most farmers use urea and TSP fertilizers, especially for onions and tobacco. However, the rate and frequency of application is highly variable.

Approach for the Future

This chapter has described a *Leucaena* fallow system that is a well-established indigenous practice. After a five-year fallow period, the leaves and other green parts of the *Leucaena* contribute to each hectare of land as much as 254 kg of N, 12 kg of P, 171 kg of K, 251 kg of Ca, and 38 kg of Mg (Table 25-3). Of these nutrients, N may be the most important. The P recycled by *Leucaena* is a small part of the P required by each annual crop, which is estimated to be 20 to 40 kg/ha. Calcium, Mg, and K are not limiting, so the additional amounts provided by *Leucaena* prunings may not affect crop growth. In addition to N and organic matter, *Leucaena* trees also provide firewood (Table 25-4).

In the existing system, it takes three to five years of *Leucaena* fallow to support three to five years of annual crop production. I propose the modification of the fallow system to make it into a hedgerow system, with a hedgerow width of 0.5 to 1 m, and an alley width of 4.5 to 9 m. The land devoted to *Leucaena* would therefore be about 10 to 20% of the total land area. The hedgerow trees would be cut at 30 cm height about every three to six months, and the supply of organic matter and nitrogen to the soil would be more constant, instead of the present flushes of carbon and nitrogen every five years followed by a serious deficit over the following years. In addition, the hedgerows would serve as gully and rill plugs.

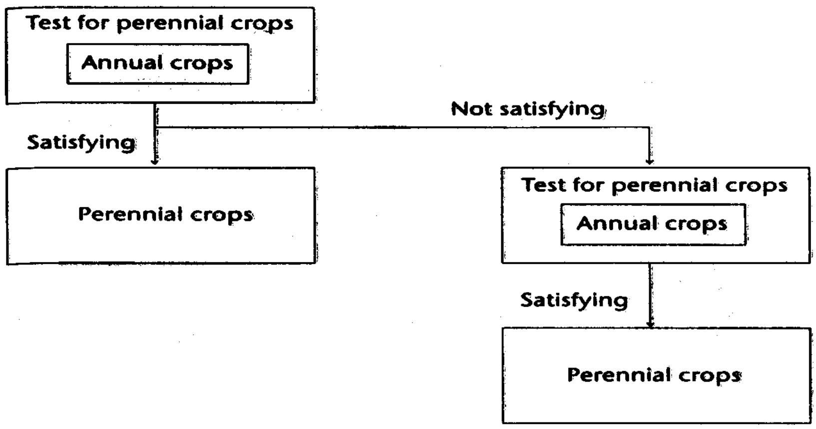

Figure 25-2. Indigenous Approach for Testing New Perennial Crops at Tetewatu Village
Source: Agus et al. (1995).

Plant Residue Management

Plant residues are usually arranged in windrows along the contour lines of annual crop production. Heavier plant residues, such as banana trunks, are usually dumped into gullies. This indigenous technique lessens the erosion problem to some extent, but its effectiveness declines over time.

Fallow Rotation with Leucaena

Annual crops, consisting of corn, onions, tobacco, and peanuts are planted either singly or in multiple cropping arrangements for three to five consecutive years, depending on a farmer's use of fertilizers. After this period, soil productivity becomes uneconomical and the land is left fallow. *Leucaena leucocephala* emerges, appearing to regenerate from the leftover stumps of the most recent fallow or from dormant seeds scattered on the surface soil layer. The former is the more likely because during the annual cropping period *Leucaena* seedlings constantly emerge near tree stumps and are treated like weeds. The fallow period lasts three to five years, after which the *Leucaena* is cut at ground level. The woody parts are harvested as firewood and the green parts are left on the ground to decompose.

This fallow system rejuvenates soil fertility by contributing nitrogen, organic matter, and plant nutrients; increases water penetration and storage in the deeper soil layers after *Leucaena* roots penetrate the sticky bangi soil layer; prevents rill and gully erosion, which disappear after a few years under the *Leucaena* fallow; and allows humus to accumulate. Field observations revealed that the thickness of humus under the one-, three-, and five-year *Leucaena* fallows was two, four, and seven centimeters, respectively (Husen and Agus 1998).

In general, it has been shown that soil properties do not change much between the start of annual cropping and three years into the *Leucaena* fallow. Organic C and total N accumulate after the fallow period reaches five years of age (Table 25-2). There is a significant increase in K, but it may not be important because the soil has a relatively high number of exchangeable cations. Almost no change was observed in the physical properties of the soil.

Current Farming Systems

Corn, onions, and cacao are the most commonly grown food crops in Tetewatu. Corn is planted either on its own or intercropped with onion or tobacco. At one time, tobacco was the main cash crop, but a drop in its price in 1989 forced farmers to seek a substitute. Cacao then became popular, although its productivity on soils with vertic properties and a sticky B horizon is only about half of that in neighboring subdistricts with Alfisols having good soil structure. The most common farming systems involve mixed cultivation of annual crops with perennial tree crops. Cacao is one of the most popular smallholder plantation crops, and perennial tree crops are also very common in home gardens. Annual crops alone are very common on farms of less than one hectare. On larger farms of more than one hectare, part of the land is devoted to perennial cash crops while the remainder is planted in annual crops (see Figures 25-1 and 25-2) (Agus et al. 1995).

Field observations indicate that the soil is very prone to water erosion, especially rill and gully erosion. At a depth of 10 to 50 cm, there is a very distinctive layer of soil referred to locally as the *bangi* layer. It is pale in color, is sticky when wet and hard when dry. Farmers believe that the bangi layer reduces the productivity of corn, onion, garlic, and cacao. It is very different from the overlying surface layer, which has a crumbly, friable, and soft consistency. This contrast is believed to have resulted from the accumulation of organic matter in the surface layer. Farmers are well aware of the effects of erosion. They believe that the closer the bangi layer is to the surface, the lower the soil productivity will be, and they attribute reduced thickness of the friable surface layer to erosion. In fields covered with five-year-old *Leucaena,* the saturated hydraulic conductivity was found to be 3.5 cm/hr in the A horizon and 1 cm/hr in the B horizon. This drastic change in hydraulic conductivity makes the soil susceptible to erosion.

One-meter-wide gullies with depths up to 1.5 m are commonly found on soils under annual crop production, especially in areas where water flow concentrates. Signs of rill erosion can be seen everywhere, especially on fields planted to annual crops. Farmers have adopted a number of measures to reduce the erosion hazard. They include plant residue management; fallow rotation with *Leucaena leucocephala*; terracing the land; and what is known as the "Tetewatu system," in which perennial crops are planted around the borders of fields.

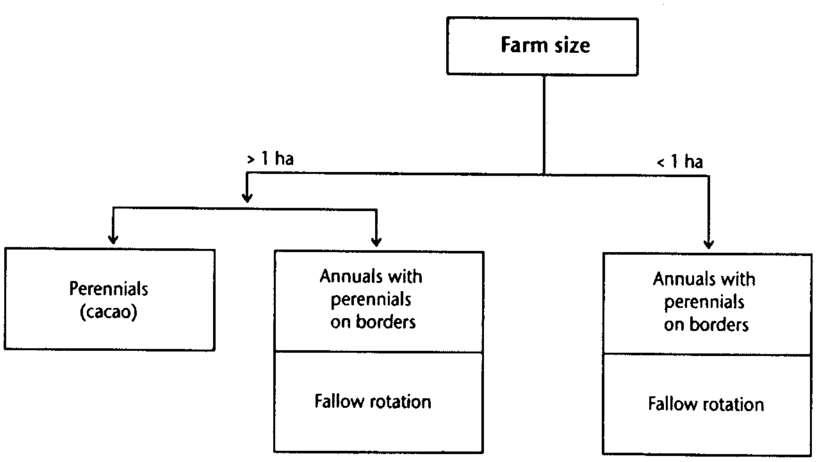

Figure 25-1. Indigenous Decision Tree for Determining Cropping Systems at Tetewatu Village
Source: Agus et al. (1995).

Table 25-1. Comparison of Selected Soil Properties

Sample	*Horizon*	*Soil Depth (cm)*	*pH*	*Silt (%)*	*Clay (%)*	*CEC (cmol(+)/kg)*
	A	0–15	7.8	24	75	38
	Bw1	15–40	7.5	23	77	36
L-2	Bw2	40–64	7.7	29	71	39
	Bw3	64–90	7.7	24	75	38
	B/C	90–130	8.0	28	71	38
	A	0–9	7.3	24	75	36
	Bw1	9–32	8.1	25	75	37
Lo	Bw2	32–67	8.0	25	75	36
	Bw3	67–94	7.8	22	77	37
	B/C	94–130	7.9	16	83	37

Notes: L-2 = Fields under annual crop cultivation for two years; Lo = Fields under annual crop cultivation a few months after cutting the *Leucaena* fallow crop, in a 10-year rotation of annual crops and *Leucaena*.
Source: Husen and Agus (1998).

Table 25-2. Selected Soil Properties at Different Years of the Annual Crop–*Leucaena* Rotation

Code and Horizon	*Organic C*	*Total N*	*Olsen P*	*Exchangeable Cation (1 N NH4-OAc, pH 7)*				*BD*	*Total Pore Volume*	*K-sat*
				Ca [a]	*Mg*	*K*	*CEC*			
	(g/kg)		*(mg/kg)*	*(cmol(+)/kg)*				*(g/cm³)*	*(%)*	*(cm/h)*
L-2, A	9.8	1.1	0.9	63	6.9	0.5	38	1.1	59	0.16
L-2, Bw1	3.3	0.6	1.3	56	10.6	0.3	36	1.1	58	1.24
LO, A	7.9	1.1	1.3	65	2.4	0.5	36	1.1	58	2.37
LO, Bw1	3.7	0.6	0.9	73	2.5	0.4	37	1.1	58	0.13
L1, A	7.8	0.8	1.3	65	5.3	0.6	37	1.0	62	1.59
L1, Bw1	3.7	0.6	2.6	66	6.2	0.4	43	1.1	60	2.39
L3, A	12.0	1.0	2.2	64	4.6	0.6	35	1.1	60	2.77
L3, Bw1	5.3	0.7	3.1	64	6.0	0.3	34	1.2	54	0.77
L5, A	14.9	1.6	2.6	71	3.7	1.0	42	1.0	63	3.45
L5, Bw1	6.0	0.8	1.7	70	2.8	0.5	39	1.1	58	1.01

Notes: [a] Soluble cations were not separated from the exchangeable cations; L-2 = two years under corn and onion cultivation; LO = zero year, after cutting *Leucaena*, and just planted to onion and corn; L1 = one year under *Leucaena* fallow; L3 = three years under *Leucaena* fallow; L5 = five years under *Leucaena* fallow.
Source: Husen and Agus (1998).

———, A. Rachman, and N.L. Nurida. 1995. Analisis Agroekosistem di Daerah Aliran Sungai Billa Walanae: Desa Tetewatu, Kecamatan Lilirilau, Kabupaten Soppeng, Sulawesi Selatan. In *Analisis Agroekosistem dan Pengelolaan DAS, Prosiding Lokakarya Pembahasan Hasil Penelitian 1994–1995 dan Rencana Penelitian 1995–1996*, February 15–17, 1995, Cipayung, edited by A. Abdurachman, D. Santoso, B.R. Prawiradiputra, M.H. Sawit, A.N. Gintings, and F. Agus. Bogor, Indonesia: Pusat Penelitian Tanah dan Agroklimat, 111-134.

Cairns, M. 1994. Stabilization of Upland Agroecosystems as a Strategy for Protection of National Park Buffer Zones: A Case Study of the Co-Evolution of Minangkabau Farming Systems and the Kerinci Seblat National Park. MSc thesis. York University, Ontario, Canada.

Garrity, D.P., and F. Agus. 1999. Natural Resource Management on a Watershed Scale: What Can Agroforestry Contribute? In *Integrated Watershed Management in the Global Ecosystem*, edited by R. Lal. Washington, DC: CRC Press, 165–193.

Husen, E., and F. Agus. 1998. Karakteristik dan Pendekatan Konservasi Tanah di DAS Billa Walanae, Sulawesi Selatan. In *Prosiding Lokakarya Nasional Pembahasan Hasil Penelitian Pengelolaan Daerah Aliran Sungai*, October 27–28, 1998, Bogor, edited by F. Agus, B.R. Prawiradiputra, A. Abdurachman, T. Sukandi, and A. Rachman. Bogor, Indonesia: Pusat Penelitian Tanah dan Agroklimat, 291-304.

Kang, B.T., L. Reynolds, and A.N. Atta-Krah. 1990. Alley Farming. *Advances in Agronomy* 43, 315–359.

Lal, R. 1991. Myths and Scientific Realities of Agroforestry as a Strategy for Sustainable Management for Soils in the Tropics. *Advances in Soil Science* 15, 91–137.

Maclean, R.H., J.A. Litsinger, K. Moody, and A.K. Watson. 1992. Increasing *Gliricidia sepium* and *Cassia spectabilis* Biomass Production. *Agroforestry Systems* 20, 199-212.

USDA Soil Survey Staff. 1994. *Keys to Soil Taxonomy*, 6th ed. Soil Conservation Service, US Department of Agriculture.