CHAPTER 9

Alley cropping

A promising agroforestry technology for the humid and subhumid tropics, which has been developed during the past decade is alley cropping. Alley cropping entails growing food crops between hedgerows of planted shrubs and trees, preferably leguminous species. The hedges are pruned periodically during the crop's growth to provide biomass (which, when returned to the soil, enhances its nutrient status and physical properties) and to prevent shading of the growing crops.

Alley cropping is, thus, a form of the so-called hedgerow intercropping,[1] and combines the regenerative properties of a bush fallow system with food-crop production. Pioneering work on this technology was initiated at the International Institute of Tropical Agriculture (IITA), in Nigeria, by B.T. Kang and co-workers, in the early 1980s. The underlying scientific principle of this technology is that, by continually retaining fast-growing, preferably nitrogen-fixing, trees and shrubs on crop-producing fields, their soil-improving attributes (such as recycling nutrients, suppressing weeds, and controlling erosion on sloping land) will create soil conditions similar to those in the fallow phase of shifting cultivation. Alley cropping is currently being evaluated in many parts of the tropics (Figure 9.1) and even in the temperate zones (see Chapter 25). Much has been written about this technology; the most comprehensive among these numerous publications is the review by Kang *et al.* (1990). Much of the research on alley cropping has so far been on biophysical aspects; these are summarized in this chapter. Research has also been initiated recently on socioeconomic aspects; these are discussed later, in Chapter 22.

[1] Hedgerow intercropping involves zonal (as opposed to mixed) arrangement of components, in which the components occupy definite zones, usually strips of varying widths. In the case of alley cropping, there are single or sometimes multiple rows or strips of woody plant, which is managed so as to restrict its growth in the form of a hedge (Huxley, 1986).

Figure 9.1. Alley cropping:
(top) *Leucaena leucocephala* and cow pea in Ibadan, Nigeria.
(bottom) *Leucaena leucocephala* and maize in Machakos, Kenya.

9.1. Nutrient yield

The growing emphasis on the role of nitrogen-fixing trees in soil-fertility improvement in agroforestry systems in general, and alley cropping in particular (Brewbaker *et al.,* 1982; Dommergues, 1987; Nair, 1988), has encouraged several field trials in a number of places. As research shows, there are great variations in the estimates of nitrogen fixation (see Chapter 17) by different tree species, and it is clear from this and other research results that much more information is needed.

The nitrogen contribution of woody perennials (that is, the amount of nitrogen made available from the decomposition of biomass added to soil) is the most important source of nitrogen for agricultural crops in unfertilized alley cropping systems. Obviously, the amount of nitrogen added varies, and largely corresponds to the biomass (and nitrogen) yield of trees, which in turn depends on the species and on management and site-specific factors. As noted above, nitrogen contributions may also vary according to the rate of nitrogen fixation as well as the turnover rate of nodulated roots.

Some data on the biomass yield of four woody species growing on Alfisols in Ibadan, Nigeria, under different management systems, are provided in Table 9.1. Kass (1987) reported similar data from alley cropping studies conducted in CATIE, Costa Rica in which *Erythrina poeppigiana* was grown as a hedgerow species. Torres (1983) estimated that the annual nitrogen yield of *Leucaena leucocephala* hedgerows, cut approximately every eight weeks, was 45 g per meter of hedgerow; if the hedges were planted 5 m apart, this amounted to 90 kg N hal yrl. Higher nitrogen contributions have been reported from other field studies where the hedgerow species was *L. leucocephala* or *Gliricidia sepium* (Yamoah *et al.,* 1986a; Budelman, 1988). In a comparative study of the effect of various pruning practices on *L. leucocephala, G. sepium,* and *Sesbania grandiflora,* Duguma *et al.,* (1988) found that, for all three species,

Table 9.1. Average pruning yields from woody species alley-cropped with food crops at IITA, Nigeria.

Species'	Pruning yield (t dry matter ha^{-1}yr-^{1})
Alchornea cordifolia	3.77
Dactyladenia (Acioa) barteri	2.07
Gliricidia sepium	5.18
Leucaena leucocephala	8.64
LSD (0.05)	1.52

Note: Three-year old hedgerows; 25 cm between plants in a row; rows spaced 2 m and 4 m apart; hedgerows pruned five times a year; fertilizers applied to accompanying crops at two different levels; 45-20-20 and 90-40-40 N, P and K kg ha-^{1}, respectively
Source: Kang *et al*. (1990).

Table 9.2. Nutrient yield from five prunings of hedgerows of five woody species grown at IITA, Nigeria (4 x 0.5 m spacing).

	Nutrient yield (kg $h^{-1}yr^{-1}$)				
Species	N	P	K	Ca	Mg
Alchornea cordifolia	85	6	48	42	8
Dactyladenia (Acioa) barteri	41	4	20	14	**5**
Gliricidia sepium	169	11	149	66	17
Leucaena leucocephala	247	19	185	98	16

Source: Kang *et at.* (1989).

the highest yields were obtained from biannual prunings at 100 cm pruning heights (245.1, 205.6, and 110.8 kg N ha^{-1} yr^{-1}, respectively).

Hedgerow prunings are also an important source of other nutrients. Table 9.2 gives the nutrient yield data from studies carried out at IITA, Nigeria. In studies conducted in Cote d'lvoire, yields of 44, 59 and 37 kg of K ha^{1} were obtained over a period of three months from *G. sepium, L.leucocephala* and *Flemingia macrophylla* (syn. *F. congesta),* respectively (Budelman, 1988).

The amount of data on these aspects of alley cropping is growing; but more research needs to be conducted regarding the extent to which the nutrients produced by the hedgerow species will meet the nutrient requirements of the crop(s) grown in the alleys at critical stages of their growth. Some information is available on the decomposition pattern and nutrient release characteristics of hedgerow species. Budelman (1988) reported that the decomposition half-lives (see the discussion in Chapter 16) of *L. leucocephala, G. sepium,* and *F. macrophylla* were 30.7, 21.9, and 53.4 days, respectively. These half-lives were correlated with *in vitro*[1] digestibility of organic matter, although the digestibility of *F. macrophylla* was half that of the other two species. Simply stated, the shorter the half-life, the faster is the decomposition of the mulch and consequently, the faster the release of the nutrients to the soil. Yamoah *et al.* (1986a) reported from a field study of the decomposition rates of hedgerow leaves during 120 days that prunings from *G. sepium, F. macrophylla,* and *Cassia siamea* exhibited dry-matter losses of 96, 58, and 46% respectively. Nitrogen mineralization from *G. sepium* supplied 71 % of the nitrogen needed for maize production, while *F. macrophylla* supplied only 26 %. From a similar study in the Peruvian Amazon basin, Palm and Sanchez (1988) reported that leaves of *G. sepium* produced significantly higher levels of nitrogen mineralization than did the leaves of 10 other local tree species. At the same site, Palm (1988) found that the ratio of soluble phenolics to nitrogen was a better indicator of likely nitrogen release. It was concluded from these studies that, on the highly acidic soils of the Peruvian Amazon basin, *G. sepium* and *Erythrina* species are suitable for nutrient enrichment use, while *Inga edulis* and *C. siamea,* because of the slow rate of decomposition of their leaves, could be

[2] In biology, *in vitro* refers to processes that are allowed to occur, or are used for erosion control and increasing soil organic matter (for further discussion on this topic, see Chapter 16).

used for erosion control and increasing soil organic matter (for further discussion on this topic, see Chapter 16).

9.2. Effect on soil properties and soil conservation

One of the most important premises of alley cropping is that the addition of organic mulch, especially nutrient-rich mulch, has a favorable effect on the physical and chemical properties of soil, and hence on crop productivity. However, there are few reports on the long-term effects of alley cropping on soil properties; of those that are available, most are from IITA, the institution with the longest record of alley cropping research.

Kang *et al.* (1989) and Kang and Wilson (1987) reported that, with the continuous addition of *L. leucocephala* prunings, higher soil organic matter and nutrient levels were maintained compared to no addition of prunings (see Table 9.3). Atta-Krah *et al.* (1985) showed that soil under alley cropping was higher in organic matter and nitrogen content than soil without trees. Yamoah *et al.* (1986a) compared the effect of *C. siamea, G. sepium,* and *F. macrophylla* in alley cropping trials, and found that soil organic matter and nutrient status were maintained at higher levels with *C. siamea* (which, surprisingly, is not a N_2-fixing species). Another set of reports from IITA by Lal (1989) showed that, over a period of six years (12 cropping seasons), the relative rates of decline in the status of nitrogen, pH, and exchangeable bases of the soil were much less under alley cropping than under nonalley cropped (continuous cropping without trees) control plots (see Table 9.4). These studies also implied a possible nutrient cycling capability of *L. leucocephala* hedgerows, as there was evidence of a slight increase in soil pH and exchangeable bases during the third and fourth years after the establishment of these hedgerows.

Very few studies have been carried out on the effect of alley cropping on other soil properties. A study by Budelman (1989) near Abidjan in Cote d'lvoire compared the effect of three mulches - *F. macrophylla, G. sepium,*

Table 9.3. Some chemical properties of the soil after six years of alley cropping maize and cowpea with *Leucaena leucocephala* at IITA, Nigeria.

Treatment (kg N ha^1)	Leucaena prunings	pH-H_2O	Org. C (mg	kg^{-1})	Exchangeable cations (c mole kg-^{1})	
				K	Ca	Mg
0	removed	6.0	6.5	0.19	2.90	0.35
0	retained	6.0	10.7	0.28	3.45	0.50
80	retained	5.8	11.9	0.26	2.80	0.45
LSD (0.05)		0.2	1.4	0.05	0.55	0.11

Source: Kang *et al.* (1990).

Table 9.4. Changes in soil nitrogen and organic carbon contents under different management systems at 1ITA, Nigeria.

	1982		1986	
Treatment	0-5 cm	5-10 cm	0-5 cm	5-10 cm
Soil nitrogen (%)				
Plow-till	0.214	0.134	0.038	0.042
No-till	0.270	0.174	0.105	0.063
Leucaena - 4 m	0.397	0.188	0.103	0.090
Leucaena - 2 m	0.305	0.160	0.070	0.059
Gliricidia - 4 m	0.242	0.191	0.066	0.067
Gliricidia - 2 m	0.256	0.182	0.056	0.038
LSD (0.05)		0.01		0.01
Organic carbon (%)				
Plow-till	1.70	1.12	0.42	0.28
No-till	2.50	1.41	1.08	0.52
Leucaena - 4 m	3.01	1.59	0.90	0.91
Leucaena - 2 m	2.35	1.10	0.71	0.65
Gliricidia - 4 m	2.26	1.53	0.63	0.60
Gliricidia - 2 m	2.38	1.47	0.62	0.61
LSD (0.05)		0.12		0.12

Source: Lai (1989).

and *L. leucocephala* - applied at a rate of 5000 kg ha^{-1} dry matter. As shown in Table 9.5, all three, particularly *F. macrophylla,* had a favorable effect on soil temperature and moisture conservation. The report by Lal (1989), based on experiments at IITA, indicated lower soil bulk density and penetrometer resistance and higher soil moisture retention and available plant water capacity under alley cropping practices compared to nonalley cropping practices (see Table 9.6).

Although it seems clear from the numerous field projects being undertaken in various parts of the tropics that planting contour hedgerows is an effective soil conservation measure, only a few reports have been produced from these studies. Apart from the review by Young (1989), which contains convincing arguments regarding the beneficial effect of agroforestry on soil conservation, two reports produced in 1989 are worth mentioning.

The first report, by Ghosh *et al.* (1989), is based on a study carried out in a 1700 mm yr' rainfall zone in southern India. Hedges of *L. leucocephala* and *Eucalyptus* (species not reported) were intercropped with cassava, groundnuts, and vegetables in a field with 5-9% slope; the *L. leucocephala* hedgerows are pruned to 1 m at 60-day intervals after the first year. In the second year of study, the estimated soil loss from the bare fallow plot was 11.94 t ha^{-1} yr^{-1}, whereas for the *L. leucocephala* and *L. leucocephala* + cassava plots, the estimated loss was 5.15 t ha^{1} yr' and 2.89 t ha^{1} yr^{1}, respectively.

Table 9.5. Average temperature and soil moisture content over a 60-day period after adding three different mulches at a rate of 5000 kg dry matter ha '.

Treatment/ mulch material	No. of observations at **15.00 h**	Average temperature at 5 cm (°C)	Average % soil moisture over 0-5 cm
Unmulched soil	40	37.1	4.8
Leucaena leucocephala	40	34.2 (-2.9)	7.1 (+ 2.3)
Gliricidia sepium	40	32.5 (-4.6)	8.7 (+ 3.9)
Flemingia macrophylla	40	30.5 (-6.6)	9.4 (+ 4.6)
LSD		1.20	**1.84**

Note: Values in parentheses: the difference relative to an unmulched soil
Source: Budelman (1989).

Table 9.6. Changes in some physical properties of an Alfisol under alley cropping and no-till systems at **1ITA,** Nigeria.

	Infiltration rate at 120 min. (cm h-')			Bulk density (g cm^3)		
Cropping system	year 1	year 3	year 5	year 1	year 3	year 4
Plow-till	**24.2**	23.2	21.4	1.36	1.51	1.42
No-till	**18.0**	**12.4**	5.0	1.30	1.47	1.62
Alley cropping						
Leucaena 4 m	**39.8**	**13.0**	22.2	**1.26**	**1.44**	1.50
Leucaene 2 m	**13.6**	**22.4**	22.8	1.40	**1.39**	**1.65**
Gliricidia 4 m	**18.8**	18.8	**16.8**	1.30	1.35	1.57
Gliricidia 2 m	**13.8**	**21.0**	19.61	**1.33**	**1.45**	**1.55**
LSD (0.1)		5.8			0.03	

Source: **Lai (1989).**

The study by Lal (1989), conducted in Nigeria, produced several significant results: the erosion from *L. leucocephala-based* plots and *G. sepium-based* plots was 85 and 73% less, respectively, than in the case of the plow-tilled control plots; *L. leucocephala* contour hedgerows planted 2 m apart were as effective as nontilled plots in controlling erosion and run-off (see Chapter 18). Additionally, there were significantly higher concentrations of bases in water run-off from alley cropped plots than from nonalley cropped plots, indicating the nutrient-enhancing effect of the hedgerow perennials. This study also showed that, during the dry season, the hedgerows acted as windbreaks and reduced the desiccating effects of "harmattan" winds; soil moisture content at a 0-5 cm depth was generally higher near the hedgerows than in nonalley cropped plots.

9.3. Effect on crop yields

The criterion most widely used to assess the desirability of alley cropping is the effect of this practice on crop yields. Indeed, most alley cropping trials produce little data other than crop yield data, and these are usually derived from trials conducted over a relatively short period of time.

Many trials have produced promising results. An eight-year alley cropping trial conducted by Kang *et al*. (1989, 1990) in southern Nigeria on a sandy soil showed that, using *L. leucocephala* prunings only, maize yield could be maintained at a "reasonable" level of 2 t ha^{1}, as against 0.66 t ha-^{1} without leucaena prunings and fertilizer (see Table 9.7). Supplementing the prunings with 80 kg N ha"' increased the maize yield to over 3.01 ha^{-1}. Unfortunately, the effect of using fertilizer without the addition of leucaena prunings was not tested. Yamoah *et ah* (1986b) reported that, to increase the yield of maize alley cropped with *C. siamea, G. sepium,* and *F. macrophylla* to an acceptable level, it was necessary to add nitrogen. However, an earlier report by Kang *et* o/.(1981) indicated that an application of 10 t ha^{-1} of fresh leucaena prunings had the same effect on maize yield as the addition of 100 kg N ha-^{1}, although to obtain this amount of leucaena leaf material it was necessary to supplement production from the hedgerows with externally-grown materials.

Table 9.7. Grain yield of maize grown in rotation with cowpea under alley cropping at 11TA, Nigeria (t ha-^{1}).

Treatment '	Year						
	1979	1980	1981[2]	1982	1983	1984 +	1986
0N-R		1.04	0.48	0.61	0.26	0.69	0.66
0N + R	2.15	1.91	1.21	2.10	1.91	1.99	2.10
80N + R	2.40	3.26	1.89	2.91	3.24	3.67	3.00
LSD (0.05)	0.36	0.31	0.29	0.44	0.41	0.50	0.18

Note: + Plots fallowed in 1985

1. N-rate 80 kg N ha^{1}; (-R) *Leucaena* prunings removed; (+ R) *Leucaena* prunings retained. All plots received basal dressing of P, K, Mg and Zn
2. Maize crop affected by drought

Source: Kang *et al*. (1990).

Kang and Duguma (1985) showed that the maize yield obtained using *L. leucocephala* leaf materials produced in hedgerows planted 4 m apart was the same as the yield obtained when 40 kg N ha^{-1} was applied to the crop. In a study conducted in the Philippines, O'Sullivan (1985) reported that when maize was intercropped with *L. leucocephala,* yields of 2.4 t ha" (with fertilizer) and 1.2 t ha^{-1} (without fertilizer) were obtained; the corresponding yields for maize grown without *L. leucocephala* were 2.1 and 0.5 t ha^{1}. However, the experimental details of this study, such as the quantity of fertilizer added and length of experiment, are not clear.

Results from other alley cropping trials are less promising. For example, in trials conducted on an infertile acid soil at Yurimaguas, Peru, the yields of all crops studied in the experiment, apart from cowpea, were extremely low, and the overall yield from alley cropped plots was equal to or less than that from the control plots (see Table 9.8). Rice grain yields in rotations four and six were significantly lower than those from the nonfertilized control plots; cowpea yields in rotations two and five were highest in the nonfertilized control plots. Szott (1987) and Fernandes (1990) concluded from these data that the main reasons for the comparatively poor crop performance under alley cropping treatments were root competition and shading. Fernandes (1990) noted that reduced crop yields, due to root competition between hedgerows and crops in the alleys, were detected at 11 months after hedgerow establishment, and that competition increased with age of the hedgerow as measured by steadily declining crop yields close to the hedgerow. Other possible explanations are that the surface mulch physically impeded seedling emergence, that the decomposing mulch caused temporary immobilization of nutrients, thus seriously reducing the amount of nutrients available to young seedlings at a critical stage of their growth, and that the inherent low levels of nutrients in the soil hampered the recycling mechanism by tree roots.

Other results suggest that alley cropping may not be effective under moisture-stressed conditions. In a four-year study carried out at the

Table 9.8. Grain yield and dry matter production from crops in different cropping systems at Yurimaguas, Peru.

	Yield ($kg \cdot ha^{-1}$) under cropping system[1]							
Cycle crop	Cc	Ie	Nc	Fc	Cc	Ie	Nc	Fc
	Grain[2]				Dry matter			
1. Maize	634a		390a	369a	1762b		2268b	4339a
2. Cowpea	778ab	526b	1064a	972ab	1972b	1791b	2597b	4766a
3. Rice	231a	211a	488a	393a	1138b	1160b	1723b	3718a
4. Rice	156c	205bc	386b	905a	929b	1151b	2121b	5027a
5. Cowpea	415a	367a	527a	352a	1398b	1353b	1404b	3143a
6. Rice		386b	382b	1557a		1054b	1037b	4897a

Note: For grain of dry matter, means within a row that are followed by the same letter are not significantly different, based on Duncan's test, p = 0.05.

1. Cc = *Cajanus cajan* alley cropping; Ie = *Inga edulis* alley cropping; Nc = nonfertilized, nonmulched control; Fc = fertilized, nonmulched control.
2. Maize grain yield based on 15.5% moisture content; rice and cowpea grain yields based on 14% moisture content. *Inga* plots in cycle 1 and *Cajanus* plots in cycle 6 were not cropped.

Source: Szott (1987).

International Crop Research Institute for the Semiarid Tropics (ICRISAT) near Hyderabad, India, growth of hedgerow species was greater than that of the crops when there was limited moisture, resulting in reduced crop yields (Corlett *et al.,* 1989; ICRISAT, 1989; Rao *et al.,* 1990). Similar observations have been reported from semiarid areas in north-western Nigeria (Odigi *et al.,* 1989) and in Kenya (Nair, 1987; ICRAF, 1989; Coulson *et al.,* 1989). A six-year study in north-western India showed that maize, black gram, and cluster bean yields were lower when these crops were alley cropped with *L. leucocephala* hedgerows than when grown in pure stands (Mittal and Singh, 1989). The fodder and fuelwood yields of *L. leucocephala* were also lower under alley cropping than under nonalley cropped hedgerows. However, in this study it appears that, instead of returning the *L. leucocephala* prunings to the soil as green manure, they were taken away as fodder.

The IITA study by Lal (1989) (referred to above) showed that maize and cowpea yields were generally lower under alley cropping than when grown as sole crops (see Tables 9.9 and 9.10). A significant observation in this study was that, in the years when rainfall was below normal, yield decline was more drastic under closer-spaced alleys, indicating severe competition for moisture between the hedgerows and the crops. Recent studies at IITA by Ehui *et al.*(1990) have projected maize yields in relation to cumulative soil losses under different fallow management systems. However, when land in fallow and land

Table 9.9. Mean grain yield of maize grown under alley cropping over a six-year period at IITA, Nigeria.

System	Treatments		Maize grain yield (t ha')					
	Perennial species	Spacing (m)	1982	1983	1984	1985	1986	198
A	Plow-till		4.1	4.9	3.6	4.3	2.7	2.3
	No-till		4.0	4.1	4.0	5.0	2.4	2.7
B	*Leucaena*	4	3.7	3.3	3.7	4X	2.1	2.0
	Leucaena	2	4.4	3.6	3.8	4.2	1.7	2.5
C	*Gliricidia*	4	3.9	3.9	3.6	4.5	2.6	2.2
	Gliricidia	2	3X	3.2	3.3	4.8	1.6	2X
Mean			4.0	3.8	3.7	4.6	2.2	2.4
LSD				(0.05)		(0.01)		
(i) Systems (S)				0.27		0.22		
(ii) Treatments (T)				0.34		0.28		
(iii) Years (Y)				0.48		0.39		
(iv) S x T				0.48		0.39		
(v) T x Y				0.83		0.68		

Source: Lai (1989).

Table 9.10. Mean grain yield of cowpea in a maize-cowpea rotation under alley cropping over a six-year period at 11TA, Nigeria.

System	Treatments		Cowpea grain yield (kg ha^{-1})					
	Perennial species	Spacing (m)	1982	1983	1984	1985	1986	1987
A	Plow-till		720	442	447	435	992	369
	No-till		1520	829	1193	784	1000	213
B	*Leucaena*	4	1000	514	581	409	285	222
	Leucaena	2	730	319	503	159	146	236
C	*Gliricidia*	4	950	600	670	590	452	207
	Gliricidia	2	700	533	678	405	233	233
Mean			937	540	679	464	518	319
LSD				(0.05)		(0.01)		
(i) Systems (S)				120		99		
(ii) Treatments (T)				147		121		
(iii) Years (Y)				208		171		
(iv) S x T				208		171		
(v) T x Y				361		297		

Source: Lai (1989).

occupied by the hedgerows (in shifting cultivation and alley cropping respectively) were considered,[3] and maize yields were adjusted accordingly to account for these possible losses (due to reduced cropping area) in production, the highest yields would be obtained if alleys were spaced 4 m apart, whereas the lowest yields would be obtained from nine-year fallow treatments.

In a recently concluded study at the ICRAF Research Centre in Machakos, Kenya, Jama-Adan (1993) compared the relative performance of *Cassia siamea* and *Leucaena leucocephala* as hedgerow species for alley cropping. He found that during six cropping seasons (1989-1991; two crop seasons per year) in the semiarid conditions (average rainfall 700 mm; bimodal distribution), maize grain yield was better when alley-cropped with cassia than with leucaena (Figure 9.2). Indeed, maize alley-cropped with leucaena yielded lower than under no-alley-cropping control; but, control and cassia alley-cropping treatments had similar yields. The results show that cassia is a better species for alley cropping than leucaena under such semiarid conditions. The importance of choosing appropriate species for alley cropping is clear from the study.

[3] In alley-cropping experiments, as in other woody and herbaceous mixtures, crop yields are expressed per unit of gross area, i.e., combined area of both the hedgerows and the crops. Moreover, crop yields are measured in transects across the hedgerows, i.e., from all crop rows extending from the row closest to the hedgerow to the farthest row (Chapter 20; Rao and Coe, 1992).

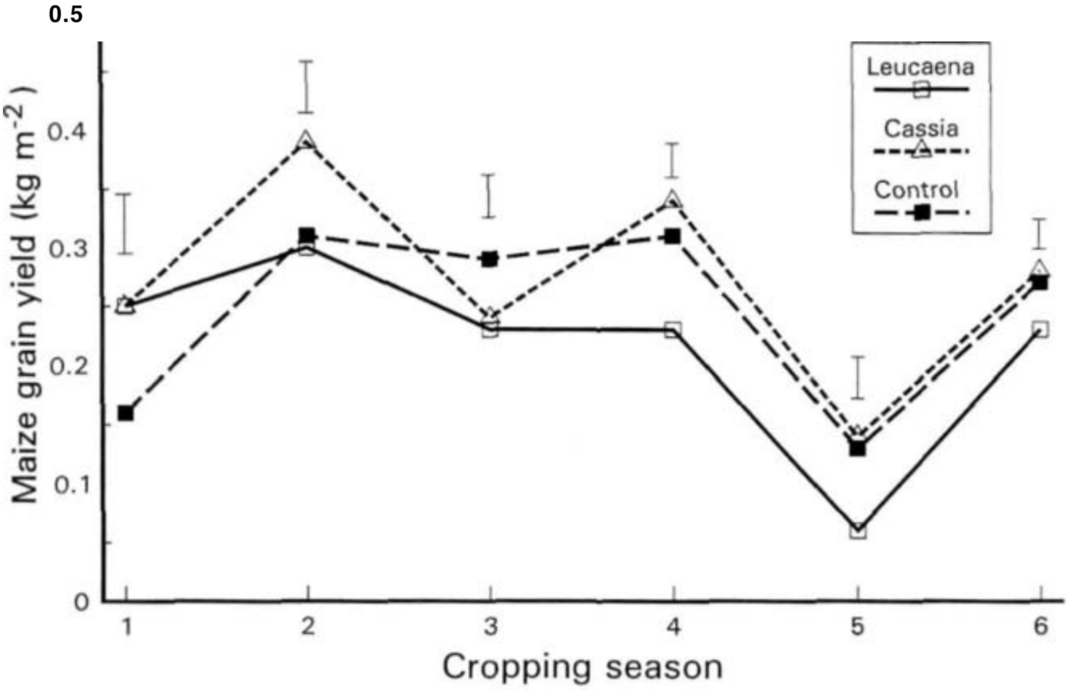

Figure 9.2. Yield of maize alley-cropped with *Cassia siamea* and *Leucaena leucocephala* in comparison with no-alley-cropping control during six cropping seasons (1989-1991) in semiarid conditions, Kenya.
Source: Jama-Adan (1993).

9.4. Future directions

Many studies on alley cropping are now being undertaken in various parts of the tropics; in the next few years there is likely to be a rapid increase in the amount of available data. As more data become available, the interpretation of the data will become more refined and consistent. Many experts seem to have taken extreme positions in interpreting the results that have been obtained so far, some going to great lengths to use the data to defend alley cropping, others to denigrate it. However, the merits or demerits of alley cropping cannot be judged according to any single criterion or on the basis of short-term results. Benefits other than crop yield, such as soil fertility improvement and the yield of fuelwood and fodder, must be carefully weighed against drawbacks, such as labor requirements, loss of cropping area, or pest management problems.

A key issue is ecological adaptability. Many research results suggest that alley cropping offers considerable potential in the humid and subhumid tropics. A generalized schematic presentation of the potential benefits and advantages as proposed by Kang and Wilson (1987) is given in Figure 9.3. However, the scenario is different in the drier regions. The provision of nutrients through decomposing mulch, a basic feature of alley cropping, depends on the quantity, quality, and time of application of the mulch. If the ecological conditions do not favor the production of sufficient quantities of nutrient-rich mulch for timely application, then there is no perceptible advantage in using alley cropping.

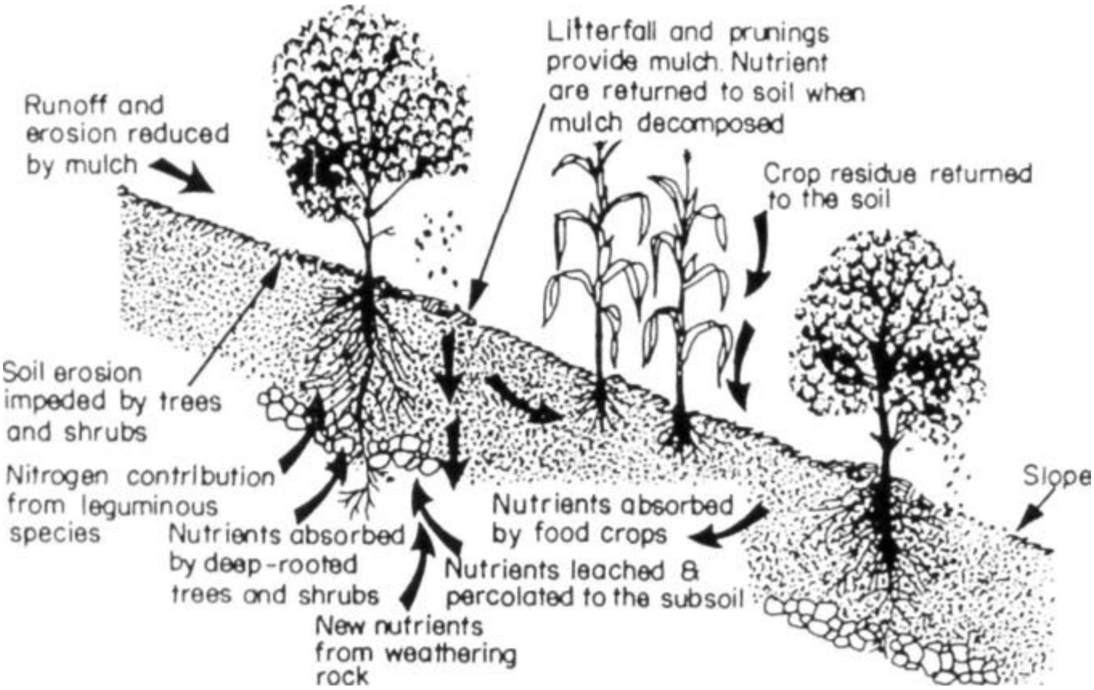

Figure 9.3. Schematic representation to show the benefits of nutrient cycling and erosion control in an alley-cropping system.
Source: Kang and Wilson (1987).

Let us examine, for example, the quantity that could potentially be produced from 1 ha, an area in which it is feasible to have 20 hedgerows of *L. leucocephala,* each 100 m long and 5 m apart. If the hedgerows are pruned three times per cropping season (once just before the season and twice during the season), and if the rainfall conditions permit two crops a year, this results in six prunings a year. Assuming that each meter of hedgerow produces 375 g of dry matter (1.5 kg fresh matter) from each pruning, the total biomass yield will be 4500 kg of dry matter (derived from 375 g X 2000 m x 6 cuttings). If, on average, three percent of this dry matter consists of nitrogen, the total nitrogen yield would be 135 kg ha^{-1} yr^{-1}, about half of which can be expected to be taken up by current season crops.

There are several factors, however, which may limit the realization of this potential. A major factor is soil moisture. In most semiarid regions, rainfall is unimodal and falls over a four-month period. Thus, the number of prunings would be reduced to a maximum of three. The mulch yield and, therefore, nitrogen contributions will also be lower, implying that the nitrogen yield will not be sufficient to produce any substantial nitrogen-related benefits for the crop. A very generalized relationship between rainfall and alley cropping potential is presented in Figure 9.4. Additionally, there are shade effects caused by the hedgerows as well as the reduction of land available for crop production (20 hedgerows, each casting severe shade over an area 1 m wide and 100 m long, will cover 2000 m^2 per hectare, or 25 % of the total area). The additional labor that is required to maintain and prune the hedges is another limitation. Furthermore, farmers may choose to remove the mulch for use as animal fodder,

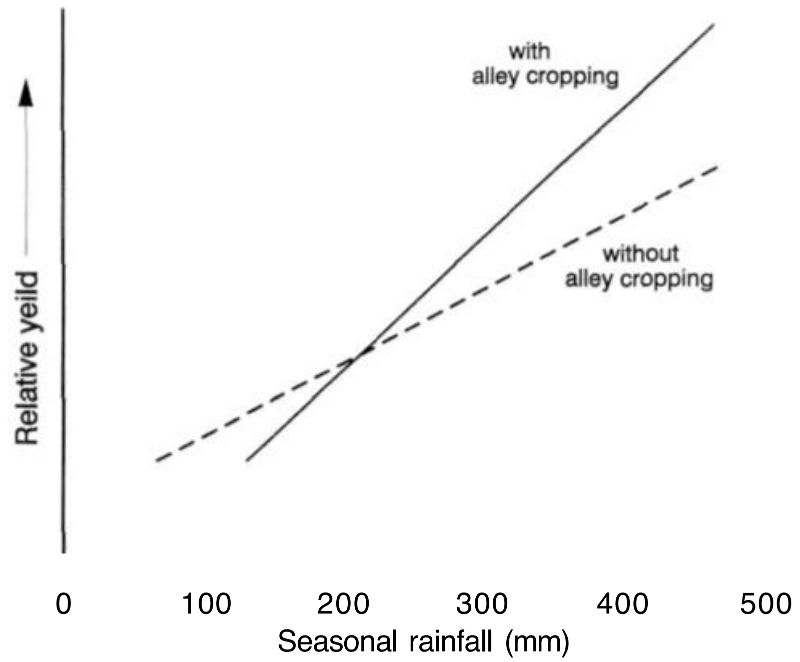

Figure 9.4. A generalized picture of crop (maize) yield with and without alley cropping in relation to rainfall during cropping season in semiarid conditions.
Source: Nair(1990).

for example, rather than adding it to the soil, as is the case in Haiti (Bannister and Nair, 1990).

Because of such limitations, alley cropping as it is known today, wherein a heavy emphasis is given on such species as *Leucaena leucocephala,* is unlikely to be a promising technology in the semiarid tropics. More efforts are needed to identify hedgerow species that are appropriate for alley cropping in such dry areas. This does not imply that agroforestry in general is unsuitable for these regions. Indeed, some of the best-known agroforestry systems are found in the semiarid tropics - for example, the systems based on fodder and fuelwood trees (described in Chapter 10).

An important point to remember is that under conditions where alley cropping is appropriate such as in the lowland humid tropics, the technology can be adopted for both low and high levels of productivity. If higher levels of crop productivity are the goal, fertilizer application will be necessary under most conditions. In other words, alley cropping cannot be a substitute for fertilizers if high levels of crop production are to be realized. But efficiency in the use of fertilizers can be substantially increased under alley cropping as compared with no-alley-cropping situations (Kang et *al.,* 1989, 1990). In extremely acidic sandy soils, such as those in the Peruvian Amazon basin (Szott *et al.*, 1991 b; TropSoils, 1988), the success of alley cropping may depend on the extent to which external inputs such as fertilizers are used. The choice of hedgerow species that can adapt to poor and acid-soil conditions is also an important management consideration under such circumstances.

Concurrent with all these efforts in enhancing the biological advantages of alley cropping, efforts should also be made to improve its social acceptability and adoption potential. In addition to the common difficulties in popularizing an improved agricultural technology developed at research stations among the target farmers, there are some features of alley cropping that counterbalance its advantages and hinder its widespread adoption. These include:

- additional labor and skills that are required for hedgerow pruning and mulch application.
- loss of cropping area to the hedgerows.
- difficulty in mechanizing agricultural operations.
- potential for the hedgerow species to become a weed and/or an alternate host for pests and pathogens, or harbor grain-eating birds.
- possibilities for increased termite activity, especially under dry conditions.

Researchers and development agencies are currently addressing these problems and some questions have already been answered (e.g., see Chapters 21 and 22 for on-farm research and economic aspects, respectively). Extensive efforts such as the Alley Farming Network for Africa (AFNETA) are involved in elaborate field testing of the technology under a wide range of conditions with appropriate modifications. Even if, or when, the technology becomes well adopted, it is certain to take various forms depending on the biophysical and socioeconomic conditions that are specific to each site.

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