

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
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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 entresurcos 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 entresurco 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 entresurco. Este libro revisa la situación actual de la investigación sobre la agricultura de pasillo o de entresurco 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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Alley cropping for food crop production in the humid and subhumid tropics

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Abstract — Upland arable farming on fragile, tropical soils requires viable, sustainable, and environmentally sound production systems that can meet the requirements of farmers who use traditional cultivation practices. Alley cropping, a scale-neutral technology, offers one of the best potentials for sustainable agriculture. Trials where various crops were grown between Gliricidia sepium and Leucaena leucocephala tree rows in the lowland humid and subhumid tropics on nonacid soils have shown good results. Prunings from selected leguminous woody species such as Leucaena and Gliricidia give high nitrogen yield; these species also assist nutrient cycling. Prunings from woody species can also improve and maintain the organic matter, nutrient status, and biological activity of the soil. Results from long-term plots showed that maize yield was higher in alley-cropping plots than in control plots, even with the application of nitrogen. Cassia siamea and Acacia barterii are promising crops for alley farming on acid soils. The inclusion of hedgerows reduced runoff and erosion. Mechanized alley cropping is feasible if managed properly.

Introduction

An urgent challenge facing agricultural scientists working on upland food-crop production in the humid and subhumid tropics is the need to find viable, sustainable, and environmentally sound alternatives to the centuries-old shifting cultivation and bush-fallow, slash-and-burn cultivation system. The traditionally extensive system of food-crop production, which is known to be stable and biologically efficient, operates effectively only when there is sufficient land to allow a long fallow period to restore soil productivity, which is exhausted during the short cropping cycle.

Over the years, however, this system has undergone rapid changes because of socioeconomic factors, mainly population growth, which has reached alarming rates in many developing countries in the last few decades (McNamara 1984). The population growth has put severe pressure on the availability of fallow land and has led to increased deforestation. For example, it is estimated that the closed forest area in the coastal zone of West Africa was disappearing at a rate of 5.1% (703×10^3 ha) per year during the early 1980s, mainly for agricultural production. At this rate, these forests have a half-life of just 13 years (Brown and Wolf 1985).

As productive land becomes scarce, smallholders are compelled to exploit more fragile, marginal lands that cannot support a large population practicing subsistence agriculture.

Deforestation and increasing population together have forced traditional farmers to shorten fallow periods, setting in motion a spiral of degradation resulting in lower crop yields, a trend noticeable throughout the tropics, particularly in Africa. Overgrazing and indiscriminate fuelwood gathering further intensify the problem of land degradation. Kio (1982) mentioned that fuelwood and charcoal account for more than 90% of wood consumption in Africa. According to a recent report from the World Resources Institute (WRI 1985), this situation, which prevails in many developing countries, can only be changed if rural populations are given alternatives to this ecologically destructive way of life.

Modern technologies adopted from temperate-zone agriculture to increase food-crop production under continuous cultivation have not always been successful on fragile, upland soils. The rapid decline in the productivity of tropical soils under continuous cultivation, even with supplementary fertilization, has been documented (Allan 1965; Bache and Heathcote 1969; Le Mare 1972). The failure of various mechanized arable farming methods (Duthie 1948; Wood 1950; Baldwin 1957; Phillips 1960; Moormann and Greenland 1980) highlights the need for a different approach for continuous arable farming on low-activity, clay (LAC) soils (Kang and Juo 1983). Lal (1975) stressed the importance of mulching and minimum tillage to maintain the physical productivity of soils. However, it appears that a more important factor in the maintenance of soil productivity is the biological manipulation of soil organic matter. This can be done through a planned fallow system providing adequate in-situ mulch and green manure (Hartmans et al. 1982; Mulongoy and Kang 1985).

Because the bush-fallow system is widespread and important to the livelihood of so many people (Nair and Fernandes 1984), it will be virtually impossible to dispense with it completely. This system, in addition to its main role of restoring soil fertility and suppressing noxious weeds, provides staking material, firewood, browse, and other materials needed by traditional farmers. There is, therefore, a need to develop technologies that can improve, reduce, or eliminate the bush-fallow period as well as retain its merits. This need has led to the development of alley cropping (Kang et al. 1981; Wilson and Kang 1981).

Alley cropping system

The bush-fallow system, despite its merits, has two main weaknesses: the extravagant use of land resources and the prolonged unproductive fallow. Young and Wright (1980) showed the need for long rest periods to maintain the productivity of fragile, tropical soils. The maximum acceptable ratio of cultivation to rest period ranges from 1–2 in every 20 years for Latin America to 1 in every 4 years in Asia and Africa for Ultisols and Oxisols. For Alfisols, it is about 1 in every 3 years. This need for a rest period can be reduced by the addition of fertilizers.

A major land-use problem in Africa and other tropical regions is the long, unproductive fallow needed to restore soil fertility (Poulsen 1978). The alley cropping concept for soil improvement, which emerged from work at the International Institute of Tropical Agriculture (IITA) with woody legumes during

the early 1970s, was designed to allow a higher intensity of land use while maintaining the basic merits of the bush-fallow system (Kang et al. 1981). In alley cropping, arable crops are grown between hedgerows of woody shrubs and tree species, preferably legumes, that are periodically pruned to prevent shading of the companion crop(s). The shrubs and trees grown in hedgerows retain their functions as observed in the bush-fallow system, i.e., nutrient recycling, mulch and manure source, weed suppression, and erosion control (Fig. 1). The inclusion of leguminous, woody species also provides free nitrogen to the production system. Alley cropping can, therefore, be regarded as a bush-fallow system with improved management (Table 1), combining cropping and fallow phases to increase the land-use intensity.

To test the viability of the alley cropping concept, a long-term field trial with food crops and *Leucaena leucocephala* was carried on a degraded Entisol at the IITA main campus in 1976. Encouraged by the promising results obtained in this trial, further alley cropping trials were carried out using other woody species and crops at the IITA Ibadan campus and the Ikenne and Onne substations. Alley cropping is also being evaluated in a range of tropical environments under other names such as hedgerow intercropping (Torres 1983) and avenue cropping (Wijewardene and Waidyanatha 1984). On-farm trials were also carried out during the early 1980s in south and central Nigeria using *L. leucocephala* and *Gliricidia sepium*. The initial on-farm trials used narrow, 2-m alleys primarily for yam staking (Ngambeki and Wilson 1984). Although farmers accepted the merits of alley cropping, they felt that a 2-m alley was too narrow. This led to the use of 4-m alleys in subsequent on-farm trials. The incorporation of small ruminant production by the International Livestock Centre for Africa (ILCA) into the alley cropping system, using supplementary browse produced from the hedgerows on a cut-and-carry basis, has led to the development of the alley farming concept (see Reynolds and Atta-Krah, this volume).

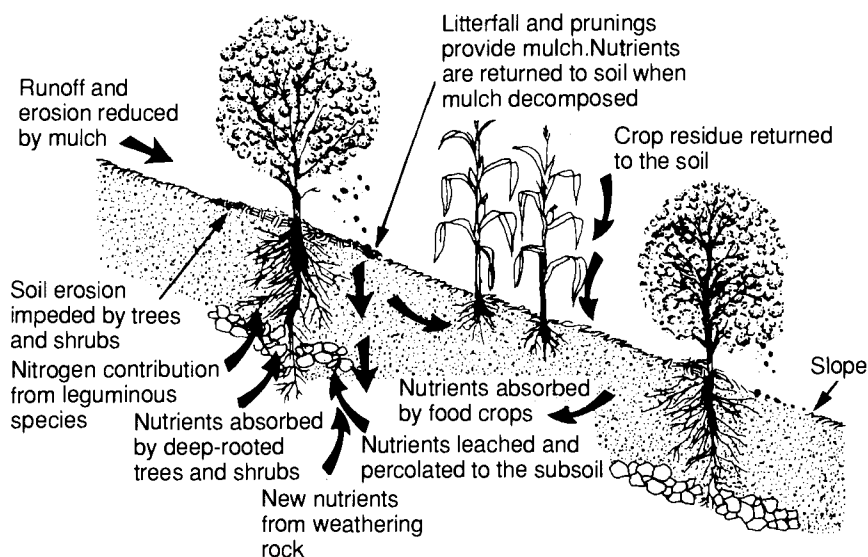


Fig. 1. The alley cropping concept.

Table 1. Differences in management of traditional bush fallow and alley cropping system.

Bush fallow	Alley cropping
<ul style="list-style-type: none"> • Retain mixed native and woody species • Irregular planting pattern • Before cropping, trees and shrubs are cut back and burned to release nutrients • Fire used for controlling growth • Allows short-term cropping 	<ul style="list-style-type: none"> • Plant selected woody leguminous species • Grown in hedgerows • Trees and shrubs are periodically pruned; pruning used as mulch and green manure • Hedgerows are periodically pruned • Allows continuous cropping

Nutrient yield

The importance of forest and savanna fallow in building up soil nutrients through the development of a closed nutrient cycle is well known. This restorative role of the fallow is linked to the ability of deep-rooting trees and shrubs to recycle plant nutrients and build up soil organic matter. Jaiyebo and Moore (1964) have demonstrated that a forest fallow is more effective than legume or grass cover in nutrient recycling and organic matter improvement. Traditional African farmers retain certain woody species that are effective in restoring soil fertility during the fallow period. These species include *Alchornea cordifolia*, *Acioa barterii*, *Anthonata macrophylla*, *Harungana madagascariensis*, *Dialium guineense*, *Crestis ferruginea*, and *Nuclea latifolia* for acid soils (Obi and Tuley 1973; Okigbo 1976) and *G. sepium* for nonacid soils (Getahun et al. 1982).

Efforts have been made to improve the efficiency of the fallow by using woody species that can accelerate nutrient buildup. Nye and Stephens (1962) reported that *A. barterii* used as planted fallow accumulates more calcium and magnesium than natural secondary forest. Juo and Lal (1977) reported that *L. leucocephala* fallow is as effective as naturally regenerated fallow in restoring soil organic matter and exchangeable cations. Nye (1958) observed that, in the savanna region of northern Ghana, *Cajanus cajan* planted at close spacing accumulates larger quantities of nutrients than a well-established *Andropogon*. In northern Brazil, Schaafhausen (1966) claimed to have obtained good results in using *C. cajan* for soil improvement and as a source of fodder.

Kang et al. (1981) and Kang and Duguma (1985) have shown that leguminous species such as *L. leucocephala* and *G. sepium* grown in hedgerows in alley farming systems yield large quantities of nitrogen; the narrower the alley, the higher the nitrogen yield. With 4-m alleys and five annual prunings, *Leucaena* and *Gliricidia* grown on degraded Alfisol produced over 210 and 110 kg N/ha per year, respectively. Duguma (1985) showed that higher N yields could be obtained with higher pruning height and lower pruning frequency.

Table 2. Annual nutrient yield (kg/ha) of hedgerow prunings (4 m between rows, exclusive of woody material) of four fallow species alley cropped on a degraded Alfisol in southern Nigeria.

Species	P	K	Ca	Mg
<i>Acioa barterii</i>	2.0	19.7	12.3	1.9
<i>Alchornea cordifolia</i>	7.0	55.7	42.1	8.3
<i>Gliricidia sepium</i>	10.6	253.4	73.7	15.7
<i>Leucaena leucocephala</i>	14.6	192.8	114.9	10.7

Note: Yields measured in 3rd year after establishment; total of five prunings.

Source: B.T. Kang, unpublished data.

Prunings from hedgerows, which produced large quantities of biomass (Kang et al. 1981; Atta-Krah et al. 1985), also helped in recycling large quantities of other plant nutrients (Kang et al. 1984). Studies on a degraded Alfisol showed a higher nutrient yield (Table 2) than on a degraded Entisol (Kang et al. 1984).

Leucaena and *Gliricidia* give the largest nutrient yield. Indigenous, nonlegume shrub species of *Acioa* and *Alchornea* show lower nutrient recycling capabilities and yields.

There are large differences in nutrient percentage of the woody material of various species (Table 3). The high nutrient yields obtained from prunings can greatly assist in nutrient recycling in alley cropping systems. However, it can also impoverish the soil in a cut-and-carry system, if no nutrients are added to the production system. As stated by Bengé (1983), woody legumes as with any other trees, require proper nutrition to maximize production and sustain yields.

Crop production

Crop performance

The performance of maize, cassava, and cowpea in alley cropping systems with *Leucaena* and *Gliricidia* has been widely studied on high base status soils in the humid and subhumid lowland tropics of Africa (Kang et al. 1984; Atta-Krah et al. 1985). Higher maize and cassava yields were obtained with alley cropping. From results of investigations conducted on an Entisol, it is estimated that *L. leucocephala* in alley cropping can contribute about 40 kg N/ha to the companion maize crop (Kang and Duguma 1985). Ngambeki (1985) also reported substantial savings in the use of nitrogen fertilizer when alley cropping *Leucaena* with maize. However, *Leucaena* either has no effect or a detrimental effect on cowpea grain yields (Kang et al. 1985; Atta-Krah et al. 1985). In investigations conducted on an Alfisol at Ikenne in southwestern Nigeria, it was observed that upland rice could be alley cropped with *Gliricidia* (Fig. 2) and *Leucaena*. Alley cropped with *Leucaena*, rice did not respond to nitrogen application. In the control plot, however, rice responded to an application of 30 kg N/ha.

Trials carried out in per-humid conditions at Onne in southeastern Nigeria

Table 3. Nutrient composition of "young" and "old" woody materials of various multipurpose tree and shrub species grown on Alfisol.

Species	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)
<i>Acioa barterii</i>						
Young, green stem	0.59	0.08	0.66	0.49	0.11	20
Mature stem	0.55	0.07	0.57	0.30	0.14	16
Old wood	0.36	0.05	0.48	0.21	0.10	11
<i>Alchornea cordifolia</i>						
Young, green stem	1.12	0.18	1.83	1.19	0.22	36
Mature stem	0.65	0.11	1.42	—	—	18
Old wood	0.61	0.70	0.83	0.96	0.13	16
<i>Gliricidia sepium</i>						
Young, green stem	1.58	0.32	1.83	0.77	0.19	31
Mature stem	1.13	0.08	1.31	1.14	0.10	17
Old wood	1.01	0.05	0.87	0.97	0.12	13
<i>Calliandra calothyrsus</i>						
Young, green stem	1.98	0.19	2.32	0.63	0.22	37
Mature stem	0.95	0.20	1.33	0.26	0.08	24
Old wood	0.70	0.16	0.94	0.29	0.06	19
<i>Leucaena leucocephala</i>						
Young, green stem	1.38	0.14	1.78	0.91	0.27	32
Mature stem	0.71	0.06	1.02	0.49	0.11	31
Old wood	0.51	0.03	0.59	0.32	0.07	9

Source: B.T. Kang and H. Grimme, unpublished data.

showed poor performance of *Leucaena* and *Gliricidia* in the highly acidic Ultisols. Investigations were therefore carried out to identify suitable woody species for alley cropping on acid soils. Recent trials showed improved cassava yield when intercropped with *C. siamea* and *A. barterii* (Table 4). These investigations are still in progress.

An important aspect of alley cropping is its effect on the sustainability of crop yield (Kang and Duguma 1985) and the role it can play in the improvement of degraded soil and land (IITA 1985). Kang and Duguma (1985) reported a higher maize yield in long-term alley cropping plots than in control plots, even with nitrogen fertilizer application. This result has been confirmed by a long-term alley cropping trial carried out on a degraded Alfisol (IITA 1985). The higher maize yield may be partly due to improved and maintained chemical, physical, and biological soil conditions through the addition of the prunings.

Effect on soil properties

Long-term studies have shown significant improvement in soil properties with alley cropping (Kang et al. 1984). The periodic addition of *Leucaena* prunings helps maintain high soil organic matter and nutrient status. Observations on



Fig. 2. Alley cropping upland rice.

degraded Alfisol at Ibadan in southwestern Nigeria have also shown earlier and increased earthworm activity during the rainy season as measured by wormcast production in the alley cropping plots.

Planting trees on critical land can also play a significant role in soil conservation. Using *Leucaena*, Metzner (1982) significantly improved and maintained the productivity of degraded and sloping lands on the island of Flores in Indonesia. Recent studies by Kabeerathumma et al. (1985) in Kerala, southern India, have also shown a remarkable reduction in runoff and soil erosion with the inclusion of *Leucaena* in a cassava plot (Table 5). Similarly, in experiments at IITA with mechanized alley cropping on degraded land following bulldozer clearing, root raking, and conventional tillage, the land stabilized and improved compared with an adjacent plot that was shear-blade cleared and continuously cropped under no tillage.

Mechanized system

Alley cropping was originally developed for traditional farmers. In the course of investigation, however, it was observed that alley cropping could also be used as a scale-neutral technology. For this purpose, observations were made on two fields of over 2 ha each. Plots were planted with *Leucaena* by direct seeding together with a maize crop in 1983. The hedgerow spacing was 4.5 m to fit the machinery available at IITA. The plots were sequentially cropped with maize and cowpea.

Hedgerows must be frequently pruned in a mechanized system to prevent reseeding and prevent the stems from becoming too thick, which would interfere with future mechanical pruning. A rotary slasher is used to prune the hedgerows to ground level before planting maize or cowpea. The hedgerows are slashed again

Table 4. Effect of alley cropping cassava with various woody species on Ultisols at Onne, Nigeria.

Species and treatment ^a	Fresh cassava yield (t/ha)	
	Stem	Tuber
Control		
No fertilizer	7.3	14.2
Fertilizer	10.4	16.0
<i>Acioa barterii</i>		
Prunings only	11.4	15.0
Fertilizer only	15.3	20.1
Prunings + fertilizer	15.0	16.0
<i>Gmelina arborea</i>		
Prunings only	4.1	5.4
Fertilizer only	2.3	3.5
Prunings + fertilizer	5.2	6.9
<i>Cassia siamea</i>		
Prunings only	7.0	13.2
Fertilizer only	6.7	10.7
Prunings + fertilizer	9.2	17.2

Note: Cassava was harvested 9 months after planting.

Source: B.T. Kang, A.C.B.M. van der Kruijs, and P.D.

Austin, unpublished data.

^a Control cassava stand, 10 000 plants/ha; other treatments, 6 667 plants/ha. Fertilizer rate, 30–13–25 kg/ha (N–P–K).

Table 5. Surface runoff and soil loss under various multiple cropping systems on an 8.9% slope in Trivandrum, India, from July to December.

Treatment	Runoff (mm)	Soil loss (t/ha per 6 months)
Bare fallow	21.6	2.37
Cassava	12.4	0.85
Banana	11.0	0.75
<i>Eucalyptus</i>	11.5	0.73
<i>Leucaena</i>	12.6	0.53
Banana + cassava	8.1	0.33
<i>Eucalyptus</i> + cassava	7.8	0.33
<i>Leucaena</i> + cassava	9.2	0.25

Note: Total rainfall from July to December, 252 mm.

Source: Kabeerathumma et al. (1985).

before harvesting the food crops, using a tractor with a 1.5-m wheel track and narrow tires. With 4.5-m spacing between hedgerows, however, only two-thirds of the land was effective for planting. A wider spacing of 7.5 m would be preferable, reducing the amount of land devoted to the hedgerows.

Soil conditions appear to improve under alley cropping, allowing continuous cropping. Sustained yields will compensate for a reduction in yield. Costs of pruning for the hedgerow can be reduced using machinery. Navasero (IITA 1984) showed that it took 6.7 h to slash 1 ha of 4 m wide hedgerows of *Leucaena* with a brush cutter; the same task took 37 h when manual pruning was performed with a thick-blade cutlass. Results of the 3-year observations have shown that mechanized alley cropping is feasible.

References

- Allan, W. 1965. The African husbandman. Oliver and Boyd, Edinburgh, UK. 505 pp.
- Atta-Krah, A.N., Sumberg, J.E., Reynolds, L. 1985. Leguminous fodder trees in the farming system. An overview of research at the Humid Zone Programme of the International Livestock Centre for Africa in southwestern Nigeria. International Livestock Centre for Africa, Ibadan, Nigeria.
- Bache, B.W., Heathcote, R.G. 1969. Long-term effects of fertilizer and manure on soil and leaves of cotton in Nigeria. *Experimental Agriculture*, 3, 241–247.
- Baldwin, K.D.S. 1957. The Niger Agricultural Project: an experiment in African development. Blackwell Scientific Publications Ltd, Oxford, UK. 221 pp.
- Benge, M.D. 1983. The miracle tree: reality or myth? In *Leucaena* research in the Asian-Pacific region: proceedings of a workshop held in Singapore, 23–26 November 1982. International Development Research Centre, Ottawa, Ont., Canada. IDRC-211e, 95–98.
- Brown, L.R., Wolf, E.C. 1985. Reversing Africa's decline. Worldwatch Institute, Washington, DC, USA. Worldwatch Paper 85, 81 pp.
- Duguma, B. 1985. Studies of factors affecting establishment of selected tree species of potential importance in agroforestry. University of Ibadan, Ibadan, Nigeria. PhD thesis, 413 pp.
- Duthie, D.W. 1948. Agricultural development. *East African Journal*, 13, 129–130.
- Getahun, A., Wilson, G.F., Kang, B.T. 1982. The role of trees in farming systems in the humid tropics. In McDonald, L.H., ed., *Agro-forestry in the African humid tropics*. United Nations University, Tokyo, Japan. pp. 28–35.
- Hartmans, E.H., Kang, B.T., Wilson, G.F., Akobundu, I.O. 1982. Role of planted fallow in developing stable cropping systems. Paper presented at the Multiple Cropping Systems meeting of the Latin American Association of Plant Sciences (ALCA), Chapingo, Mexico, 24–26 June 1982. ALCA, Caracas, Venezuela.
- IITA (International Institute of Tropical Agriculture). 1984. Annual report. IITA, Ibadan, Nigeria.
- _____. 1985. Research highlights. IITA, Ibadan, Nigeria.
- Jaiyebo, E.O., Moore, A.W. 1964. Soil fertility and nutrient storage in different soil vegetation systems in a tropical rain forest environment. *Tropical Agriculture*, 41, 129–130.
- Juo, A.S.R., Lal, R. 1977. The effects of fallow and continuous cultivation on the chemical and physical properties of an Alfisol. *Plant and Soil*, 47, 567–568.
- Kabeerathumma, S., Ghosh, S.P., Lakshmi, K.R. 1985. Soil erosion and surface runoff: multiple systems compared. *Cassava Newsletter*, 9, 5.

- Kang, B.T., Duguma, B. 1985. Nitrogen management in alley cropping systems. *In* Kang, B.T., van der Heide, J., ed., Nitrogen management in farming systems in humid and subhumid tropics. Institute of Soil Fertility, Haren, Netherlands. pp. 269–284.
- Kang, B.T., Grimme, H., Lawson, T.L. 1985. Alley cropping sequentially cropped maize and cowpea with *Leucaena* on a sandy soil in southern Nigeria. *Plant and Soil*, 85, 267–276.
- Kang, B.T., Juo, A.S.R. 1983. Management of low activity clay soils in tropical Africa for food crop production. *In* Beinroth, F.H., Neel, H., Eswaran, H., ed., Proceedings of 4th International Soil Classification Workshop, Rwanda. Administration générale de la coopération au développement, Brussels, Belgium. pp. 450–470.
- Kang, B.T., Wilson, G.F., Lawson, T.L. 1984. Alley cropping, a stable alternative to shifting cultivation. International Institute of Tropical Agriculture, Ibadan, Nigeria. 22 pp.
- Kang, B.T., Wilson, G.F., Sipkens, L. 1981. Alley cropping maize (*Zea mays* L.) and *Leucaena* (*Leucaena leucocephala* Lam.) in southern Nigeria. *Plant and Soil*, 63, 165–179.
- Kio, P.R.O. 1982. Forest conservation strategies for tropical Africa. *In* MacDonald, L.H., ed., Agroforestry in the African humid tropics. United Nations University, Tokyo, Japan. pp. 36–40.
- Lal, R. 1975. Role of mulching techniques in tropical soil and water management. International Institute of Tropical Agriculture, Ibadan, Nigeria. Technical Bulletin 1.
- Le Mare, P.H. 1972. A long-term experiment on soil fertility and cotton yield in Tanzania. *Experimental Agriculture*, 8, 299–310.
- McNamara, R.S. 1984. The population problem: time bomb or myth? Washington, DC, USA. 28 pp.
- Metzner, J.K. 1982. Agriculture and population pressure in Sikka, Isle of Flores. A contribution to the study of the stability of agricultural systems in the wet and dry tropics. Australian National University, Canberra, Australia. Monograph 28, 355 pp.
- Moormann, F.R., Greenland, D.J. 1980. Major production systems related to soil properties in humid tropical Africa. *In* Priorities for alleviating soil-related constraints to food production in the tropics. International Rice Research Institute, Los Baños, Philippines. pp. 54–77.
- Mulongoy, K., Kang, B.T. 1985. The role and potential of forage legumes in alley cropping, live mulch and rotation systems in humid and subhumid tropical Africa. *In* Haque, I., Jutzi, S., Neate, P.J.H., ed., Potential of forage legumes in farming systems of sub-Saharan Africa. International Livestock Centre for Africa, Addis Ababa, Ethiopia. pp. 212–231.
- Nair, K., Fernandes, E. 1984. Agroforestry as an alternative to shifting cultivation. *In* Improved production systems as an alternative to shifting cultivation. Food and Agriculture Organization of the United Nations, Rome, Italy. pp. 169–182.
- Ngambeki, D.S. 1985. Economic evaluation of alley cropping *Leucaena* with maize–maize and maize–cowpea in southern Nigeria. *Agriculture Systems*, 17, 243–258.
- Ngambeki, D.S., Wilson, G.F. 1984. Economic and on-farm evaluation of alley cropping with *Leucaena leucocephala* 1980–1983: progress report. International Institute of Tropical Agricultural, Ibadan, Nigeria. 45 pp.
- Nye, P.H. 1958. The relative importance of fallow and soils in storing plant nutrients in Ghana. *Journal for West African Science Association*, 4, 31–49.
- Nye, P.H., Stephens, D. 1962. Soil fertility. *In* Will, J.B., ed., Agriculture and land use in Ghana. Oxford University Press, London, UK. pp. 127–143.

- Obi, J.K., Tuley, P. 1973. The bush fallow and ley farming in the oil palm belt of southeastern Nigeria. Land Resources Division, Overseas Development Administration, London, UK. Miscellaneous Report 161.
- Okigbo, B.N. 1976. Role of legumes in small holdings of the humid tropics. In Vincent, J.M., Whitney, A.S., Bose, J., ed., Exploiting the legume-rhizobium symbiosis in tropical agriculture. Department of Agronomy and Soil Science, University of Hawaii, Honolulu, HI, USA. Publication 145, 97-117.
- Phillips, J.F.V. 1960. Agriculture and ecology in Africa. Praeger Publishers, Inc., New York, NY, USA. 243 pp.
- Poulsen, G. 1978. Man and tree in tropical Africa: three essays on the role of trees in the African environment. International Development Research Centre, Ottawa, Ont., Canada. IDRC-101e, 31 pp.
- Schaafhausen, R.M. 1966. Fotos que falam sobre leguminosas tropicais. Separata da revista. Sirel Agricola, 74.
- Torres, F. 1983. Potential contribution of *Leucaena* hedgerows intercropped with maize for the production of organic nitrogen and fuelwood in the lowland humid tropics. Agroforestry Systems, 1, 323-333.
- Wijewardene, R., Waidyanatha, P. 1984. Conservation farming. Department of Agriculture, Paradeniya, Sri Lanka. 40 pp.
- Wilson, G.F., Kang, B.T. 1981. Developing stable and productive biological cropping systems for the humid tropics. In Stonehouse, B., ed., Biological husbandry: a scientific approach to organic farming. Butterworth & Co. (Publishers) Ltd, London, UK. pp. 193-203.
- Wood, A. 1950. The groundnut affair. The Bodley Head Ltd, London, UK. 254 pp.
- WRI (World Resources Institute). 1985. Tropical forests: a call for action. Part I. The plan. WRI, Washington, DC, USA.
- Young, A., Wright, A.C.S. 1980. Rest period requirements of tropical and subtropical soils under annual crops. In Land resources for populations of the future. Food and Agriculture Organization of the United Nations, Rome, Italy. pp. 197-268.