ALLEY FARMING

AN ANNOTATED BIBLIOGRAPHY

B.T. Kang, Y.A. Adedigba,
O.A. Osiname, F.K. Akinnifesi

International Institute of Tropical Agriculture

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INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

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The goal of the International Institute of Tropical Agriculture (IITA) is to increase the productivity of key food crops and to develop sustainable agricultural systems that can replace bush fallow, or slash-and-burn cultivation in the humid and subhumid tropics. Crop improvement programs focus on cassava, maize, plantain, cowpea, soybean, and yam. Research findings are shared through international cooperation programs, which include training, information, and germplasm exchange activities.

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PREFACE

Trees and shrubs are important components of traditional farming systems. For generations, they have been incorporated in various traditional agroforestry practices. The woody species play important roles in improving and maintaining the fertility and productivity of the soil exhausted during cropping, in soil conservation, and weed control. They are also sources of browse and other auxiliary products. However, deforestation and overexploitative traditional farming, and lack of appropriate upland farming methods have led to increased degradation of the finite and nonrenewable upland soil resources in the quest for increasing food production in the tropics. This concern has spurred the need to develop sustainable and more productive farming methods.

Since the 1970s, the International Institute of Tropical Agriculture has researched various options for sustaining crop production at acceptable input levels, including the incorporation of woody species, which has led to the development of the alley farming system.

Alley farming is a complex subject as it deals with woody species (trees and shrubs), crops, and, in some instances, livestock in the production system. Traditional alley farming is already practised in some areas in southeast Asia and Africa. Various international and national research centers are currently doing research on or are extending alley farming into various parts of the tropics. Several of these institutions use different synonymical names for alley farming such as hedgerow intercropping at the International Centre for Research in Agroforestry (ICRAF), avenue cropping (Sri Lanka), and the contour hedgerow system.

Although traditional agroforestry has been practised for many generations, scientific agroforestry is a very recent practice. Literature on agroforestry is limited and quantitative data on the system is scanty. Since the publication of the Institute's work on alley farming, several publications have become available covering research results from different parts of the tropics. As we are dealing with a new science, many agriculture and forestry practitioners working in different parts of the topics are unaware of this technology. Lack of library facilities in many developing countries and lack of published information on the subject have also contributed to this problem. This bibliography contains extended summaries of published papers or reports so that those interested in the topic can have a head start. It includes summaries of articles closely related to alley farming or multipurpose woody species (MWS) production and their auxiliary uses, and on socioeconomic issues. Attempts have been made to collate all available information up to 1994, however, some articles may have been missed. We therefore ask that you inform us of any articles that have escaped our search or any errors in this publication. We hope that this publication will be useful for those interested in pursuing research on alley farming.

B.T. Kang and O.A. Osiname

USING THE BIBLIOGRAPHY AND INDEXES

Materials have been grouped into 14 broad subject categories. References are identified by a master file number at the top of the entry. Below it is the subject category code number. Definitions of important terminologies relating to alley farming and listing of subject matter, descriptors, and author indices are included.

Many entries cover more than one subject category; to save space, such entries are placed in only one category, with cross references in the Subject Index. To find out what the bibliography contains on a given subject, check the appropriate category as shown in the table of contents as well as the Subject Index. There is also an Author Index to help locate the publications by a given author. References in the indices are to the Master File Number found at the top of every bibliographical entry.

SUBJECT CATEGORIZATION

A. General

B. Multipurpose Woody Species (biomass production, rooting, performance and evaluation)

C. Hedgerow Husbandry (seed production, establishment, management, biomass and nutrient yields, N-fixation)

D. Crop Husbandry (cropping systems and production)

E. Crop and Hedgerow Competition (light, water, and nutrients)

F. Effects on Soil Properties (chemical, physical, and biological effects, fertility, nutrient contribution, and erosion)

G. Effects on Weeds and Pests

H. Fodder and Forage Production

I. Livestock Nutrition/Production

J. Auxiliary Products (fuelwood, stakes, food, medicinal)

K. Socioeconomics (labor use, budget)

L. Land and Tree Tenure

M. On-farm Research and Extension (adoption, development)

N. Training

DEFINITIONS

Agroforestry	The deliberate use of woody perennials, crops, and/or pasture and/or animals on the same land unit.
Alfisols (Luvisols}	Soils with a clayey subsoil and high base saturation [>35% of effective cation exchange capacity (ECEC) in subsoil]. Slightly acid soils with low to moderate fertility, low structural stability, and occurring mainly in subhumid zone.
Adaptation	To select trees or shrubs for new growing environment.
Adoption	To accept other practices.
Biomass	Weight of vegetative/reproductive material of entire or plant parts, e.g., aboveground (foliage, stem, wood) or below-ground (root) parts.
Browse	Parts of woody plants which are eaten by livestock.
Contour	Line joining places of same elevation on the land.
Coppicing	Resprouting of stump of woody species, to produce new shoots. Takes place when plant tops are damaged or cut.
Cut-and-carry	Fodder or other plant products harvested and transported for use at different location.
Dormancy	Arrested development of a plant owing to structural or chemical properties of the seed that prevent germination when environmental conditions are not favorable.
Entisols	Soils with little or no horizon development in the profile. They are mostly developed from alluvial or colluvial materials.
Extensive	Low intensity land-use management spread over a large area where land is plentiful.
Exotic	A plant species which has been introduced from outside its natural range.
Fallow	Land resting from cropping, which may be grazed or left unused, often colonized by natural vegetation. Leaving land either uncropped and weed-free, or with volunteer vegetation during at least one period when a crop would normally be grown.
Farming systems	Interactions of all components of the farm, including people, crops, livestock, vegetation, wildlife, the environment, and the social, economic, and ecological factors.
Fodder	Parts of plants which are eaten by domestic animals. These may include leaves, stems, pods, bark, and flowers.
Forage	Herbaceous plants or plant parts consumed by animals.
Green manure	Plant material applied to the soil to supply nutrients and to improve soil fertility.
Herbaceous	A plant without woody parts throughout its growth cycle.
Hedgerow	A closely planted line of shrubs or small trees, often forming a boundary, fence, or hedge.
High altitude	Areas with an altitude of > 1500 m for the purpose of this bibliography.
Humid zone	Climatic zone with annual rainfall > 1300 mm and length of growing period of > 270 days.

Inceptisols	Young soil from colluvial and alluvial materials with limited profile development. Soils derived from volcanic ash are considered a special group of Inceptisol and are classified as Andept.
Indigenous	Plants which originate or are native to a particular area.
Intensive	High degree of land use or management of a piece of land.
Interface	The area of contact or interactions between two entities, such as between a row of trees and a row of crops.
Intercropping	Growing of two or more plant species in the field at the same time in a mixture. It can involve crops and/or woody species.
Land use	The way land is used by a particular group of people within a specified area.
Lopping	To cut one or more branches of a standing tree.
Low activity clays (LAC)	LAC soils have an ECEC < 16 meg/100 g clay in the subsoil.
Low altitude	Areas with an altitude of < 750 m for the purpose of this bibliography.
Microclimate	Involves temperature, solar radiation, humidity, and other climatic parameters in a small, localized area, e.g., in a field, a stand of trees, or in the vicinity of a plant.
Mid-altitude	Areas with an altitude between 750 and 1300 m for the purpose of this bibliography .
Mulch	Plant or non-living materials used to cover soil surface to protect the soil from the impact of rainfall, suppress weeds, reduce soil moisture loss, and fertilize the soil.
MPTS	Multipurpose trees and shrubs (MPTS) are woody perennials grown to provide more than one product or service. Also called multipurpose woody species (MWS).
N-fixation	Relating to a plant that has the ability to convert nitrogen from the air into a form which can be used by plants. This process, called biological nitrogen fixation (BNF), is performed by another organism that normally lives in symbiosis in plant roots. In legumes, the organism is a rhizobial bacteria. In other plant species such as *Casuarina*, it is an actinomycete.
Nutrient yield	Amount of nutrients present in a certain amount of plant biomass harvested.
On-farm Research	Conducting research on farmers' fields with full participation of the farmers.
Oxisols	Strongly weathered soils with little variation in texture with depth. Strongly weathered soils are red, deep, and porous. Soils have good physical structure with low fertility.
Participatory	Involving farmers in the decision process from survey to execution of activities.
Palatable	Plant characteristics eliciting a choice between two or more forages or parts of the same forage, conditioned by animal and environmental factors that stimulate a selective intake.
Perennial	A plant that grows for more than one year.
Pollarding	Cutting back the crown of a tree in order to harvest wood and browse to produce regrowth beyond the reach of animals and/or to reduce shading.

Productivity	Capacity of soil for producing a specified crop or sequence of crops under specified management systems.
Pruning	Cutting back plant growth. It includes coppicing, lopping, pollarding, or other cutting methods.
Ration	A 24-hour allowance of feed or mixture of feedstuff making up the animal diet.
Rotation	In agriculture, changing of crops grown on a particular piece of land from season to season. In forestry, the length of time between establishment and harvesting of a tree plantation.
Rotational grazing	A system of pasture utilization embracing periods of heavy animal stocking followed by periods of rest for herbage growth recovery during the same season.
Runoff	Amount of precipitation that is lost by surface flow.
Seed pre-treatment	Soaking seeds with water or treating with acids, insecticides and fungicides to improve germination.
Semiarid	Refers to climatic zone with annual rainfall of 200–900 mm and a length of growing period between 90 and 165 days.
Shrub	A woody plant that remains < 10 m tall and produces shoots or stems from its base.
Sloping land	Land with surface at certain inclination or angle from the horizontal plane.
Sustainable	The successful management of resources for agriculture to satisfy changing human needs, while maintaining or enhancing the quality of the environment and conserving natural resources. On a field plot basis it is the ability of a cropping system to produce a reasonable stable yield over a long time without environmental degradation.
Conservation	Measures to preserve plants, water, and soil.
Soil erosion	Process by which the soil surface is washed or worn away by water and wind.
Subhumid	Climatic zone with annual rainfall of 900–1300 mm, and a length of growing period of between 165 and 270 days.
Tenure	The right to property, granted by custom and/or law, which may include land, trees and other plants, animals, and water.
Trees	A woody plant with one trunk and a more-or-less distinct and elevated head.
Ultisols (Acrisols)	Soils with clayey subsoil and low base saturation (< 35% of ECEC in subsoil). Acidic to highly acidic soils with low fertility and low structural stability, occurring mainly in the humid zone.
Vertisols	Dark soils containing large amounts of swelling clay minerals. Soils crack during dry season and become sticky when wet. Occurring mainly in subhumid and semiarid zones.
Woody	Nonherbaceous plants containing wood in shoot and root.
Zero grazing	Livestock production systems in which the animals are fed in pens or other confined areas and are not permitted to graze.

General

001
A
Ala, A. and R. Fadjung. 1993.
Cropping system for marginal land at South Sulawesi, Indonesia. Agronomy Abstracts 55.

In spite of the use of high yielding varieties and fertilizers, the productivity of many agricultural regions in South Sulawesi is still very low. There is even a tendency for productivity to decline and evidence of soil erosion. A study was undertaken in two regencies of South Sulawesi, Indonesia, to determine the best cropping system in terms of productivity, sustainability, and adoptability. Extensive soil survey, climatic data collection, and farmer cautionary were done in the study area. Two types of systems, alley cropping and agroforestry, are proposed. Also, depending on the edaphic, climatic, and socioeconomic conditions of the farmers, the best mixtures of crops for alley cropping and agroforestry are proposed.

General

002
A
Amara, D.S. 1989.
Alley farming in Sierra Leone. Pages 154–157 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. International Development Research Centre (IDRC), Ottawa, Canada.

This paper focuses on alley farming research activities at Njala University College, Sierra Leone. The objectives of, and data from, this research are summarized and information on some recent alley farming research is provided.

General

003
A
Anderson, L.S. and F.L. Sinclair. 1993.
Ecological interactions in agroforestry systems. Agroforestry Systems 6: 58–91.

Agroforestry is a form of land-use system whereby the benefits of growing woody and herbaceous species together are optimized by the addition of trees to land already being used for pasture or for growing annual crops. It also involves the ways in which the presence of a plant can change the environment of another, generating a favorable balance between negative and positive plant interactions, and thereby increasing total yield, reducing yield variability, and conserving resources. These ecological issues include a time dimension, and are crucial to socioeconomic concepts regarding productivity, stability, and sustainability in marginal land-use systems. Theories regarding interspecific and intraspecific interactions, and the mechanisms concerned, have been formulated as a basis for interpreting the results of experimental studies in agroforestry, thereby enabling a better understanding of the processes that determine productivity and its maintenance in agroforestry systems. The review is presented in three main sections. The first considers agroforestry in the context of ecological principles concerning interactions between species and the ways in which the presence of a plant can change the environment of another. The second section concerns the conceptual framework developed to appraise concisely published research findings, involving competition, predation, mutualism, and commensalism. The third section elaborates three key issues connected with the objectives of agroforestry: overyielding, the reduction of yield variability, and maintenance of resources.

General

004
A
Anonymous. 1988.
Agroforestry: Farming with trees. Spore 14: 4–6.

The upsurge of interest in agroforestry during the last decade is due to increasing demographic pressures and shortages of food and fuel among the poor in many developing countries. Agroforestry is seen as one way of solving these problems, since by including trees in their farming systems, farmers benefit from a supply of wood and other tree products and help ensure that their land remains fertile and productive as well. A mixture of tree and annual crops of different heights provides a more complete ground cover which again helps protect the soil from erosion and makes maximum use of available sunlight. Originally from Asia, agroforestry is one of the innovative approaches adopted to tackle the problems caused by reduced bush fallows. Food crops are grown in the alleys between the lines of trees or shrubs. The trees are cut back to form a hedge while the crop is grown, but allowed to grow out and cover the soil once the crop is harvested. The benefits are similar to those in a traditional bush fallow, but in this case, cropping and fallowing occur side by side, so allowing continuous use of the same piece of land. Researchers have confirmed that alley cropping can be adapted to Nigerian conditions and have tested several tree species, examining how they can be established and at what height they should be pruned. Several villages in southwest Nigeria have accepted the system although researchers were surprised to discover farmers growing highly competitive crops such as yam, melon, and cassava between the young trees instead of the recommended maize.

General

005
A
Ashley, M.D. Undated.
Agroforestry in Haiti. Imprimerie Henri Deschamps. 69 pp.

This booklet is the result of studies of Haitian agricultural and agroforestry practices coordinated by the US Agency for International Development (USAID) Agroforestry Outreach Project. The many ideas and questions on agroforestry and farming systems highlighted the need to have a visual reference for these systems. It presents agroforestry as practised by farmers in Haiti today and serves as a good introduction to such systems.

General

006
A
Atta-Krah, A.N. and B.T. Kang. 1990.
Alley farming as an agricultural production system for the humid tropics. Agronomy Abstracts 52.

Traditional farming systems in humid tropical Africa, characterized by low productivity and dependence on natural soil fertility, are undergoing rapid and destabilizing changes due to rapid population growth. Increasing land-use intensity without proper soil management measures and adequate replenishment of required nutrients have resulted in soil degradation and decreasing crop yields. Alternative sustainable production systems have been developed and tested by various institutions. One such system is alley farming which involves the integration of tree hedgerows within cropping fields. The potential of the alley farming technique as a low input conservation farming technique for the humid tropics is discussed. The activities of the Alley Farming Network for Tropical Africa (AFNETA) which was established in 1989 to promote alley farming research and development in national institutions in tropical Africa is also presented.

General

007
A
Atta-Krah, A.N., J.E. Sumberg, and L. Reynolds. 1986.
Leguminous fodder trees in the farming systems: an overview of research at the humid zone programme of ILCA in southwestern Nigeria. Pages 307–329 *in* Potential of forage legumes in farming systems of sub-Saharan Africa, edited by J. Haque, S. Jutzi, and P.J.H. Neate. ILCA, Addis Ababa, Ethiopia.

The potential of leguminous fodder trees in the farming systems of humid West Africa is considered in the light of research work carried out by the Humid Zone Programme of the International Livestock Centre for Africa (ILCA) at Ibadan, Nigeria. ILCA's agronomy research effort focuses on the leguminous species *Leucaena leucocephala and Gliricidia sepium.* The paper reviews a variety of research trials ranging from the improvement of germplasm materials to the development of fodder production systems, and concludes with a recommendation for more research and development attention on the integration of fodder trees within existing farming systems.

General

008
A
Balasubramanian, V. 1983.
Alley cropping: Can it be an alternative to chemical fertilizer in Ghana? Paper presented at the Third National Maize Workshop held at Kwadeso Agricultural College, Kumasi, Ghana, 1–3 Feb 1983. 22 pp.

Alley cropping is one of the low-input crop production systems which integrates arable crops with trees (agroforestry). It is a system in which food crops are grown in the spaces between rows of planted trees or woody shrubs pruned periodically during the cropping season to prevent shading, minimize intercrop competition, and provide green manure mulch for the companion crops. The species selected for alley cropping must be fast growing, adaptable to a wide range of habitats, able to withstand frequent pruning, have a root system to pump nutrients from the subsoil to the surface, and have the ability to fix atmospheric N. Potential fallow species being tested at the International Institute of Tropical Agriculture (IITA) for use in alley cropping include *Leucaena leucocephala, Gliricidia sepium, Sesbania grandiflora, Alchornea cordifolia, Acioa barteri,* and *Tephrosia candida.*

General

009
A
Balasubramanian, V. and A. Egli. 1986.
The role of agroforestry in the farming systems in Rwanda with special reference to the Bugesera-Gisaka-Migongo (BGM) region. Agroforestry Systems 4: 271–289.

Faced with a perpetual land shortage, Rwandan farmers have evolved some intensive systems of organic farming, such as homestead (compound) farming, which involves the combination of food, fodder, and tree crops. To a certain extent, these systems can satisfy the multiple needs of the subsistence farmers living under several risks and constraints. However, they cannot meet the increasing food demand of the rapidly increasing population. Agroforestry approaches have been designed to improve the productivity of these traditional systems. These include inter/mixed cropping systems and rotation, alley cropping with leguminous trees and shrubs, use of planted "fallow", planting tree legumes on anti-erosive lines, mixed farming, community forestry and woodlots, and tree planting on farm/field boundaries. The essential aspects of these technologies are briefly discussed.

General

010
A
Benge, M.D. 1987.
Agroforestry systems. Contour hedgerows of woody perennials (alley cropping). S&T/FENR Agroforestation series No. 12: 39.

Agroforestry systems using nitrogen-fixing woody perennials, such as *Leucaena leucocephala* and *Gliricidia sepium* planted in contour hedges on hillsides (or alleys on level ground), have proven to be an inexpensive and effective technology to control soil erosion, improve soil structure, and increase crop yields. Simultaneously, these systems produce abundant forage and fuelwood. The use and benefits of *Leucaena* in contour hedgerows were reviewed. The background and establishment of the alley cropping system were described.

General

011
A
Chew, S.T. 1988.
Agroforestry projects for small farmers: project manager's reference. Agency for International Development (AID). Evaluation special study No. 20. US Agency for International Development (USAID), Washington, DC, USA. 88 pp.

Between 1977 and 1987, agroforestry activities funded by the US Agency for International Development (USAID) included 43 bilateral assistance projects, research projects at international research institutions, and community development projects implemented under the PL 480 Food Aid Program or cofinancing arrangements with private voluntary organizations. The projects' common objectives are to encourage farmers to grow trees using species and techniques which can protect and sustain the productivity of topsoils, increase crop or livestock production, and, in most cases, also provide wood and other products to augment home consumption and cash income. Various tree-growing techniques are used, ranging from cultivating trees to form windbreaks or contour hedgerows to techniques that are especially relevant to agricultural and rural development programs directed to farming communities cultivating land generally unsuitable for sustained intensive monoculture and subject to soil erosion and environmental degradation. Issues concerning agroforestry projects for small farmers are discussed.

General

012
A
Coe, R. 1994.
Through the looking glass: 10 common problems in alley cropping research. Agroforestry Today 6(1): 9–11.

Gives a cursory look into some methodological and interpretational problems common to alley cropping experiments and agroforestry in general. Emphasis is given to the need for selecting appropriate control plots. Implication of wrong hedgerow alignment, neighbor effects, and how to avoid these problems are discussed.

General

013
A
Cook, C.C. and M. Grut. 1989.
Agroforestry in sub-Saharan Africa: a farmer's perspective. World Bank Technical Paper No. 112. 97 pp.

Reviews agroforestry practices in sub-Saharan Africa as seen from the farmer's perspective. Seven case studies were conducted by an interdisciplinary team, covering

indigenous and innovative systems found in the highlands of East Africa, the semiarid zone, and the humid lowlands of West Africa, including chagga home gardens, the agropastoral project, alley farming, and maijia valley windbrakes. Key findings in this review include the importance of understanding the economics of agroforestry systems from the farmer's point of view as well as from the broader perspective of societal benefits. Project evaluation should, therefore, consider local markets and opportunities for off-farm employment offered by tree products, as well as the opportunity costs perceived by farmers in making adoption decisions. Farm households are not homogeneous, and project design should be adapted to the socioeconomic level, age, and gender of the people who are expected to adopt the proposed technology. In Africa, trees are integral parts of agrosylvopastoral farming systems and should be considered in this sociocultural context, with particular attention to the constraints imposed by customary and legal rules regarding land and tree tenure. The institutional framework for implementation should be selected and developed with a view to long-term sustainability. Recommendations are made for the technical, economic, social, and institutional design of projects and for the direction of future research.

General

014
A
Devendra, C. 1990.
Shrubs and tree fodders for farm animals. International Development Research Centre (IDRC), Ottawa, Canada. 349 pp.

This publication presents the results of an international meeting held in Denpasar, Bali, Indonesia, 24–29 July 1989, that focused on the use of shrubs and tree fodder by farm animals. Through 26 papers, the workshop addressed feed-resource availability, use by ruminants and nonruminants, processing methodology, economics, and development issues. These aspects and the current knowledge on shrubs and tree fodder were further highlighted by country case studies detailing prevailing situations and policy matters. A special session was held to discuss the successful development and results achieved in the three-strata forage system in Indonesia. The workshop concluded with important working group discussions on the priorities for further research and development, and on the potential for the wider use of shrubs and tree fodders in the developed world.

General

015
A
Garity, D.P. 1993.
Sustainable land-use systems for sloping uplands in southeast Asia. Pages 41–66 *in* Symposia on technologies for sustainable agriculture in the tropics, edited by J. Ragland and R. Lal. Special Publ. No. 56. American Society of Agronomy, WI, USA.

Increasing land area expansion due to an increasing population of subsistence farmers coupled with inequitable land distribution and continuous cultivation (annual at the expense of the wide range of land uses including rangelands, cash crops, and forestry) were presented as major threats to the sustainability of the sloping uplands of south Asia. The use of *Leucaena leucocephala* and *Gliricidia sepium* for erosion control is described. Upland rice was reported to have increased in yield due to alley cropping with *Cassia spectabilis* (syn. *Senna spectabilis*) and *Gliricidia sepium.* The use of grass and natural vegetation strips are also noted. Management of coffee, papaya, citrus, and mulberries as hedgerows for erosion control is indicated. Phosphorus is also presented as an important soil nutrient constraint in the area. The relevance of reduced tillage, grassland management, fallow management, and small-scale farm diversification is stressed. Interactions among land tenure policy infrastructural support and technological innovation also features. A model is presented which integrates separate traditional agricultural land uses.

General

016
A
Getahun, A. 1983.
The role of agroforestry in soil and water conservation in the tropics. Pages 338–349 *in* Soil and water conservation in Kenya, edited by D.B. Thomas and W.M. Senga. University of Nairobi Development Authority, Kenya.

The role of agroforestry in soil and water conservation is discussed. It attributes the success of agroforestry as a productive and appropriate system of land use to the *effective enriching and/or soil conserving role of trees and shrubs in the ecosystem* through nutrient cycling, soil organic matter and litter building, and erosion control. The different agroforestry systems—traditional and modern—including agricultural and forest-based systems and alley cropping are also discussed. The soil-enriching principles of agroforestry (tree) systems are also discussed.

General

017
A
Getahun, A. and K. Reshid. 1988.
Agroforestry in Kenya: a field guide. Motif Creative Arts Limited, Nairobi, Kenya.

This preliminary guide on agroforestry with an emphasis on alley cropping is prepared for extension workers and self-help group farmers who are interested in knowing about agroforestry practices. The guide emphasizes the form of tree/crop intercropping whereby tree/shrubs are planted with food crops in alternating bands to maximize productivity and sustainability of the *shamba* or farm enterprise. Such intercropping is commonly known as alley cropping or hedgerow intercropping. The interactions between the tree/shrub component and food crops and livestock and how this mix benefits the farmer are described. Details of different establishment and management techniques are discussed. The ecology, characteristics, uses, and limitations of several potential agroforestry woody species are also highlighted.

General

018
A
Getahun, A., G.F. Wilson, and B.T. Kang. 1982.
The role of trees in farming systems in the humid tropics. Pages 28–35 *in* Agroforestry in African humid tropics, edited by L.H. MacDonald. The United Nations University, Tokyo, Japan.

The bush fallow-food crop rotation system has been the most popular and stable arable cropping system in the humid tropics of Africa. The system's stability is attributed to the presence in the fallow of deep-rooted woody plant species that are essential to soil fertility restoration. Population increases and the associated pressures on land have been threatening the stability and productivity of the system. As more land is brought into production, the fallow period is shortened and woody species are eliminated or become ineffective. A recent survey in southern Nigeria confirmed that the bush fallow-food crop rotation is still the dominant land-use pattern. Other important patterns are permanent tree crops (including plantain and banana), taungya, and permanent compound farming, in which trees are major components. The role of trees in nutrient recycling, soil organic matter buildup, and erosion control has been recognized by traditional farmers, who have identified and have been encouraging the most effective tree species in the fallow. With these selected species, the fallow period can be effectively shortened. To exploit the potential of selected tree species in land and soil management further, we have been perfecting a system called alley cropping. This system embodies the agroforestry concept of combining crops and trees and ensures the dominance of effective tree species during the fallow period.

General

019
A
Glover, N. 1989.
***Gliricidia* production and use. The Nitrogen Fixing Tree Association (NFTA), Hawaii, USA. 44 pp.**

Gliricidia is a versatile, fast-growing, nitrogen-fixing tropical tree. Farmers around the world grow *Gliricidia* for fuelwood, animal feed, green manure, shade, poles, and as a support plant. It is easy to establish, coppices vigorously, and tolerates regular lopping. *Gliricidia* is useful for planting in fence lines, woodlots, alley farming systems and in association with perennial crops and pasture lands. Its ability to fix nitrogen makes it an excellent source of this important nutrient. Nitrogen-fixing trees (NFTs) contribute greatly to the productivity and sustainability of many agriculture and forestry ecosystems. Plants cannot grow without nitrogen, and many tropical soils have low supplies of this nutrient. Although nitrogen is abundant in the earth's atmosphere, this nitrogen is not available for plant growth. *Gliricidia* and other NFTs convert atmospheric nitrogen into a form available to plants. Atmospheric nitrogen is fixed by either rhizobium bacteria or an actinomycete *Frankia* in nodules present on the roots of NFTs. Fixed nitrogen is available for NFT growth in exchange for a supply of nitrogen in the leaves of NFTs, making them valuable for animal feed and fertilizer. The appropriate NFTs to use depends on site conditions, needs, and local preferences. More than 650 tree species fix nitrogen. These include species in the genera *Acacia, Albizia, Alnus, Calliandra, Casuarina, Erythrina, Gliricidia, Inga, Leucaena, Prosopis,* and *Sesbania*. All are important to rural households throughout the tropics. NFTs can be grown on farms in a number of ways ranging from scattered trees to plantations. This manual includes information from around the world in the production and use of *Gliricidia sepium*. It is hoped that extension personnel, progressive farmers, and organizations engaged in tree planting efforts will find it useful. We encourage all users of this manual to adapt the presented production systems to local needs and preferences. Comments and suggestions for improvements are welcome.

General

020
A
Hancock, I.R. 1989.
Preliminary studies in nutrient cycling within the farming systems of the Solomon Islands. Pages 287–300 *in* Nutrient management for food crop production in tropical farming systems, edited by J. Van der Heide. Institute for Soil Fertility (IB), Haren, The Netherlands.

The paper reviews the status of the major soil groups found in the Islands, particularly in relation to vegetation and climate which have influenced their pedogenesis, and the impact that present systems of agriculture (mainly shifting cultivation) are having on these soils, with particular regard to the nutrient cycles of nitrogen, phosphorus, and potassium. The interrelationships between soil fertility and the various parameters which are characteristic of these traditional systems are discussed, particularly length of cropping and fallow periods, effects of clearing and burning, influence of crop species, and intercropping practices. A brief description is made of the present investigatory program where the aims are to improve the availability of the major plant nutrients, particularly potassium, enhance the sustainability of the present systems, and include those on sloping land. Agroforestry, in the form of alley cropping, is being evaluated as a way of enhancing all these aspects.

General

021
A
Hawkings, R., H. Sembiring, D. Lubis, and D.J.O. Suwar. 1990. The potential of alley cropping in the uplands of East and Central Java. Agency for Agricultural Research and Development, Department of Agriculture, Jakarta, Indonesia. 71 pp.

Alley cropping—the intercropping of leguminous hedgerows with food crops—has received considerable attention recently. The practice has been increasingly promoted as a promising means of soil conservation, aimed at both reducing soil erosion and improving the soil conditions necessary for plant growth. The growing interest in alley cropping in Indonesia, as elsewhere, is inspired by the recognition that other means of soil conservation, such as terraces, may be inappropriate for many soil conditions, be too demanding of labor, and are not adopted by farmers. However, there is currently a lack of information quantifying the costs and benefits of alley cropping, defining practical recommendations for extension, and identifying critical aspects in need of research. This review attempts to summarize the information that is available and to assess the potential of alley cropping for the uplands of Central and East Java (the target area for the Upland Agriculture Conservation Project, or UACP). Information from international literature is considered, together with Indonesian reports and UACP experience to date. The primary objective is to improve policy, research, and extension recommendations in the UACP. It is also hoped that the information may be of interest to similar projects and researchers working on alley cropping.

General

022
A
IBSRAM (International Board for Soil Research and Management). 1993. Conservation farming and land development in Asia and Africa. International Board for Soil Research and Management (IBSRAM) Highlights, pp 23–28.

The paper presents the effects of different technologies on soil loss at various sites in Asia including China, Indonesia, Malaysia, Philippines, Thailand, and Vietnam. It was shown that the alley cropping systems with low and high input were superior to farmers' practice in reducing soil loss during 1990–1992. Highest crop yields were obtained in the Philippine and Indonesian sites, with better yield in alley cropping than residue incorporation, cover crop, and farmers' practice. It is expected that the yield gap between farmers' practice and improved technologies, especially alley cropping, will increase in subsequent years. It is concluded that alley cropping has the potential to promote sustainable agriculture on sloping lands.

General

023
A
International Development Research Centre (IDRC). 1983. *Leucaena* research in the Asia-Pacific region. IDRC, Ottawa, Canada. 192 pp.

Proceedings of a workshop on priorities of research on *Leucaena* in Asia and the Pacific. Includes thirty papers on biology and improvement, forage production, wood production, and soil restoration.

General

024
A
Juo, A.S.R. 1985.
Cultivating tropical rainforest: methods and constraints. Entwicklung und Landlicher Raum (Germany) 19: 14–15.

Despite the fact that tropical rainforests have very fertile soils, attempts in recent years to clear the rainforest for large-scale food crop farming have not been able to achieve continuous economic production of food crops, particularly cereals and grain legumes, for more than a few years. Further clearing of tropical rainforests for agriculture needs to be carefully planned on the basis of soil and land suitability for intended farming systems. A better way to cultivate annual food crops in the tropical rainforest regions may be to retain certain essential features of agroforestry. Alley cropping seems to fulfil this requirement, especially with maize.

General

025
A
Juo, A.S.R. 1989.
New farming systems development in the wetter tropics. Environmental Agriculture 25: 145–163.

The dominant farming systems in the wetter tropics are: the irrigated paddy-rice multistorey homestead garden complex of Asia, the tree and cash crop plantations of Latin America, and the mixed root crop-bush fallow systems of Africa. In upland ecosystems, sustainable farming systems development rests on a delicate balance between conservation and utilization. The improvement and adaptation of multistorey homestead gardens and mixed systems which include trees and annual and perennial crops have great potential to meet the basic food and nutritional needs of the indigenous population. The principle and practice of alley cropping provide an ecologically sound basis for future farming systems.

General

026
A
Kang, B.T. 1988.
Agroforestry systems for sustained crop production in the tropics. Agronomy Abstracts: 57.

Trees and shrubs featured prominently in traditional farming systems in the tropics because of their many uses and their environmental and socioeconomic benefits. Woody species form a major component of the bush-fallow system and are also widely grown in cropped land in the humid and subhumid tropics. Intercropping of woody species with annual crops in temporal and spatial agroforestry systems is known to provide more sustainability of the production system. Inclusion of woody trees, particularly certain leguminous species, can enhance nutrient cycling, soil fertility maintenance, soil protection, and provide biologically fixed N. It also provides a better basis for developing intensive, low input agricultural production systems.

General

027
A
Kang, B.T. 1993.
Alley cropping: past achievements and future directions. Agroforestry Systems 23: 141–155.

The need to develop viable farming systems for tropical uplands dominated by low-activity clay soils is imperative; such systems should ensure sustained crop production while protecting the soil resource base. Alley cropping has the potential to meet this need. The alley cropping technique has been tested, with varying results, in

various agroecological zones for over a decade. The potential and limitations of the alley cropping technique are highlighted and areas of future research discussed. Results obtained so far show that the system has greater potential on the high-base status soil in the humid and subhumid zones, and that crop production can be sustained in this ecozone with low chemical inputs. Further research is needed to increase the suitability of this system in other ecozones, particularly with inclusion of better adapted or indigenous hedgerow species.

General

028
A
Kang, B.T. and R.C. Gutteridge. 1993.
Forage tree legumes in alley cropping systems. Pages 267–288 *in* Forage tree legume in tropical agriculture, edited by R.C. Gutteridge and H. Max Shelton. CAB International, Wallingford, UK.

The biological merits of alley cropping make it an important conservation farming practice for smallholders and resource-poor farmers. However, with minor modifications, it could also be adapted to the broader farming systems of the world. The system exploits moisture and nutrients deep in the soil profile. It permits nutrient recycling, improves soil structure, provides good soil erosion control, and reduces the need for chemical fertilizers. Following a decade of intensive research on alley cropping in various parts of the tropics, a better understanding has now emerged of the potential and limitations of the system and the areas requiring further research. Competition for light can largely be eliminated by judicious pruning of the tree species during the cropping phase. Below-ground competition for moisture has not been well defined and further research is required especially in subhumid regions. Identification of additional tree species suited to low-base status, acid soils is also an important research goal as well as defining management practices to enhance the beneficial effects of the system.

General

029
A
Kang, B.T., O.A. Osiname, and A. Larbi. (eds.) 1992.
***Alley farming. Proceedings of the International Conference on alley farming.* Alley Farming Network for Tropical Africa (AFNETA), Ibadan, Nigeria, 14–18 Sep 1992. 593 pp.**

This publication presents the results of an international conference on alley farming held at IITA, Ibadan, Nigeria, 14–18 September 1992. Through 58 papers, the conference addressed wide research topics which are grouped into seven parts: (1) synthesis of alley farming (AF) research at the three supporting international agricultural research centers: IITA, ICRAF, and ILCA (now ILRI), (2) processes and management studies in AF, (3) multipurpose trees and shrubs and fodder production in AF for ruminants, (4) experiences in AF from humid and subhumid tropics of sub-Saharan Africa, (5) experiences in Southeast Asia, the South Pacific, and South America, (6) concepts and methodologies for on-farm research and economics of AF, and (7) development/extension experiences. Based on the demonstrated successes and constraints of the AF technology, the conference concluded with important recommendations for further research and development that will enhance its biophysical adaptability, adoptability by farmers, and increase the overall sustainability of AF technology in these fragile ecosystems.

General

030
A
Kang, B.T. and L. Reynolds. 1986.
Alley farming in the humid and subhumid tropics (state of the art, research, training, and collaboration). Paper presented at the IITA Board of Trustees' meeting, 12–15 April 1986. International Institute of Tropical Agriculture (IITA) and International Livestock Centre for Africa (ILCA), Ibadan, Nigeria. 41 pp.

Alley farming is an agroforestry approach for managing farming systems using particularly woody leguminous species. This management system allows continuous low input and sustainable crop production on fragile upland soils in the humid and subhumid tropics. Tree foliage provides high quality supplementary food for ruminant livestock. This working paper summarizes the state of the art of alley farming and alley cropping for the humid and subhumid tropics. It identifies the potential, management problems, and research needs. In addition the working paper also contains a summary of the proceedings and recommendations made by the participants in the alley farming workshop that was jointly organized by IITA and ILCA and held at IITA, Ibadan Nigeria, from 10 to14 March 1986. The workshop was sponsored by IDRC and USAID and was attended by over 100 persons from 19 countries.

General

031
A
Kang, B.T. and L. Reynolds. 1988.
Alley farming: its potential for humid and subhumid tropics. *In* Agroforestry for food and wood production, edited by J.O. Adegbehin. Proceedings of a national agroforestry training workshop, 1–4 Aug 1988, Ibadan, Nigeria.

The traditional shifting (and related bush fallow-slash and burn) cultivation system is biologically a stable production system when adequate land is available. However, increasing land pressure due to rapid population growth and other land uses, which makes long fallow periods unattainable, has destabliized the system. Rapid increase in food, feed, and household fuel demands have resulted in increasing deforestation in West Africa including Nigeria. The alley farming system has been shown to be an attractive and potential alternative for modernizing the less productive traditional systems, particularly for food and browse production. Observations for a number of years of Alfisols and related upland soils in southern Nigeria have shown that continuous alley farming of food crops with *Leucaena* and *Gliricidia* is feasible. The system can sustain crop yield, maintain soil productivity with low input levels, conserve the soil, and suppress weeds. In addition, the system can provide much needed browse throughout the year, staking materials, and firewood. Investigations are still underway to identify suitable species for alley farming on Ultisols, Oxisols, and related soils. Results of on-farm trials in Nigeria have shown that the alley farming system is readily accepted by farmers in areas where there is a need for either the entire package or some of its components. Technology transfer and adoption of the system in Nigeria need to be promoted. Adoption of the technology can assist in increasing food and livestock production and reduce the problem of deforestation and land degradation.

General

032
A
Kang, B.T. and R. J. Van Denbeldt. 1990.
Agroforestry systems for sustained crop production in the tropics with special reference to West Africa. Pages 13–35 *in* Agroforestry land-use systems, edited by E. Moore. Nitrogen Fixing Tree Association (NFTA), Hawaii, USA.

Trees and shrubs feature prominently in traditional farming systems in the tropics because of their many uses and their environmental and socioeconomic benefits.

Woody species form a major component of the bush fallow system and are also widely grown on cropped land. Intercropping of woody species with annual crops in temporal and spatial agroforestry systems are known to enhance sustainability of production systems. Inclusion of woody species, particularly certain legumes, can enhance nutrient cycling, soil fertility maintenance and soil protection; provide biologically fixed N; and provide a basis for developing intensive, more productive, and sustainable upland food crop production with low purchase inputs. In this paper, potential agroforestry systems suitable for sustainable crop production in the humid and semiarid tropics of sub-Saharan West Africa are described and recent research advances and future research needs discussed.

General

033
A
Kang, B.T., M.N. Versteeg, O.A. Osiname, and M.P. Gichuru. 1991.
Agroforestry in Africa's humid tropics: three success stories. Agroforestry Today 3: 4–6.

Describes traditional agroforestry systems in tropical Africa. Brief accounts are given of the following three low input and sustainable systems. The Adja oil palm fallow system, the traditional *Acioa barteri* alley cropping system, and the *Cajanus cajan* fallow system.

General

034
A
Kang, B.T. and G.F. Wilson. 1987.
The development of alley cropping as a promising agroforestry technology. Pages 227–243 *in* Agroforestry: a decade of development, edited by H.A. Steppler and P.K.R. Nair. International Centre for Research in Agroforestry (ICRAF), Nairobi, Kenya. (French translation available.)

Reviews traditional slash and burn food-crop production in the humid and subhumid tropics, particularly for sub-Saharan Africa. Discusses roles of multipurpose woody species in crop production systems and evolution of various agroforestry systems including the alley cropping system. Highlights potential and adoption of alley cropping and research needs.

General

035
A
Laquihon, W.A. and M.V. Pagbilao. 1993.
Sloping agricultural land technology (SALT) in the Philippines. Pages 336–373 *in* Forage tree legumes in tropical agriculture, edited by R.C. Gutteridge and H. Max Shelton. CAB International, Wallingford, UK.

The paper discusses benefits of the shrub and tree legume-based alley farming system (e.g., soil protection and amelioration, landscape stability, sustained production, and economic benefits), and problems of adoption by upland farmers in the Philippines of the SALT scheme.

036
A
Lasco, R.D. 1989.
An assessment: alley cropping in Philippine uplands. IESAM Bulletin IX(1) (Jan–Mar): 10–11.

Alley cropping is an agroforestry system which involves planting of hedgerows along the contours and growing agricultural crops in the "alleys" formed between two hedge-

rows. The 1-meter-wide hedgerows are composed of one or two rows of woody perennials and are regularly pruned to prevent shading. The basic idea behind planting hedgerows is to minimize soil erosion by trapping sediment at the base of the hedgerows and reducing surface runoff velocity. After a few years terraces can be formed.

General

037
A
Lasco, R.D. and P.D. Suson. 1993.
A Multipurpose Tree Species (MPTS)-based indigenous fallow system in the Philippines, the Naalad System. Paper presented at the International Symposium on Multipurpose Trees for Rural Livelihood, Manila, the Philippines, 3–6 May 1993.

The Naalad indigenous fallow system is an indigenous alley cropping system. Very limited information is available on how and why the system works. The objective of the study was to document the indigenous practices of the farmers in Naalad villages, Cebu province of Central Philippines. In addition, the effect of the production system on selected soil properties was evaluated. The paper presents the preliminary findings of the study. The production system is discussed with a focus on the role of a multipurpose tree (*Leucaena leucocephala*) on the sustainability of the system. Results of soil analysis are presented and discussed. Initial data show that selected chemical soil properties remain constant over time in both the fallow and cultivated portions of the farm.

General

038
A
Liyange, L.V.K. 1987.
Traditional uses of *Gliricidia* in Sri Lanka. Pages 92–93 *in Gliricidia sepium* (Jacq.) Walp.: management and improvement, edited by D. Withington, N. Glover, and J.L. Brewbaker. Nitrogen Fixing Tree Association (NFTA) Special Publication 87-01, Waimanalo, Hawaii, USA.

Various uses of *Gliricidia sepium* (Jacq.) Walp. in Sri Lanka are reviewed. It is one of the most widely used shade trees and windbreak species in tea plantations. *Gliricidia* also provides shade in many cocoa, coffee, and forest plantations. Other uses include green manure for coconuts and rice, support for pepper vines, ornamental plantings, firewood, living fences, cattle fodder, and rat poison.

General

039
A
Macklin, B. 1988.
An overview of agroforestry systems: A classification developed for extension training. Pages 1–12 *in* Agroforestry land use systems in international agronomy, edited by E. Moore. American Society of Agronomy Annual Meeting, 28–29 Nov 1988, Anaheim, California, Nitrogen Fixing Tree Association (NFTA), Hawaii, USA.

An overview of agroforestry systems is presented and is followed by a classification developed for extension training from 1982 to 1987, during the coordination of the training and extension activities of a national agroforestry program in Kenya. The classification of agroforestry systems that developed from this project was designed to meet the practical needs of trainees in extension work. This system ignores most of the peculiarities of the earlier schemes, but clearly makes land-use options for the farmer. This system is largely based on planting niches on the farm, and, secondarily, on the functional roles of the trees. This classification and the ideas presented have gone through some modification since 1987. The agroforestry systems outlined

are discussed in more detail in subsequent sections. The more important nitrogen fixing tree (NFT) genera for each system are listed at the end of each description, although many non-fixing trees are also useful for these systems.

General

040
A
Mungai, D.N., C.L. Coulson, and C.J. Strigter. 1990.
Economic consideration of alley cropping for food production in semiarid areas. Pages 311–321 *in* Agroforestry for sustainable production: economic implications, edited by R.T. Prinsley, Commonwealth Science Council.

The biological potential of the alley cropping system was evaluated based on preliminary ecophysiological research at the National Dry Land Farming Research Station, Machakos, Kenya from 1987 to 1988. The study involved *Senna siamea* hedgerows and maize. The paper suggests relevant variables for a cost-benefit analysis of the system.

General

041
A
Nair, P.K.R. 1990.
The prospects of agroforestry in the tropics. Technical paper No. 131. World Bank, Washington, DC, USA.

Agroforestry has come of age remarkably during the past 10 to 15 years. However, the lack of a synthesized "package" of technical and socioeconomic information on agroforestry is a serious drawback in channelling development assistance to agroforestry projects. The objective of this report is to fill this gap. By reviewing the scientific information currently available, the report seeks to establish the scientific basis and principles of agroforestry and to evaluate field research on agroforestry practices; it also discusses the economic and sociocultural aspects of agroforestry, as seen by a nonexpert. A comprehensive bibliography is appended to the report. The emphasis in this report is on Africa, but extensive use is also made of experiences from other parts of the developing world to ensure that the report is applicable to all tropical regions. It is addressed primarily to agroforestry practitioners—both foresters and agriculturalists—of the World Bank and similar development-support agencies.

General

042
A
Okigbo, B.N. 1982.
Impact of agricultural systems and rural development on Nigerian forests. Pages 41–45 *in* Agroforestry in the African humid tropics, edited by L.H. MacDonald. The United Nations University, Tokyo, Japan.

Agriculture is still the dominant means of livelihood in Nigeria, even though urban areas are growing rapidly in size and the rural-urban income and services gap is widening. The different types of traditional farms are discussed, with special emphasis on forest-farm interactions. The sequence of agricultural intensification from shifting cultivation to sedentary agriculture in southwestern Nigeria is defined, with special reference to the woody and perennial species of compound farms. Possible alternatives, such as specialized horticulture and animal husbandry, are briefly reviewed with regard to their impact on the tropical rainforest. Recommendations are then made regarding the future course of agricultural development.

General

043
A
Okigbo, B.N. and R. Lal. 1978.
Residue mulches and agrisilviculture in tropical African agriculture. Paper presented at the International Conference on Basic Techniques in Ecological Agriculture held 2–5 Oct 1978, Montreal, Canada.

The forest zone of the lowland humid tropics is the last frontier that, if properly managed, has a potential of meeting the challenge of increased demand for food production and raw materials for industry. The traditional system of bush fallowing, though stable, is fast breaking down under population pressure and shortened fallow periods. Alternative systems of land management must evolve practices that are ecologically sound in controlling erosion, and in maintaining soil fertility and adequate levels of organic matter. In this connection, the role of crop residue mulches cannot be overemphasized. A thin layer of residue mulch protects the soil surface against the impact of rain drops and adds soil organic matter. The principles of mulch-farming techniques can be profitably used for large-scale commercial farming by the use of no tillage techniques and appropriate herbicides to control weeds. A viable alternative for small farmers should also be based on appropriate low-input technology that is efficient in meeting the demands for subsistence and commercial production on small farms. The use of leguminous mulch materials can sustain crop yield while providing adequate protection against soil erosion, and maintaining soil fertility. Agrisilviculture, with the use of suitable trees and arable crops, can be profitably used to produce food crops and restore soil fertility while growing forest trees that can be put to other uses such as timber, firewood (fuel), and animal feed. Priority urgently needs to be given to adaptive research on land-clearing techniques, and use of suitable tree and crop combinations for a range of soils and crops species. Integrated watershed development and soil management for ecologically sound land use takes into account the varying capabilities of different toposequences in producing a range of crops that give optimum yields on a sustained basis. Sustained crop production in the humid tropical environments is possible through techniques of soil management and associated crop production practices that do not cause drastic degradation of the soil and adverse effects on the environment. The potential of crop residues, mulches, intercropping, and agri-silviculture with appropriate techniques for increasing production have not yet been exploited.

General

044
A
Ong, C.K. 1994.
Alley cropping: ecological pie in the sky? Agroforestry Today 6: 8–10.

The paper compares results from a few selected alley cropping experiments in a wide range of environments including highly acidic and nonacidic soils, and low to high annual rainfall. Yields of major crops increased in Ibadan, Claveria, and Kasàma, but only bean yields increased in La Montana (Costa Rica). However, alley cropping affected crop yields in Hyderabad and Machakos, and even reduced crop yields in Yurimaguas where pruning was done only once. The paper identifies some experimental and interpretational problems in most of the compared trials. It also emphasizes the need to select for complementarity in rooting patterns of trees and crops in alley crops, and the need for more research that can be reproduced on farmers' fields.

General

045
A
Osiname, O.A. and J. Tonye. 1994.
Alley farming research at the International Institute of Tropical Agriculture (IITA). Entwicklung und Landlicher Raum 5/94: 31–32.

The paper describes the history of alley farming at the International Institute of Tropi-

cal Agriculture (IITA) from the 1970s. It reviews the benefits of the system for crop production and describes the research focus and future direction in alley farming research at IITA. It stresses that in spite of all the attributes of alley farming, experience shows that the adoption of the system will require a determined extension effort. It therefore concludes that testing of social acceptability of alley farming should, in the first instance, be carried out in areas where deforestation and "savannization" are already in an advanced stage thus creating demand for restoration of soil fertility, soil erosion control, and provision of animal feed and fuelwood. Alley Farming Network for Tropical Africa (AFNETA) Phase II projects are designed to address the issues of farmer acceptability and adoption of alley farming technology.

General

046
A
Raintree, J.B. undated.
Conservation farming with soil-improving tree legumes: farming systems approach to tropical agroforestry. Discussion paper No. 9/80. Agricultural Economics, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 8 pp.

The paper explores the advantages of an alternative bias and attention on a different—and highly promising—branch of agroforestry research and development in arable crop farming with soil improving tree legumes. The discussions are against the background of interwoven problems of declining productivity and stability of smallholder farming systems, the inability of diminishing forest resource systems to keep pace with demand for domestic fuelwood, environmental deterioration from overexploitation of agricultural and forest resources, and a history of low adoption rates for conservation oriented agricultural innovations. The integration of multipurpose leguminous trees into smallholder farming systems is proposed as a system which offers substantial benefits and which simultaneously addresses all the major problems cited. These are achieved through nitrogen fixation, provision of fuelwood and stakes by the trees, and the conservation functions of the trees. Promising techniques for achieving the above goals include planted fallows, alley cropping, and multistorey intercropping. These systems are discussed within the farming systems perspective.

General

047
A
Raintree, J.B. and K. Warner. 1986.
Agroforestry pathways for the intensification of shifting cultivation. Agroforestry Systems 4: 39–54.

Shifting cultivation is one of the most ancient, widespread and, until recently, ecologically stable forms of agroforestry land use systems. However, population pressure coupled with other competing land uses, labor, and traditional shifting cultivation systems tend to undergo more or less predictable processes of intensification. Scientific agroforestry is not, an alternative to shifting cultivation, which is an indigenous form of agroforestry, but rather a systematic approach to improving its basic elements into more intensive, sustainable, and politically viable forms of land use. Different agroforestry options emerge from different stages of land use intensification in shifting cultivation systems. A review of evolutionary typologies of shifting cultivation gives rise to a framework for the identification of agroforestry interventions and development pathways appropriate to specific systems. Technological proposals are limited to a short list of the most promising agroforestry interventions in "main sequence". These include "integral taungya", improved fallows, variations on the alley cropping theme, and various tree-crop alternatives to annual cropping systems. Practical examples and quantitative data are cited as bases for hypothesized proposals.

General

048
A
Rao, M.R. and R. Coe. 1992.
Evaluating the results of agroforestry research. Agroforestry Today 4(1): 4–8.

Under diverse and rapidly changing conditions—particularly socioeconomic conditions—no one evaluation method can give all the answers. An agroforestry system that works well in one location may not be appropriate in another and a system that works well today may not be appropriate tomorrow. In addition, if systems are judged purely according to short-term results, important sustainability aspects may be overlooked. A comprehensive evaluation must consider the economic and social aspects of an agroforestry system, as well as the biological. Such an evaluation requires accurate long-term data. Experiments should be conducted over a minimum of five years—even longer if possible. A shorter experiment not only misses out the long-term potential of an agroforestry system, but also risks inaccurate conclusions due to short-term vagaries of climate. Finally, the difficult task of integrating the effects of soil, climate, and various plant-management options calls for the development of appropriate computerized models. Models could help assess resource capture and utilization, nutrient cycling, the growth and productivity of components, and long-term sustainability. This is an area where considerable work is yet to be done.

General

049
A
Reynolds, L. 1994.
A review of the biophysical and socioeconomic basis of alley farming and its adoption potential. Consultant Report for AFNETA (Alley Farming Network for Tropical Africa). 86 pp.

The report synthesized the biophysical and socioeconomic basis of alley farming, and its adoption potential based on the available results so far. Key findings in the report cover below- and above-ground effects of alley farming, integration of livestock, social and economic factors, tree screening and selection, adoption, future research needs, and institutional arrangements. Below-ground processes have a major influence on the biological impact of alley farming. Nitrogen fixation in mature trees needs quantification in a range of environments, as does the impact of regular pruning on root turnover, nutrient release, and uptake. Mulch decomposition and nutrient release in the soil may be affected by polyphenolic compounds. Interdisciplinary linkages may prove beneficial to understanding these processes. The possibility of growing mixed hedgerows to provide slow and faster decomposing mulch and forage should be investigated. Recommendation on experimental designs and treatments must accommodate the concerns relating to root invasion of control plots, competition, and spacing. Mixed cropping and economic evaluation of benefits must include land equivalent ratios rather than dry matter yields. Alley farming can only enhance soil fertility either with external input or the inclusion of fallows. Fallow studies involving trees will, however, require a longer term commitment than the normal lifetime of a research grant. Livestock research should give attention to factors controlling palatability and post-ruminant digestion. Forage production in alleys will be demanding of soil nutrients, and attention must be given to optimizing the use of manure. AFNETA funding should focus on on-farm research where the national extension service is effective. Below-ground competition and land tenure are given as limitations to the adoptability of alley farming in some areas. Stronger links between AFNETA and the international centers such as the International Institute of Tropical Agriculture (IITA), the International Centre for Research in Agroforestry (ICRAF), and the International Livestock Research Institute (ILRI formerly ILCA) as well as with national systems are advantageous. The international centers should be encouraged to take advantage of their links with AFNETA to access on-farm data to validate predictive biological models, and for microeconomic and social studies.

General

050
A
Rogers, S. 1992.
The potential for alley cropping as a sustainable land-use system in the volcanic islands of the South Pacific. Journal of South Pacific Agriculture 1: 3–10.

The paper reviewed the biophysical and socioeconomic conditions in the South Pacific of alley cropping trials in Africa, Asia, and the Pacific Islands. Maize was shown to be promising in Africa under the alley cropping system; this was due to its nitrophilic characteristics. However further investigations are advocated on the effects of alley cropping roots on crops such as taro (*Colocasia esculenta*) on volcanic soils.

General

051
A
Smith, O.B. and O. Speedy. 1992.
Alley farming and protein banks for tropical Africa. FAO Animal Production and Health paper No. 102: 245–256.
In tropical Africa, crop-livestock integration systems such as alley farming, intensive feed gardens, and fodder banks are used to optimize the use of resources. This paper provides a review of the development of these methods and future research needs.

General

052
A
Ssekabembe, C.K. 1985.
Perspectives on hedgerow intercropping. Agroforestry Systems 3: 339–356.

Alley cropping is a relatively new agroforestry technology involving growing agricultural crops between rows of planted tree species. *Leucaena* is the most widely studied tree species for alley cropping and research has indicated that it can yield over 200 kg N ha/yr. More biomass (and nitrogen) is obtained from narrow alleys. Utilization of nitrogen by crop is improved when prunings are incorporated into the soil before planting. Low pruning heights may reduce shading of the crops. Most of the agronomic aspects of the practice have been investigated in humid lowlands with high rainfall. There is a need to focus research on testing the practice under varied agroecological conditions, and using several suitable multipurpose tree species at a wide range of alley width and plant population. Investigations need to include more than one crop in the alleys, and at different spatial arrangements. Management schedules, like time and frequency of pruning the trees and method of applying the prunings under different ecological conditions, need more research. Studies on competition also need to be undertaken in order to suggest improvements to the practice. In this paper, some of the recent advances on these and other management aspects concerning hedgerow intercropping and areas that need further research are discussed.

General

053
A
Sturmheit, P. 1989.
Alley cropping in southern Zambia: the potential of alley cropping in Mazabuka District. MSc thesis, University of Wales, Wales. 338 pp.

Preliminary results of alley cropping trials conducted in the semiarid to subhumid transition zone of southern Zambia as well as findings from Kenyan and Nigerian investigations led to the development of a simulated *Cassia siamea*/maize based alley strip cropping system which combines elements of alley cropping with those of shelterbelts. Widely spaced multiple hedgerow zones are clipped only once annually during the slack labor period and are trimmed as low shelterbelts. This is to minimize

the percentage of crop border rows, the risk of storm damage, labor for tree pruning as well as erosion induced soil loss. The profitability of this system, of the existing sole-maize cropping system as well as that of the indigenous *Faidherbia albidal* maize agroforestry system has been assessed by means of cost-benefit analysis. The environmental advantages of soil erosion induced nutrient losses were costed in terms of replacement fertilizer. At low- discount rates, the indigenous *Faidherbia* based system is the most profitable option. At discount rates in excess of 10, alley strip cropping maximizes returns to land and labor. On sloping land, both agroforestry systems are far more profitable than the existing maize monocropping practice. Profitability is further enhanced by physical soil conservation measures. In conclusion, a combination of alley strip cropping with interspersed *Faidherbia albida* trees could provide optimized profitability over the whole range of tested discount rates. Security of land tenure for all members of the community, including women and extension workers, must be guaranteed if the above agroforestry option is to stand a chance of adoption. Furthermore, successful rural development requires holistic as opposed to current sectoral approaches, and target group participation in decision making and formulation of policies must no longer be neglected. More detailed investigations of soil ameliorating agroforestry systems under local field conditions are called for, and a research program for such investigations is outlined.

General

054
A
Sumberg, J.E. and A.N. Atta-Krah. 1988.
The potential of alley farming in humid West Africa: a reevaluation. Agroforestry Systems 6: 163–168.

This paper reexamines the previously published hypothesis regarding the potential impact of alley farming on maize yields in the humid regions of West Africa. When more realistic assumptions regarding the availability of organic nitrogen are used, it is evident that alley farming may have potential in a wider range of maize yield environments in West Africa than previously proposed. A more pragmatic approach to alley farming research is proposed, and the importance of on-farm alley farming research is stressed which will make the system more farmer friendly.

General

055
A
Ter Kuile, C.H.H. 1983.
Farming in the tropics. The Courier 82: 53–56.

The activities of the farming systems program of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria from inception is reviewed in this paper. It provides an insight into what informed the decisions and research directions of the Institute. This includes a realization that the concentration on the improvement of one or two crops by genetic and agronomic means would not be effective for the regions for which IITA would be responsible. The answer also lies in the management of soils and the organic residues of plants growing on these soils. This would mean imitating as closely as possible the original forest system. A number of alternative systems that prevent or delay the breakdown of soil productivity developed by the IITA farming system program are highlighted. They include the no-till system, alley cropping, mulching, multiple cropping systems, and research on black sigatoka diseases of plantains and cooking bananas. The development of on-farm adaptive research (OFAR), in which IITA will play a key role in the development of methodologies and training, is discussed.

General

056
A
Toledo, M.J. and F. Torres. 1990.
Potential of silvopastoral systems in the rainforest. Pages 35–52 *in* Agroforestry land-use systems, edited by E. Moore. Proceedings of a Special Session on Agroforestry Land Use Systems in International Agronomy, American Society of Agronomy Annual Meeting, 28–29 Nov 1988, Anaheim, California. Nitrogen Fixing Tree Association (NFTA), Hawaii, USA.

Grazing animals, mainly cattle and sheep, are important components of the agricultural production systems in rainforest areas. Dwarf sheep and goats are common in the humid zone of Africa as sources of meat and income. Carabao (water buffalo) and cattle are the main draft force in crop (mainly rice) production systems in southeast Asia, where grazing under plantations for beef production is also common. Given the high cattle population and high demand for beef and milk in tropical America, ranching for cattle production in the humid tropics has been expanding in the Brazilian Amazon and in Central America. Also, small farmers after clearing the forest for crop production move on to mixed farming systems incorporating cattle as a way of generating income. The main problem of cattle ranching and mixed farming in the rainforest areas is the lack of sustainability of production systems. Open pastures under the existing technology rapidly degrade the land, increasing pressure for further deforestation. The paper discusses the possibilities and potential of integrated tree-pasture systems on rain forest lands as a means of developing sustainable production systems. Examples of a spontaneous low stocking silvopastoral system (grazed tree plantations) occurring in southeast Asia, as well as experience with multipurpose trees (fence-shade-crop-fodder) in tropical America are presented. Research results on the interaction between trees and pastures, and trees and grazing animals in silvopastoral systems; and on the shade tolerance of grasses and legumes are presented. The socioeconomic and biological constraints for the development of integrated silvopastoral systems are discussed. Finally, suggestions for future research are presented.

General

057
A
Torres, F. 1983.
Role of woody perennials in animal agroforestry. Agroforestry Systems 1(2): 131–163.

Woody perennials have two main roles in agroforestry: the productive one where woody perennials yield a material output (fuel, fodder, etc.), and the "service" type, with no tangible product (shelter, nutrient recycling, etc.). In their productive role, trees and shrubs may supply fodder in browsing systems, or industrial material, wood products, and food in forest and plantation grazing systems. Service roles are often linked with productive ones and arise mainly from relationships between woody perennials and herbaceous vegetation growing in the vicinity. The relatively low productivity and palatability of high protein content foliage from most woody perennials would indicate a supplementary role as a fodder source, particularly during dry seasons in arid and semiarid zones. In these areas, pod-bearing trees seem to have a greater potential for improving fodder production in silvopastoral systems. The adverse effect of trees on pasture production in forest and plantation grazing is compensated by their contribution to the system through other products. Certain species of woody perennials have the potential to foster pasture growing underneath, mainly through soil enrichment. Windbreaks can also indirectly benefit pasture growth, by decreasing waterloss from the soil. It is postulated that research efforts focused on woody perennials particularly on pod-bearing trees for browsing systems in animal agroforestry, have beneficial effects on the herbaceous layer growing underneath.

General

058
A
Tothill, J.C. 1987.
Application of agroforestry to African crop-livestock farming systems. ILCA Bulletin 29: 20–23.

The value of tree legumes and constraints to their production in the different agroecological zones of Africa are assessed. Considerable research effort is required to solve the problems of germplasm availability and adaptation. Management issues, such as the identification of suitable entry points, are emphasized as the key factors determining the contribution of woody legumes to African farming systems. Depending on ecological conditions and the farming system, different management strategies can be adopted, including alley or terrace farming, fodder banks or intensive feed gardens, compound planting, and plantation farming.

General

059
A
Watson, H.R. and W.A. Laquihon. 1987.
Sloping agricultural land technology: an agroforestry model for soil conservation. Pages 209–226 *in* Agroforestry in the humid tropics: its protective and ameliorative role to enhance productivity and sustainability, edited by N.T. Vegara and N.D. Bariones. Environment and Policy Institute, USA.

The Mindanao Baptist Rural Life Centre (MBRLC) developed and spread the agroforestry system termed "sloping agricultural land technology" (SALT) to help the small hillside farmers of Mindanao. The model has been tested both in demonstration and farmers' plots and has proved to be an appropriate land-use system, which the farmers can adopt to conserve their farms' topsoil and at the same time to generate steady income. The model's development from its initial conception to the present status is detailed in this discussion.

General

060
A
Wilson, G.F. 1981.
Towards improved cropping systems for the humid tropics. Pages 239–246 *in* Proceedings of the Third Research Planning Conference on Rootknot Nematodes, *Meloidogyne* spp., 16–20 Nov 1981, IITA, Ibadan, Nigeria.

In the humid tropics, food production has lagged behind population demand because research efforts have failed to identify and solve the problems limiting production increase. Previously, research emphasized the testing of improved technologies developed for temperate regions in the tropics. Presently, emphasis has shifted to a better understanding of the indigenous cropping systems with a view towards understanding the underlying principles and developing practices which enhance productivity. In-situ mulch appears to be a potential alternative to green manuring. Alley cropping as an improved bush fallow system may provide rapid soil restoration under reduced fallow periods. Its effect in producing stakes and firewood offers promise to those areas where deforestation threatens fuel supply and environmental stability. The exploitative efficiency of locally evolved crop combinations should be developed along with other combinations developed to suit new technologies and demands.

General

061
A
Wolf, G.W. 1994.
Multipurpose trees and aspects of their yield evaluation for agroforestry. Plant Research and Development 40: 88–109.

Multipurpose trees and shrubs (MPTS) are important in agroforestry systems, as they not only yield numerous products such as timber and fuelwood, fruits, animal fodder, medicines and poisons, fibers, rubber, tannin agents and mulch, but may also perform specific protective and soil amelioration functions. Research on MPTS is still inadequate and over 2000 tree and shrub varieties need to be scientifically evaluated with regard to their potential for use in agroforestry systems. There are few methodological approaches and guidelines to assess the applicability of agroforestry interventions proposed to farmers due to the relatively short history of agroforestry and the use of MPTS in development. The continued acceptance of such practices by farmers makes it imperative to disseminate methods and data that can help to evaluate the economic and ecological benefits of MPTS. This paper summarizes parts of research work, that aims to contribute to the objective evaluation of product-specific MPTS yields in the context of locally used agroforestry practices.

General

062
A
Young, A. 1989.
Agroforestry for soil conservation. CABI, Wallingford, UK. 276 pp.

The book reviews the potential of agroforestry to contribute to soil conservation, summarizes the present state of knowledge, and suggests the needs for research. It concludes that appropriate agroforestry systems have the potential to control erosion, maintain soil organic matter and physical properties, and promote efficient nutrient cycling.

General

063
A
Zimmermann, T. 1986.
Agroforestry: a last hope for conservation in Haiti. Agroforestry Systems 4: 255–268.

Haiti is one of the poorest countries in the world and the poorest in the western hemisphere. Severe structural problems have characterized its economy, and the gap between rich and poor is extremely wide. In 1983 the per capita income was US$ 315, and only about $50 in the rural areas where many people live on the edge of starvation. Indices such as illiteracy, infant mortality, and life expectancy are the worst in the hemisphere. The country's external dependence has been compounded by prolonged drought conditions since the mid-1970s and much of the population depends on food aid. Several aid organizations have concentrated their efforts on reforestation programs with small farmers in the last few years. Some programs are directed towards production of fuelwood and timber as a source of cash income; while others propagate agroforestry as one possible solution to soil conservation and sustainable agricultural productivity. The author has worked in Haiti since 1983 as a technical consultant to local Caritas organizations working with many small groups of farmers engaged in agroforestry and soil conservation activities. The primary goal is to arrest the process of hillside erosion, devise new ways to prevent loss and degradation of agricultural land, make more efficient use of rainwater, and so promote self-reliance in producing basic food crops in the country.

General; Hedgerow Species

064
AB
Kwesiga, F.R. 1990.
The potential of *Sesbania sesban* in the traditional land use systems in Zambia. Pages 131–138 *in* Perennial *Sesbania* species in agroforestry systems, edited by B. Macklin and D.O. Evans. Nitrogen Fixing Tree Association (NFTA), Special Publication 90-01, Waimanalo, Hawaii, USA.

Sesbania sesban is widely distributed in the flood plains of Chambeshi, Banguela, Kafue Flats, and many other depressions and river valleys in Zambia. However, the potential of *S. sesban* in the traditional land-use system of Zambia has not been exploited. This is mainly due to lack of information by potential users, inadequate research on the species, and the fact that most farming activities occur on the upland plateau where *S. sesban* is not widely distributed. Recently, research has been initiated to study the potential of *S. sesban* for fodder, mulch, and firewood production, and improvement of soil fertility under agroforestry systems such as planted fallows and alley cropping. This paper is intended to review the land-use systems in Zambia where *S. sesban* may have some relevance. Finally, preliminary data on growth performance of *S. sesban* after one year of investigation at Msekera Regional Research Station are presented.

General; Hedgerow Species; Soil Fertility

065
ACF
Fernandes, E.C.M, D.P. Garrity, L.T. Szott, and C.A. Palm. 1994.
Use and potential of domesticated trees for soil management. Pages 137–147 *in* Tropical trees: the potential for domestication and the rebuilding of forest resources, edited by R.R.B. Leakey and A. Newton.

The ancient and widespread use of tree and bush fallows to restore soil productivity following several years of cropping has resulted in research aimed at identifying, planting, and managing trees for soil improvement. The goal is either to reduce or eliminate traditional fallow periods (usually 4–25 years) using soil-improving trees that are managed together with crops or pasture species (agroforestry). Commonly used trees include *Dactyladenia barteri, Calliandra calothyrsus, Senna reticulata, Erythrina poepigiana, Faidherbia albida, Gliricidia sepium, Inga edulis, Leucaena leucocephala, Prosopis cineraria,* and *Sesbania sesban.* Several of these species constitute major foci of genetic improvement programs to improve soils. This paper synthesizes the research data from work on acid and high base status soils in the humid, subhumid, and semiarid regions of Central and Latin America, Africa, and Asia and evaluates critically the tree-soil improvement hypothesis related to nutrient cycling, organic matter additions, and N-fixation. These hypotheses are discussed in the context of developing domestication strategies for multipurpose species taking into account the influence of the species on the environment.

Crop Production; General

066
AD
Fluery, J. 1985.
Trees take to the fields. The IDRC Reports 14: 18–19.

Alley farming—growing crops between rows of frequently pruned leguminous trees—offers a promising alternative to the traditional bush fallow system for maintenance of soil fertility in the humid and subhumid tropics. Work at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, has demonstrated that alley cropping can maintain crop yields at moderate levels without fertilizer. In addition, the prunings can be used as feed for small ruminants, particularly in the dry season, when their reproduction and growth may be limited by protein deficiency. There are 26 million sheep and goats in West Africa; they make an important contribution to the diet of the region's inhabitants, many of whom suffer from malnutrition. In 1981, a nursery of 20

species from the Forestry Research Institute of Nigeria was established. Treatments designed to exploit the different strengths of each species were developed, but to date no species has shown the vigor or desirable growth habit of either *Leucaena* or *Gliricidia*. As a result it has been decided to concentrate on *Leucaena* and *Gliricidia*, and a small evaluation trial of 46 locally collected lines of *Gliricidia sepium* has been started. Maize yields were 2.2 t/ha in the continuous maize plots, 2.5 t/ha in the continuous alley cropped plots, and 2.6 t/ha in plots in which maize was rotated with grazing in between the *Leucaena* rows. The *Leucaena* contributed a total of 155 and 178 kg N/ha in the two alley cropped treatments, respectively. A nitrogen response trial, also established in 1983, will provide a base from which to estimate the fertilizer replacement value of the *Leucaena* prunings.

Alfisol-
Crop Production-
Soil Fertility-
General

067
ADF
Kang, B.T., G.F. Wilson, and T.L. Lawson. 1984.
Alley cropping: a stable alternative to shifting cultivation. International Institute of Tropical Agriculture, Ibadan, Nigeria. 22 pp. (French and Spanish editions available.)

Although bush fallow and shifting agriculture provide only a subsistence living, it is ecologically stable and therefore suited to the tropical environment. Unfortunately, most programs for improving agriculture in the tropics have tried to remove components of the bush fallow system, replacing them with destabilizing temperate climate farming methods. Alley cropping is a stable alternative to the bush fallow system. It retains the basic principles and components of traditional agriculture while introducing important improvements. In the traditional system, trees and shrubs are grown in a random mixture, but in alley cropping they are planted in an organized system which makes continuous cultivation of food crops possible. Biological recycling of nutrients and soil conservation, suppression of weeds, and rapid production of by-products such as stakes and firewood are major advantages of alley cropping. Where firewood has become scarce as a result of increased demand for land for crops and livestock production, alley cropping or alley farming offers a means of combining crops and/or livestock with firewood production. Research at IITA on alley cropping has led to the development of the following alley cropping systems: (1) the *Leuceana/Gliricidia*/maize/cowpea alley cropping system, (2) the *Leucaena*/maize/yam alley cropping system, and (3) by integrating *Leucaena* and *Gliricidia* alley cropping with livestock production, the International Livestock Centre for Africa (ILCA) has developed alley farming, a promising small-ruminant production system for the humid region of Africa. Intensive work with alley cropping has been done on the high base status or less acidic Alfisols and associated Inceptisols and Entisols. More research is in progress on the low base status and acidic Ultisols. Suitable tree and shrub species (particularly legumes) have yet to be identified. Promising species such as *Gmelina arborea, Acioa barteri, Flemingia congesta, Alchornea cordifolia*, and others are being tested on acid soils (Typic Paleudult) at IITA's high rainfall substation at Onne. As a biological low input production system, alley cropping should be a preferred production technique in developing countries where shortages of foreign exchange prohibits the importation or use of large quantities of inputs such as fertilizers and pesticides.

Crop Production-
Livestock
Production-
General

068
ADI
Kang, B.T. and L. Reynolds. 1988.
Alley farming: its potential for humid and subhumid tropics. Pages 99–120 *in* Agroforestry for food and wood production, edited by J.O. Adegbehin. Agricultural Extension and Liaison Services, Ahmadu Bello University, Zaria, Nigeria.

The traditional shifting (and related bush fallow-slash and burn) cultivation system is biologically a stable production system when adequate land is available. However, increasing land pressure due to rapid population growth and other land uses has made long fallow periods unattainable and so destablized the system. Rapid increase in food, feed, and household fuel demands have resulted in increasing deforestation in West Africa, including Nigeria. The alley farming system has been shown to be an alternative and potential alternative for modernizing the less productive traditional systems, particularly for food and browse production. Observations over a number of years on Alfisols and related upland soils in southern Nigeria have shown that continuous alley farming of food crops with *Leucaena* and *Gliricidia* is feasible. The system can sustain crop yield, maintain soil productivity with low levels, conserve the soil, and suppress weeds. In addition, the system can provide much needed browse throughout the year, staking materials, and firewood. Investigations are still underway to identify suitable species for alley farming on Ultisols, Oxisols, and related soils. Results of on-farm trials in Nigeria have shown that the alley farming system is readily accepted by farmers in areas where there is a need for either the entire package or some of its components. Technology transfer and adoption of the system in Nigeria need to be promoted. Adoption of the technology can assist in increasing food and livestock production and reduce the problem of deforestation and land degradation.

Crop Production-
Livestock
Production-
General

069
ADI
Kang, B.T., L. Reynolds, and A.N. Atta-Krah. 1990.
Alley farming. Advances in Agronomy 43: 315–359.

Increasing demand for food and feed has resulted in rapid deforestation and land degradation in many parts of the tropics. In sub-Saharan Africa, food production relies mainly on area expansion and the use of traditional farming methods that depend on inherent soil fertility. Alley farming research was developed in the 1980s as a low input and sustainable food production package for smallholder farmers. Alley farming involves the cultivation of food crops between hedgerows of multipurpose trees. The use of woody legumes provides N-rich mulch and green manure to maintain soil fertility and enhance crop production, and protein-rich fodder for livestock. On sloping land, hedgerows planted along the contours have been shown to greatly reduce soil erosion within the forest zone, and particularly in the forest-savanna transition areas of Africa with nonacid soils. In addition, on-station and on-farm trials have shown that alley farming with *Leucaena* and *Gliricidia* allows a higher level of production than the traditional system. Similar results have also been obtained in comparable agroecological zones in Asia and the Pacific regions.

Crop Production-
Livestock
Production-
On-Farm Rsearch-
General

070
ADIM
Kang, B.T. and L. Reynolds. 1989.
Alley farming in the humid and subhumid tropics. International Development Research Centre (IDRC), Ottawa, Canada. 251 pp.

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 tech-

nology, 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 from 10 to 14 March 1986. 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. Twenty-four papers were presented at the workshop. This book reviews the present state of alley farming systems, highlights training and research needs, and proposes the establishment of channels for collaborative research.

Competition; Fallowing; General

071
AEF
Huxley, P.A. 1986.
Rationalizing research on hedgerow intercropping: an overview. Working paper No. 40. International Centre for Research in Agroforestry (ICRAF), Nairobi, Kenya.

The paper discusses some of the background issues to the plant-environment interactions that affect hedgerow intercropping in particular, and agroforestry in general, putting forward various sets of conclusions that indicate where critical research problems lie. Hedgerow intercropping is one form of zonal agroforestry in which plant residues (from the hedge) are utilized to sustain crop production. Some comparative examples from tropical agricultural research are given of the effect on crop yields of applying organic matter to the soil. The need to maintain a balance of soil available nutrients is emphasized. In many systems this has involved using some fertilizers. Relatively large and consistently applied amounts of plant residues are usually needed in order to improve the normally measured soil chemical and physical parameters. A summary of three extensive reviews of tree planting in the tropics is given. These highlight the fact that continuous cropping on most tropical soils brings about long-term soil deterioration. Tree clearing can cause major problems, but even in the maximum production phase nutrients are lost from the system. Any kind of cropping which removes a high proportion of the plant biomass can degrade soils. However, hedgerow intercropping in high rainfall areas (1000 mm/yr) and in reasonably fertile soils (Alfisols) does, so far, appear to maintain crop yields. It is suggested that we need to know more about the short-term environmental effects of using plant residues that can help bring this about if we are to be able to extend the practice to other environments. In dry regions, hedgerow intercropping may have an important function in preventing soil erosion and rainfall runoff. Hedgerow intercropping can certainly be seen as a potential alternative to shifting cultivation or degraded cropping systems in the tropics. It can further evolve to a system whereby alley cropping alternates (with no removal of the hedgerow plants) with a rotational tree plot phase; the latter functioning mainly as a soil fertility restorer. There are, indeed, numerous possibilities, including having hedgerow intercropping *sensu stricto*, or rotational alley cropping, or either, with a litter-forming higher canopy leading eventually, of course, to designed multi-strata systems. "Prototype" research on these possibilities is also seen to be required, but it will only be effectively carried out when we understand more fully some of the ways in which the components in the system interact and we have clearly identified the processes by which environmental resource-sharing can be optimized, both by selection of species with appropriate characteristics, and by suitable management practices. Without this knowledge the design and management of hedgerow intercropping schemes (or any agroforestry scheme) reverts to a process of trial and error.

General; Soil Fertility

072
AF
Adiningsih, J.S., M. Sudjadi, and S. Rochayati. 1988.
Organic matter management to increase fertilizers' efficiency and soil productivity. Paper presented at ESCAP/FAO/TCDC Regional Seminar on the Use of Recycled Organic Matter. Guangzhou, Chengdu, 4–14 May 1988. Centre for Soil Research, Agency for Agricultural Research and Development, Bogor, Indonesia. 28 pp.

There is a tendency for production to level off while maintaining self-sufficiency in rice and increasing production of other food crops. Imbalanced fertilization and decreasing efficiency in the use of fertilizers due to improper soil management are assumed to be one of the main causes of this phenomenon. Soil is a living system that needs to be managed properly through organic matter management to increase the efficient use of fertilizers and to maintain its productivity. Incorporation of rice straw consistently increased yield, N and P fertilizer efficiency, and soil fertility level and reduced the need for K fertilizer and maintained a high yield. The use of *Sesbania rostrata* and *Azolla* as organic matter sources on lowlands had good prospects in increasing soil fertility. Organic matter management on upland soils showed that the use of crop residues, green manures, and *Imperata cylindrica* could increase fertilizer efficiency, reduce the need for lime, and improve soil fertility. Alley cropping is one of the low-input technologies to increase the soil productivity of upland soils. This technology should be introduced to the farmers while its economic impact needs further study. Organic matter management should be the first general policy before increasing sources and rates of fertilizer application. The use of integrated organic matter and inorganic fertilizers is the best method to increase fertilizer efficiency and soil productivity while maintaining high yield.

General; Soil Management

073
AF
Kang, B.T., M.P. Gichuru, N.R. Hulugalle, and M.J. Swift. 1971.
Soil constraints for sustainable upland crop production in humid and subhumid West Africa. Pages 101–112 *in* Soil constraints on sustainable production in the tropics. Tropical Agriculture Research Center, Tsukuba, Japan, Series No. 24.

Major upland soils in the humid and subhumid zones of West Africa consist of low activity clays (LAC), Alfisols, Ultisols, and Oxisols. Alfisols, which are less leached and have a high base saturation, are more dominant in the subhumid zone. Chemically, they are more fertile but they have a low structural stability. The Ultisols/Oxisols, which are more prevalent in the humid zone, are less fertile with major nutrient and acidity constraints. The major constraints to sustainable crop production on these soils can be removed by proper seedbed and residue management, and by judicious fertilizer application and liming amendments. These measures are needed to ensure the maintenance of adequate chemical, physical, and biological fertility of the soils. Prototype technology research in West Africa that seeks to improve productivity and sustainability on these LAC soils has shown that minimum tillage and/or alley cropping are promising technologies for managing these soils. Further research is still needed to refine these systems and to identify alternative systems for the region.

General; Soil Fertility

074
AF
Mongoy, K. and I.O. Akobundu. 1992.
Agronomic and economic benefits of N contributed by legumes in live-mulch and alley cropping systems. IITA Research 4: 12–16.

In efforts to evolve sustainable agriculture for Africa, live-mulch and alley cropping systems are being studied as alternatives to the traditional bush-fallow system. The

improved systems offer several benefits in which nitrogen provided by leguminous trees is known to play a key role. This article excerpts findings from several years of research on the agronomic and economic benefits accruing in this manner. The success of the improved systems is based on biological processes that use renewable resources to sustain food production, with little or no purchased inputs.

General: Soil Fertility

075
AF
Pellek, R. 1992.
Contour hedgerows and other soil conservation interventions for hilly terrain. Agroforestry Systems 17: 135–152.

In the tropical world, the management of hillside cropland is a critical issue due to the extremely high pressure on the land resulting from the decision to farm the marginal lands. The contour hedgerows and other soil conservation techniques could be more effective if they were aligned in such a way that the land capability potential in various sectors of typical catenas could be maximized; and if biological control crops including trees, shrubs, and grasses were spatially arranged to maximize their intrinsic biological potential of the edaphic dissimilarities of steep hillsides. Spatial arrangements of annual and perennial crops in natural geosequences are discussed in terms of how to match crop mixes of trees, shrubs, and grasses in order to reduce soil erosion and better protect the environment. Land-use planning on a physiographic and soil capability basis is proposed. Effective implementation, however, is subject to a determined campaign for sound land management and the provision of technical assistance to rural farmers by demonstrating the concepts and interpreting the results of the practices. Certain aspects of physiographic and edaphic similarities and constraints of rural farming practices on steep slopes are explored in this paper. Some theoretical bases upon which hedgerow technology can be applied to improve water and plant relations, ameliorate environmental effects, and be initiated by individual farmers at little cost are discussed. Examples of other soil conservation or agroforestry techniques used in Haiti are described. and a simple model to determine the amount of soil saved is provided, The possibility of teaching the methods to minimally trained field technicians is explored, and the need for farmers to give greater attention to the value of soil conservation and proper land use planning is discussed.

General: Nitrogen Fixation Soil Fertility

076
AF
Sanginga, N. 1988.
Nitrogen fixing trees in agroforestry: biological nitrogen fixation and contribution to soil fertility. Essay submitted for an International Institute of Tropical Agriculture (IITA) Award. IITA, Ibadan, Nigeria. 50 pp.

The essay discusses some aspects of biological nitrogen fixation of trees especially in relation to its contribution to soil fertility and improvement of a companion or a subsequent crop in tropical areas of Africa. Brief comments are made on some problems and some future research needs in the management of nitrogen fixation by N-fixing trees (NFT) and the essay demonstrates that only a few studies deal with tree N-fixing systems that can be used in agroforestry. While the principles and methods learned from work with annual legumes may be used, there are many special problems to be considered in studying NFT. There are, for example, the great heterogeneity of *Rhizobia/Frankia* and variations in the N-fixing activity throughout the year and the whole life of the trees. Further studies are to evaluate this genetic variation between and within species of NFT and screening of their nodulation ability with *Rhizobia/Frankia*. This will facilitate the choice of the systems which deserve N-fixing investigation together with other extensive physiological and ecological studies. Environmental factors on fixation have obvious important consequences. It is appropriate to further examine soil factors such as the ones cited above, in order to appreciate the critical steps being affected. The measurement of nitrogen fixation in the field

and questions such as the rate of nitrogen availability to associated plants are important areas requiring research priority. Methods such as N balance studies, difference method, 15N gas, and acetylene reduction assay of nitrogenase activity have serious shortcomings in field conditions. Techniques such as 15N dilution methods and the use of 15N natural abundance have a particular attraction with perennials but these have to be developed. The foundation for assuming that agroforestry, e.g., alley cropping systems, can lead to a steady state of soil lies in the observation that three fallows build up soil fertility, as demonstrated by systems of shifting cultivation. This counteracts the decline in fertility under continuous cultivation of annual crops. We have indicated that current research in agroforestry suffers from an overemphasis on the pragmatic approach at the expense of an understanding of basic processes. Some aspects of the favorable effects of trees on soils are well known, and what is required is the application of this knowledge through pod land use planning and management. Other aspects, particularly some of the key relationships between tree litter (above and below ground) and soil biological processes, require further research. If some of the basic hypotheses given by tropical soil biology and fertility (TSBF) can be proven, then there are considerable opportunities for applying such knowledge to practical land development, often with relative low-cost inputs.

General: Fertilization

077
AF
Szott, L.T. and D.C.L. Kass. 1993.
Fertilizers in agroforestry systems. Agroforestry Systems 23: 157–176.

This paper reviews the results of fertilization experiments on several agroforestry systems—alley cropping, perennial shade systems, home gardens. Fertilizer response was found to be most common in alley cropping, variable in perennial shade systems, and rarely reported in home gardens. The level of nutrient removal in harvested products is probably the major determinant of fertilizer response. Greater accumulation of organic residue, slower growth under shade, and longer periods of nutrient uptake also contribute to the relatively smaller fertilizer response of the perennial shade systems and home gardens. Considerable knowledge gaps exist regarding the breakdown of organic residues and interactions between mineral and organic amendments. Systems based on annual crops (e.g., alley cropping) are likely to be less nutrient efficient and sustainable than systems based on perennial crops due to reduced fixation and transfer of N to the crops. The fact that trees may compete for and sequester nutrients, the relatively high P requirements of the crops, and the high labor cost of tree management are additional constraints. The relative advantages of including low-value tree legumes, high-value shade trees, and fertilization in shaded perennial systems are only recognized in research.

Fodder: General

078
AH
Ivory, D.A. 1990.
Major characteristics, agronomic features, and nutritional value of shrubs and tree fodder. Pages 22–38 *in* Shrubs and tree fodder for farm animals, edited by C. Devendra. International Development Research Centre (IDRC), Ottawa, Canada.

Shrubs and trees, particularly leguminous species, are increasingly being used to provide a strategic source of high-quality forage for supplementary feeding to farm animals. This paper reviews research aimed at identifying suitable species for forage and other multipurpose uses. Research has concentrated on evaluating species adaptation to various climatic and edaphic conditions, defining optimum cutting and grazing strategies, defining fertilizer requirements, developing systems for the use of trees as forage and for other uses, and assessing the nutritive or feeding value of tree

and shrub species. Areas for further research on these various aspects are suggested.

Forage Production, General

079
AH
Okali, C. and S. Berry. 1985.
Alley farming in West Africa in comparative perspective. Discussion paper No. 11. African-American Issues Center, Boston, Massachusetts, USA. 17 pp.

The paper examines the ways in which leguminous fodder trees are likely to be incorporated into existing farming systems in the humid zone of West Africa. Leguminous trees have multiple uses and may be combined with crop and livestock production in a variety of ways. Because of this flexibility, it is difficult to capture the likely effects of leguminous trees through standard techniques of monitoring and evaluation which treat technology as a simple flow of inputs and outputs. The paper also considers the prospects for leguminous trees in terms of farmers' access to land and labor, and the social organization of mixed farming enterprises, as well as the technical requirements of tree cultivation. To do this, existing reports of on-farm research with leguminous fodder trees in southern Nigeria and the literature on other tree crops—such as cocoa, coffee, kola, and oil palm—in the humid zone of West Africa were consulted. The leguminous trees discussed differ from trees such as cocoa in their fast-growing features. In subsequent sections, the details of three models using leguminous trees—alley farming, specialized feed lots, and alley grazing—are presented and examined in the light of the experience already gained with farmers in southern Nigeria. Finally, leguminous trees are compared with other tree crops, in terms of tenure and labor arrangements, and issues warranting further investigation in ongoing experiments with leguminous trees are suggested.

Extension, General

080
AI
Parera, V. 1989.
The role of *Leucaena leucocephala* in farming systems in Nusa Tenggara Timur, Indonesia. Pages 143–153 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. Proceedings of an international workshop held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 10–14 Mar 1986. International Development Research Centre (IDRC), Canada.

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 practised 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 1970s 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.

Auxiliary Products: General

081
AJ
Masai, J. 1988.
Trees, people, and sustainable development agroforestry in western Kenya. CIAFA News 2(1): 3–8.

Agroforestry interventions, which are being extended to the rural landowners of the area in the hope that they will adopt them, and management practices are presented. These interventions include alley cropping, woodlots, border planting, live fences, windbreaks, hedgerow terracing, fruit orchards, and fodder crop intervention. The three tree management techniques (agrosilvicultural practices) applied in the area to meet their basic needs include coppicing, pollarding, and side pruning. The needs of local communities in western Kenya for woody biomass are starting to be met by the successful application of agroforestry systems.

Economics: General

082
AK
Walker, T.S. 1987.
Economic prospects for agroforestry interventions in India's SAT: implications for research resource allocation at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Resource Management Program Economics Group Progress Report No. 79. 53 pp.

The economic prospects for agroforestry interventions in India's semiarid tropics (SAT) were evaluated with regard to (1) the importance of existing agrofrestry systems, (2) the scope for synergistic tree-crop interactions, (3) the potential of perennial/annual intercropping land use systems, and (4) alternative land uses. Across agroforestry systems and/or interventions in India's SAT, present economic importance and the scope for tree-crop interactions are inversely related. Systems that are now important have a low potential for tree-crop interaction; systems with potential for such interactions are not now sown extensively by farmers. Emerging experimental evidence indicates narrowly spaced alley conventional field cropping systems in India's SAT. The demand for fodder is increasing, and fodder is the end use that meshes best with the International Crops Research Institute for the Semi-Arid Tropics' (ICRISAT's) present mandate. The economic prospects for agroforestry interventions are not sufficiently bright to warrant the core funding of a separate program unit to conduct and integrate agroforestry research. Several of the more promising agroforestry themes that are also more in tune with ICRISAT's crop and area mandates can be accommodated within the existing or proposed research units within the Resource Management Program. Priority areas for economic investigation include interdisciplinary research on the estimation of production possibility curves for tree and crop species combinations, an evaluation into the consequences of the rapid diffusion of farm forestry systems, an inquiry into why tree fodder markets have been so slow to develop, and an assessment of the demand for *Leucaena*.

MULTIPURPOSE WOODY SPECIES

Species: Evaluation

083
B
Amara, D.S. 1987.
Evaluation of *Gliricidia sepium* for agroforestry in Sierra Leone. Pages 135–141 *in Gliricidia sepium* (Jacq.) Walp.: management and improvement, edited by D. Withington, N. Glover, and J.L. Brewbaker. Nitrogen Fixing Tree Association (NFTA) Special Publication 87-01, Waimanalo, Hawaii, USA.

Agroforestry has been identified as a possible alternative to shifting cultivation. Studies on *Gliricidia sepium* have shown that this tree legume has potential for use in

agroforestry in Sierra Leone. The paper highlights results obtained from field evaluation on growth, nodulation, and leaf decomposition of several provenances of *Gliricidia sepium*. The ILG 52, ILG 63, and Njala local (NLG '0') provenances consistently combined good growth and high yield. Possible fodder provenances include HYB (High Yielding Bulk), ILG 58, and ILG 59. ILG 52 and NLG '0' have both firewood and fodder qualities. The proportion of plants nodulated ranged from 17% to 83%. Nodulation was improved by P fertilizer application.

Species Evaluation

084
B
Atta-Krah, A.N. 1987.
Flowering and seed production of *Gliricidia sepium*. Pages 142–145 *in Gliricidia sepium* (Jacq.) Walp.: management and improvement, edited by D. Withington, N. Glover, and J.L. Brewbaker. Nitrogen Fixing Tree Association (NFTA) Special Publication 87-01, Waimanalo, Hawaii, USA.

The paper presents results of preliminary studies on basic flowering and seeding characteristics of *Gliricidia sepium*. In West Africa flowering occurs during the dry season. Poor regeneration in natural stands is considered to be due to death of seedlings that face erratic rains in the early rainy season. Several studies indicated that pruning trees at various times delayed flowering and reduced seed yields.

Species Evaluation

085
B
Atta-Krah, A.N. 1987.
Research on *Gliricidia* germplasm evaluation and improvement in West Africa. Pages 146–161 *in Gliricidia sepium* (Jacq.) Walp.: management and improvement, edited by D. Withington, N. Glover, and J.L. Brewbaker. NFTA Special Publication 87-01, Waimanalo, Hawaii, USA.

Collection, evaluation, and improvement of *Gliricidia sepium* by the Humid Zone Programme (HZP) of the International Livestock Centre for Africa (ILCA) are outlined. In collaboration with Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) in Turrialba, Costa Rica, 49 accessions of germplasm were collected in 1983 and evaluated at Ibadan. Four accessions consistently yielded on average 30–35 more than the local *Gliricidia* over six harvests, and were composited into a single line, ILCA HYB. Subsequent germplasm collection and evaluation activity was undertaken in collaboration with the Oxford Forestry Institute (OFI). An informal network of trial sites in West Africa is reported. HYB and "Ibadan Local" *Gliricidia* varieties were used as control accessions in these evaluations. Information on height, growth, branching, stem development, foliage and wood productivity, and flowering is reported. Network operations, its opportunities, problems, and limitations are discussed, and some suggestions are offered on the establishment and organization of similar networks for collaborative research on nitrogen-fixing trees.

Herbaceous Species Root Distribution

086
B
Ball, B. 1985.
Root distribution and nutrient cycling of some tree-shrubs suitable for alley cropping in the humid tropics. MSc thesis, The University of Guelph, Canada. 268 pp.

The main objective of the study was to select tree-shrubs suitable for use in the humid tropics in an agroforestry system called alley cropping. The three main criteria used for selection were overall nutrient cycling, root distribution and Ca uptake from the subsoil. Four species were compared—*Leucaena leucocephala, Gliricidia sepium, Cassia siamea*, and *Flemingia congesta*. Nutrient cycling was determined by calcu-

lating the weight of nutrients contained in the shoot biomass for four trees of each species at two sites. To study root distribution, a method was developed to determine root length densities and skeletal root form. This method was used for excavation of 2.5-year-old *Flemingia*, *Gliricidia*, and *Cassia* at one site, and excavations of *Leucaena*, *Flemingia*, *Gliricidia*, and *Cassia* of less than 1-year-old at two other sites. The excavations showed inherent differences in root form between species; the importance of soil channels for root growth in the subsoil; the presence of nodules at depth; and the difficulties in comparing root distributions on these soils due to the high degree of soil microvariability. To determine Ca uptake from a subsoil zone, a method was developed to calculate Ca uptake from a subsoil zone injected with stable strontium (Sr). The method involved growing the trees in pots to obtain the Ca/Sr ratio in the shoot of plants growing in soil with the mean exchangeable Ca/Sr ratio that existed in the field in the zone of soil affected by Sr. This ratio—(Ca/Sr) pot—was used to convert Sr uptake to Ca uptake from the zone affected by Sr. Strontium uptake was determined for four trees of each species at two sites. In terms of nutrient cycling, *Flemingia* was superior at one site, while *Leucaena* and *Cassia* were superior at the other site. On root distribution, the characteristic skeletal root form of *Flemingia*, consisting of one or more taproots and a few lateral roots in the topsoil, appeared most suitable for alley cropping. On Ca recycling, there was a suggestion that *Cassia* was superior, although results were not conclusive due to small numbers of replications and numerous problems encountered.

N-Fixing Woody Species

087
B
Brewbaker, J.L. 1987.
Significant nitrogen fixing trees in agroforestry systems. Pages 31–43 *in* Agroforestry realities, possibilities and potentials, edited by H.L. Gholz. Martinijs Nijhoff, Dordrecht, The Netherlands.

Nitrogen fixation characterizes about 650 known tree species and several thousand suspected ones. Most of these N-fixing trees (NFT) are rhizobially nodulated legumes, largely tropical or subtropical in origin. At least nine other plant families are implicated through actinomycetin secondary forests and grasslands. They often lend themselves better to crop- and animal-based agroforestry systems than do the premier forest timber species. Characteristics are summarized here for 85 NFT species or species complexes that are potentially important in agroforestry systems. High priority trees are summarized for their uses as fodder, green manure, fuelwood, pulp, timber, shade, and windbreaks. N-fixing trees assume green manure, resulting in significant soil amelioration. Many NFT species are both multipurpose and fast-growing. Site-specific, short-duration comparisons of different N-fixing tree species in small plots should be considered a matter of urgency in much of the tropics. They constitute a primary tool for counteracting the awesome losses of tropical deforestation.

Multipurpose Woody Species

088
B
Cobbina, J., A.N. Atta-Krah, A.O. Meregini, and B. Duguma. 1990. Productivity of some browse plants on acid soils of southeastern Nigeria. Tropical Grasslands 24: 41–45.

Investigations were carried out on acid soils at two locations in southeastern Nigeria. In Experiment 1, forage yields of *Leucaena leucocephala* and *Gliricidia* accessions were compared. Experiment 2 compared forage yield of indigenous browse species *Dactyladenia (Acioa) barteri*, *Alchornea cordifolia*, and *Albizia adianthifolia* with those of *Leucaena* and *Gliricidia*. *Leucaena* K28 and *Gliricidia* HYB were the highest yielding among the introduced accessions. The indigenous browse *Alchornea* yielded as much as *Leucaena* K28. *Acioa* also yielded as much as *Gliricidia*. The results indicated that *Acioa* and *Alchornea* which showed high regrowth vigor during the dry

season are capable of replacing *Leucaena* and *Gliricidia* as browse plants on acid soils. A comparative assessment of the nutritive value of these woody species for livestock is further warranted.

Hedgerow Species

089
B
Georgis, K., N. Michael, and T. Ragass. 1989.
Observation on the effect of alley cropping shrub legumes on growth and yield of maize, sorghum, and haricot beans. PANESA Newsletter 9: 3–6.

Preliminary trials were carried out to determine the adaptation of some selected legume shrubs *Sesbania sesban*, *Leucaena leucocephala*, and *Cajanus cajan* and their suitability for alley cropping with food crops (sorghum, maize, and haricot beans) at Nazreth, Ethiopia. The results indicated that *S. sesban* and *C. cajan* are well adapted to the conditions of the area while growth and development of *Leucaena* was poor which might indicate less adaptation to the area. The results further indicated the possibility of producing both food and feed without a reduction in crop yield and therefore a great potential of alley cropping these trees with major food crops grown in the area.

Hedgerow Species

090
B
Georgis, K., T.M. Nigusse, and R. Teshome. 1989.
Observation on the effect of alley cropping shrub legumes on growth and yield of maize, sorghum, and haricot beans. PANESA Newsletter 9: 3–6.

Reports on the results of preliminary studies on the adaptation of *Sesbania (Sesbania sesban)*, *Leucaena (Leucaena leucocephala)*, and pigeon pea *(Cajanus cajan)* and their suitability for alley cropping with food crops (sorghum, maize, and haricot beans) at Melkassa Research Centre, Nazreth, Ethiopia. It was observed that *Sesbania* and pigeon pea are promising hedgerow species for the Melkassa area.

Biomass Decomposition Hedgerow Species

091
B
Gichuru, M.P. and B.T. Kang. 1988.
***Potential of woody species for alley cropping on acid soils.* Agronomy Abstracts (1988): 55.**

Woody species are known to be effective in regenerating the fertility of acid soils under natural fallow systems. In southeastern Nigeria, where fallow periods have been shortened due to land scarcity, farmers recognize the importance of including species such as *Acioa barteri* and *Anthonata macrophylla* in the planted fallow systems. Studies were undertaken to evaluate the suitability of these and other potential species for alley cropping. Biomass yield, nutrient contents, and decomposition rates of prunings were measured. Suitability of species depends on the primary purpose it serves. To recycle nutrients for short duration crops, species such as *Cassia siamea* with high biomass production and rapid decomposition rate of prunings is preferred. Species whose prunings persist, such as *Acioa barteri*, would be effective in protecting the soil from erosion, suppressing weeds, and supplying slow release nutrients.

Root Distribution

092
B
Hauser, S. 1993.
Root distribution of *Dactyladenia (Acioa) barteri* and *Senna (Cassia) siamea* in alley cropping on Ultisol: 1. Implication for field experimentation. Agroforestry Systems 24: 111–21.

Root observations were carried out in an alley cropping trial on a typic Paleudult in the humid forest zone of southeastern Nigeria using *Dactyladenia (Acioa) barteri* and *Senna (Cassia) siamea* as hedgerow trees and the interrow space planted to maize/cassava intercrop. Rooting depth of *D. barteri* and *S. siamea* exceeded 1.6 m. Lateral root propagation was 15 m and 5 m from the hedgerows, respectively, for *S. siamea* and *D. barteri*. The whole no-tree control plot was within the range of roots of the adjacent hedgerows. Rooting density and depth of *S. siamea* in the no-tree control plot was generally higher than that of cassava. *S. siamea* and cassava root density were inversely correlated. Assuming radial symmetry of root propagation, water and nutrients were available from an area 6.1 and 2.3 times larger than the allocated plot size of *S. siamea* and *D. barteri*, respectively. Lateral root propagation into the no-tree control treatment and nutrient acquisition by hedgerow species from a larger area than allocated, may result in underestimating and overestimating the performances of the respective treatments. Although no good solution can be given, possible alternative measures for avoiding root interference are discussed.

Biomass Production: Species Evaluation

093
B
Isaac, L., D.A. Shannon, and F.E. Brockman. 1994.
Biomass production of hedgerow species evaluated for alley cropping in three environments in Haiti. Agronomy Abstracts (1994): 75.

Twenty-eight tree species planted in hedgerows were evaluated for biomass production in three agroecological environments in Haiti: high elevation (1150 m), low elevation on calcareous soil, and low elevation on basaltic soil. The trials were established in May 1991. Between April 1992 and May 1993, the hedgerows were pruned to 50 cm above the ground, three times at the high elevation and calcareous sites and twice at the basaltic site. Large differences in biomass production were recorded among the species across the sites. The greatest biomass at the high elevation site was produced by *Acacia angustissima* (8.3 t/ha/1yr/) dry matter followed by three species of *Leucaena*. At the calcareous and basaltic sites, the most biomass was produced by *L. Leucocephala* (12 and 4.8 t/ha/1yr/, respectively) followed by *Leucaena* hybrid KX3. Those species which produced the greatest biomass also produced significant regrowth and their survival was excellent.

Germplasm Evaluation

094
B
Karachi, M., N. Lema, E. Sabas, and D. Shirma. 1994.
Growth, biomass production, and plant mortality of seven *Sesbania sesban* var. *mubica* and three *Sesbania macrantha* accessions at Tumbi, Tanzania. Forest Ecology and Management 64: 153–159.

The study examined the growth, biomass, and mortality of 7 accessions of *Sesbania sesban* and 3 of *Sesbania macrantha* following the cutting of trees. Trees were planted at 0.75 ¥ 1 m spacing in 1988. Results showed significant differences in basal diameter in height growth between accessions at 3 and 5 months after planting. Flower initiation, number of primary, secondary, and tertiary branches differed between accessions. Fodder yields measured over two seasons were also significantly different between accessions. Wood yield and plant mortality also differed.

General; Hedgerow Species

095
B
Maimo, A.M. 1982.
Selection of leguminous trees for agroforestry in Cameroon. Pages 121–124 *in* Agroforestry in African humid tropics, edited by L.H. MacDonald. The United Nations University.

From 1977 to 1981 the Institute of Agronomic Research (IRA), through its Centre for Forestry Research in Edea, Cameroon, conducted a project with the objectives of: identifying the climatic and ecological factors of Edea (from literature, meteorological services, and soil analyses); studying the farming systems and the utilization of forest products in the dense humid forest zone (through farmer surveys and observations); and selecting leguminous forest species of agronomic and forestry interest (through elimination trials). The soil analysis confirmed that the soil is nutrient-poor. The study of farming systems showed that, in Edea, the rural farmers cultivate 0.5–4.2 ha and that collective farming is typical. Futhermore, the farming system is essentially shifting agriculture involving a fallow of 3 to 7 years. Mixed cropping is common, and the farming practices involve very simple technology (cutlasses, hoes, and fire). Land used by the community is often subject to erosion. Finally, the rural population thrives principally on cassava, taro *(Colocasia esculenta)*, macabo *(Xanthosoma sagittifolium)*, yams, sweetpotatoes, bananas, and plantains. Also planted are maize, groundnuts, and beans. The forest trees associated with traditional farming systems were found, as in the case of the humid forest zone of western Nigeria to be *Leucaena leucocephala*, which is planted on cocoa and coffee farms as a shade tree, and *Treculia africana*, *Irvingia gabonensis*, *Dacryodes edulis*, *Samanea (Pithecellobium) saman*, *Cassia siamea*, and *Pterocarpus soyauxii*. Tree elimination trials led to a preliminary selection (made on the basis of mean height growth attained after 18 months), in order of descending importance, of *Albizia falcateria*, *Samanea saman*, *Albizia lebbeck*, *Leucaena leucocephala*, and *Pterocarpus soyauxii* as suitable for use in subsequent experiments in Edea because of their potential for yam-supports, shade trees, improvement of soil, and pulp production—a matter of prime importance to CELLUCAM, the pulp manufacturing company established in Edea.

Germplasm Evaluation; Gliricidia

096
B
Martinez, H., G.A. Sanchez, M. Kass, R. Jon-Llap, and J.F. Sanchez. 1988.
Provenance studies of *Gliricidia sepium* as a strategy to improve agroforestry systems. Agronomy Abstracts (1988): 58.

In an alley cropping system, nitrogen-fixing trees should contribute to improvement of soil N availability and to nutrient cycling in general. In silvopastoral systems, the trees also serve as a protein supplement for ruminants. In every forest tree species, it is known that variations exist in silvicultural behavior and chemical composition of the biomass components. Therefore it is possible to predict the existence of varieties/provenances of nitrogen-fixing trees that are more efficient in each of the functions attributed to the arboreal component. The first results present differences among provenances and among families within the provenances from the natural distribution of *Gliricidia sepium* in contrasting environments in Costa Rica. Twelve provenances and 177 families were tried.

Hedgerow Species

097
B
Nair, P.K.R., E.C.M. Fernandes, and P.N. Wambugu. 1984.
Multipurpose leguminous trees and shrubs for agroforestry. Agroforestry Systems 2: 145–168.

Farmers deliberately use trees and shrubs, mostly legumes, in their fields. Such

woody perennials in agroforestry systems have productive and/or protective roles. Legumes offer a high range of choice of woody species for agroforestry in terms of their economic uses as well as ecological adaptability. In addition to the several leguminous woody species that are well known in agroforestry, there are many more whose potentials have not yet been fully explored. The agroforestry potentials of a few leguminous species from the point of view of their growth characteristics, ecological adaptability, combining ability with other species and uses/functions are presented. Initial results from the establishment of several multipurpose woody species by International Centre for Research in Agroforestry (ICRAF) are presented in the paper.

098
B
Ngulube, M.R. 1994.
Evaluation of *Gliricidia sepium* provenances for alley cropping in Malawi. Forest Ecology and Management 64: 191–198.

The trial was undertaken in 1987 to evaluate the productivity of *Gliricidia sepium* under alley cropping at Kawinga in Machinga, Malawi. Line plots of provenances were established at 12 trees per plot, 0.3 ¥ 4 m spacing and replicated six times. Three maize rows were grown between tree rows at 0.9 ¥ 1 m spacing. Two border rows of trees were maintained. Results showed about 87–97% survival of the provenances at one year after establishment. Variations were 1.6–2.2 m for height, 16.7–23.5 mm for diameter, and 393–450 kg/m^3 for wood density. Mean above-ground biomass was 7–10.9 t/ha/year. Nutrient values were 2.58–3.15 t/ha per year 0.17–0.20 P, 0.98–1.77 K, 1.56–2.97 Ca, and 0.04–0.05 Na. The overall production provenances were Retalhuleu (14/84), Potencuela Bolivar (24/86), Volcan Suchitan (13/84), and Francisco (37/85). Further testing of these provenances are recommended to meet the need of agroforestry in different agroecozones.

099
B
O'Donnell, J.J. and M.C. Palada. 1993.
Establishment and growth of four hedgerow species by alley cropping systems on St. Croix. American Society of Agronomy. Agronomy Abstracts (1993): 59.

Alley cropping systems have the potential to enhance the sustainability of vegetable production on St. Croix, US Virgin Islands. As part of a long-term study of alley cropping with vegetables, an evaluation of different tree and shrub species for use in hedgerows was initiated. Four hedgerow species: *Gliricidia (Gliricidia sepium), Leucaena (Leucaena leucocephala), Moringa (Moringa oleifera),* and pigeon pea (*Cajanus cajan*) were grown in plastic bags for 19 wk and then planted at 30 cm spacing in 12 m hedgerows with 5 m between hedgerows. Plants were irrigated daily for the first 4 wk. Mean plant survival for all species was 97%. Total height measurements were made on 30 trees from the middle hedgerow of each species. Plant heights were measured 8 wk after planting and remeasured every 4 wk. In the first two measurements, the pigeon pea hedgerow grew fastest (1.6 cm d^{-1}), while *Leucaena* and *Moringa* hedgerows had the greatest growth increases (2.1 cm d^{-1}), in the last two measurements. At the end of 24 wk, the *Moringa* and pigeon pea hedgerows were the tallest (225 cm and 213 cm, respectively), followed by the *Leucaena* (173 cm) and *Gliricidia* (124 cm) hedgerows. The pigeon pea hedgerows also yielded 175 g of dry seed and 602 g green peas per hedgerow. Preliminary results indicate that hedgerow establishment would be most rapid using either pigeon pea or *Moringa.* Of the two species, pigeon pea may be preferable due to its nitrogen-fixing ability and pea production.

Hedgerow Species

100
B
Owino, F. 1989.
Methods for general and alley farming specific multipurpose trees and shrubs screening. Paper prepared for IITA/ILCA/ICRAF. Alley Farming Network for Tropical Africa (AFNETA) Training Course, IITA, Ibadan, Nigeria. August 1989.

The central role of trees and shrubs in agroforestry systems is underscored. The broader range of potential goods and services derived from multipurpose trees and shrubs in agroforestry systems is contrasted to that of traditional plantation forestry. Important attributes of multipurpose trees for specific agroforestry technologies are discussed together with possible methodologies for their assessment. Arrangements for on-station experimentation with multipurpose trees and shrubs in an agroforestry background are fully discussed. Such arrangements include (i) germplasm variability survey, (ii) germplasm collection and documentation, (iii) seed handling, and (iv) site preparation and field experimental layouts. Testing for adaptability to site, comparative growth performance, and resistance to pests and diseases is covered under species elimination trials. Testing for tree response to intended management is covered separately. Finally, opportunities for and methods of genetic improvement of multipurpose trees and shrubs for agroforestry systems are highlighted.

Hedgerow Species; Root Distribution; Ultisol

101
B
Ruhigwa, B.A., M.P. Gichuru, B. Mambani, and N.M. Tariah. 1992.
Root distribution of *Acioa barteri*, *Alchornea cordifolia*, *Cassia siamea*, and *Gmelina arborea* in an acid Ultisol. Agroforestry Systems 19: 67–78.

The competition of tree roots and companion food crops for available water and nutrients in the topsoil is a major constraint to alley cropping. Root distribution patterns of *Dactyladenia barteri*, *Alchornea cordifolia*, *Senna siamea*, and *Gmelina arborea* grown on an acid Ultisol at Onne in the humid forest zone of southeastern Nigeria were examined to a depth of 120 cm and laterally to 200 cm from the tree trunk to study the suitability of the species for alley cropping. The four woody species were rooted throughout the soil profile examined but differ in the distribution of roots both laterally and vertically. In spite of higher underground biomass production, most of the fine roots (2 mm diameter) of *Alchornea cordifolia*, *Senna siamea*, and *Gmelina arborea* were found in the top 20 cm of the soil. This soil layer had 73, 76, and 74% of the total *Alchornea cordifolia*, *Senna siamea*, and *Gmelina arborea* fine roots in the profile examined, respectively. Such root systems compete with food crops for nutrients and moisture in the surface soil. *Alchornea cordifolia* and *Gmelina arborea* have many large woody roots in the surface soil which make any tillage operation or seedbed preparation difficult. *Dactyladenia barteri*, in contrast, has the most desirable rooting system with fewer fine roots in the surface soil (49%), and roots that are concentrated close to the tree trunk and decrease rapidly away from the tree base. In addition, *Dactyladenia barteri* roots penetrate deeper soil horizons and this may result in more efficient nutrient cycling from these layers, and reduced competition with shallow-rooted food crops. The rooting patterns of *Dactyladenia barteri* has promise for alley cropping in acid soils of the humid forest ecozone. Further root studies are needed for better development of alley cropping and related agroforestry systems.

Hedgerow Species

102
B
Sumberg, J.E. 1986.
Alley farming with *Gliricidia sepium*: germplasm evaluation and planting density trial. Tropical Agriculture (Trinidad) 63: 170–172.

Two related alley farming trials with *Gliricidia sepium* are reported in this paper. Evalu-

ation of vigor and mulch yield of a *Gliricidia* germplasm collection from Costa Rica indicated significant variation for both characteristics. The four highest yielding accessions produced 37% more mulch than "Ibadan Local" over four harvests. Six planting densities were established with seedlings to determine their effects on mulch yield of *Gliricidia*. With more than 12 seedlings m^{-1}, over four harvests, the greatest mulch yield was obtained with approximately 10 established trees m^{-1}.

Hedgerow Species

103
B
Tacio, H.D. 1991.
THE SALT system: agroforestry for sloping lands. Agroforestry Today 3(1): 12–13.

The focus is on sloping land, where many small-scale farmers face serious problems of soil erosion. Work is based in Kinuskusan, Bansalan, Davao del Sur, but the system has been designed to function on at least half the hillside farms in the Philippines. Called Sloping Agricultural Land Technology (SALT), the objectives are to (i) control soil erosion; (ii) help restore soil structure and fertility, and (iii) produce food efficiently. To encourage acceptance by local farmers, the system is designed to require a minimum of labor and resources, without relying on outside loans. It is meant to be economically feasible, environmentally sound, and fully functional in as short a time as possible. It is also designed to be culturally acceptable to Filipino farmers. To date, the center has screened about 35 local and exotic hedgerow species. The criteria for screening include survival, biomass production, nitrogen-fixing capacity, rate of litter decomposition, fodder and fuelwood production, seed production, drought tolerance, and resistance to pests and diseases. Based on these criteria, five hedgerow species have been identified as good alternatives to *Leucaena leucocephala*. These are *Flemingia congesta, Desmodium rensonii, Gliricidia sepium, Leucaena diversifolia*, and *Calliandra calothyrsus*.

Root Distribution

104
B
Van Noordwijk, M., K. Hairiah, M.S. Syekhfani, and E.N. Flach. 1991. *Peltophorum pterocarpa* (DC.) Back *(Caesalpiniaceae)*, a tree with a root distribution suitable for alley cropping on acid soils in the humid tropics. Pages 526–532 *in* Plant roots and their environment, edited by B.L. McMichael and H. Persson. Elsevier Science Publications, Amsterdam, The Netherlands.

The root distribution of *Peltophorum* was investigated after 2 years of pruning (twice a year) at three different heights (25, 50, and 75 cm). Pruning height had a marked effect on the number of branch roots originating from the stem base. Possibilities are discussed for manipulating the tree so as to form a root distribution pattern desirable for alley cropping.

Hedgerow Species

105
B
Yamoah, C.F. and A. Getahun. 1990.
Alley cropping and crop yield enhancement with *Sesbania* species. Pages 109–121 *in* Perennial *Sesbania* species in agroforestry systems, edited by B. Macklin and D.O. Evans. Proceedings of a workshop held at ICRAF, Nairobi, Kenya, 27–31 Mar 1989. NFTA, USA.

A review of *Sesbania sesban* for alley cropping is presented. *Sesbania sesban* is suitable for alley cropping, because it grows fast, fixes N, coppices fairly well, and provides stakes, fuelwood, and fodder. Drawbacks to using *Sesbania* for alley cropping include easy dieback following careless management, alleged nematode and

pest susceptibility, and excessive intercrop shading. Information on *Sesbania* performance in alley cropping systems is scanty, but available evidence suggests possible crop yield enhancement with *Sesbania* prunings as green manure. *Sesbania* generally performs well in highland environments where its growth and biomass yield are better than in the lowlands. Consequently, it is among the leguminous shrub species commonly employed in agroforestry land-use systems by agricultural development projects in the East-Central African highlands. Future research in the region should focus on: (1) pruning management in different agroecological settings; (2) mixture of *Sesbania* with *Leucaena* or *Calliadra* in a hedgerow; and (3) screening of germplasm for species that can withstand intensive pruning regimes.

Biomass Yield; Hedgerow Species

106
BC
Budelman, A. 1988.
Leaf dry matter productivity of three selected perennial leguminous species in humid tropical Ivory Coast. Agroforestry Systems 7: 47–62.

The leaf biomass productivity of *Leucaena leucocephala*, *Gliricidia sepium*, and *Flemingia macrophylla* were measured at the end of regrowth cycles. The effective period of observation was minimally 24 months, or 8 regrowth cycles, after a period of establishment of slightly more than a year. Using systematic trial designs, originally developed by NELDER, yield figures were acquired for a broad range of plant densities. At a plant density of 10,000 trees per hectare, the average yearly leaf DM productivity amounted to 15.4 t for *Leucaena leucocephala*, 12.4 t for *Flemingia macrophylla*, and 10.5 t for *Gliricidia sepium*. Productivity data and leaf area indices are compared with those of related cropping systems.

Hedgerow Species; Nutrient Status

107
BC
Budelman, A. 1989.
Nutrient composition of the leaf biomass of three selected woody leguminous species. Agroforestry Systems 8: 39–51.

The value of leaf biomass and the foliar nutrient content of *Leucaena leucocephala*, *Gliricidia sepium*, and *Flemingia macrophylla* were studied under field conditions. Five series of leaf samples were collected and analyzed for N, P, K, Ca, and Mg contents over a period of 42 months of growth observation. Results are compared with mean values derived from a literature study. Factors contributing to the observed variation are discussed and measures for its control are suggested.

Biomass Production; Hedgerow Species

108
BC
Karim, A.B. and P.S. Savill. 1991.
***Effect of spacing on growth and biomass production of Gliricidia sepium* (Jacq.) Walp. in an alley cropping system in Sierra Leone. Agroforestry Systems 16: 213–222.**

Influences of spacing on the early performance and biomass production of *Gliricidia sepium* in an alley cropping system were studied in southern Sierra Leone. Four between-row spacings of 2, 4, 6, and 8 m were combined with three within-row spacings (0.25, 0.50, and 1.00 m) in a split-plot experimental design. Spacing had no effect on tree survival, tree height, and leaf nitrogen content. The lower the rectangularity of planting, the better the performance of the individual trees, and consequently the greater the biomass and N yields per hectare. Total biomass production per unit area was, expectedly, greatest where the spacings between hedgerows were closest, while production per plant decreased with closer within-row spacings. The total fresh

and dry weights of twigs and leaf nitrogen yields were strongly influenced by between-row rather than within-row spacings.

Biomass Production; Hedgerow Pruning

109
BC
Latt, C.R. and P.K.R Nair. 1994.
Interactions among pruning frequency, reserve carbohydrates, and biomass production in agroforestry trees. Agronomy Abstracts (1994): 69.

Maximizing biomass yield is an important consideration in the management of alley cropping systems, but few studies have examined the underlying physiological processes that affect biomass production in pruned agroforestry trees. To investigate this topic, *Leucaena leucocephala* and *Gliricidia sepium* in alley cropping systems at IITA in Nigeria were cut at several intensities. Postpruning biomass production was recorded, and levels of soluble sugars and starch in stems and large roots were determined using the perchloric acid method. Frequent cutting significantly reduced biomass production and stem and root starch concentrations in both species. During the rainy season, when most growth occurs, biomass production in trees pruned at 3-week and 6-week intervals was highly correlated with starch levels.

Germplasm Evaluation; N Fixing Trees

110
BC
Macklin, W.D and J.L Brewbaker. 1988.
Nitrogen fixing tree evaluation and germplasm conservation. Agronomy Abstracts (1988): 58.

A major research network for evaluation of nitrogen-fixing trees (NFTs) is being coordinated by the Nitrogen Fixing Tree Association. NFTs include some of the best fast-growing fodder and fuelwood trees in the tropics. Trials vary from fully replicated experiments with research institutions to smaller observational on-farm trials with local projects. Preliminary results are presented. Species which have given the best performances include: *Acacia angustissima, A. auriculiformis, A. mangium, A. nilotica, Calliandra calothyrsus, Erythrina variegata, Leucaena diversifolia, L. leucocephala, Leucaena* hybrids, *Mimosa scabrella, Paraserianthes falcataria*, and *Sesbania grandiflora*. A seed bank of NFTs was established at the University of Hawaii in support of these trials. Over 65 species are included, representing outstanding species for their uses of the 650 known NFTs. Several species are represented by multiple provenances. Samples are being set aside in both cold storage and cryogenic storage for preservation. In situ and ex situ stands and seed orchards are also being promoted.

Biomass Yield; Hedgerow Species

111
BC
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.

Effect of spacing and mixing on biomass production of monocropped and mixed hedgerows of seedlings and cuttings of *Gliricidia sepium* and *Cassia spectabilis* was examined. Seedlings survived better than cuttings: and no differences were observed between seedlings in either pattern at the highest density tested. Although wider spacing reduced inter- and intraspecific competition, total biomass production was greatest at higher densities. Mixing hedgerow species increased biomass production and reduced intraspecific competition in *C. spectabilis*. Six, eight, and twelve tonnes of lime per hectare significantly increased fresh *G. sepium* biomass production at all harvest dates except the first. Extrapolated to an alley cropping system, applying 6 t/ha

of lime increased fresh cumulative *G. sepium* biomass production by almost 39% over the no-lime treatment representing more than 200 kg N/ha.

Crop Production; Hedgerow Species

112
BC
Rosecrance, R.C. and W. Kuo. 1989.
Maize yields from an alley cropping experiment with nine tree species in Hawaii. Nitrogen Fixing Tree Research Reports 7: 36–37.

Many researchers have demonstrated alley cropping's major benefits: maximum use of climate and site, increased productivity, and evenly distributed economic risk to the farmer. Green leaf manure (GLM), leaves, and green stems supply nitrogen and other nutrients to the crop. Nitrogen-fixing trees (NFTs) provide added advantages to resource-poor farmers because they can fix atmospheric nitrogen which can become available to the crop, and thereby reduce dependence on expensive chemical N fertilizers. Nitrogen-fixing tree leaves applied directly to the soil have increased yields in maize, rice, and sorghum. In this paper, maize yields from an alley cropping experiment using eight NFTs and one non-fixing tree were compared.

Biomass Production; Hedgerow

113
BC
Shannon, L., L. Isaac, and F.E. Brockman. 1994.
Growth of hedgerow species in four environments in Haiti. Agronomy Abstracts (1994): 75.

Tree species were evaluated as hedgerows for alley cropping in four environments in Haiti, representing differences in temperature, rainfall and fertility, and insect pests. Sixteen species were planted at a high elevation site (1150 m), 20 species were planted on calcareous soil, 16 on basaltic soil, and 18 at a semiarid site. Height was measured periodically. Most species grew tallest at the calcareous site and were shortest at the semiarid and basaltic sites. Growth of several species was retarded at the high elevation site during the cool winter months. At 10–12 months after planting, *Leucaena leucocephala* was tallest at all sites. *Leucaena* hybrid KX3 ranked second at three sites. Good growth was also exhibited by *L. shannonii, L. diversifolia*, and *Acacia angustissima*. Differences among species in response to environmental conditions are examined.

Alfisol; Crop Production; Hedgerow Management; Woody Species

114
BCD
Duguma, B., B.T. Kang, and D.U.U. Okali. 1988.
Effect of pruning intensities of three woody leguminous species grown in alley cropping with maize and cowpea on an Alfisol. Agroforestry Systems 6: 19–35.

Field trials were carried out on an Oxic Paleustalf in the humid zone of southwestern Nigeria with *Leucaena leucocephala*, *Gliricidia sepium*, and *Sesbania grandiflora* alley cropped with maize and cowpea. The three hedgerow species were spaced at 2 m. Trials were carried out 1 year after establishment of the hedgerows using a split-plot design with four replications. The *Leucaena* trial had twenty pruning combinations consisting of five pruning heights (25, 50, 75, 100, and 150 cm) and four pruning frequencies (monthly, bi-, tri-, and six-monthly). The *Gliricidia* and *Sesbania* hedgerows were subjected to nine pruning intensities consisting of three pruning heights (25, 50, and 100 cm) and three pruning intensities (monthly, tri-, and six-monthly). For the three woody species, biomass, dry wood, and nitrogen yield from the hedgerow prunings increased with decreasing pruning frequency and increasing pruning height. Biomass, dry wood, and nitrogen yields were in the following order: *Leucaena, Gliricidia, Sesbania*. The various pruning intensities did not affect survival of *Leucaena*

plants. Pruning frequency had a larger effect than pruning height on survival of *Gliricidia* and *Sesbania*. With monthly pruning, about 25 percent of the *Gliricidia* and all of the *Sesbania* plants died within 6 months of repeated pruning. Even with lower pruning frequency, *Sesbania* plants showed lower survival rates than *Gliricidia* or *Leucaena*. Pruning intensities of hedgerows had affected the grain yield of the alley cropped cowpea more than maize grain yield. Increasing pruning frequency and decreasing pruning height enhanced better yield of maize and cowpea.

Biomass Production; Hedgerow Species; Crop Production; Soil Fertility

115
BCDF
Sanchez, J., D.C.L. Kass, and P. Ferreira. 1990.
Differences in performance of tree species in alley cropping systems. Agronomy Abstracts (1990): 62.

Biomass production and nutrient content of *Gliricidia sepium* (Jacq.) Walp., *Erythrina poeppigiana* (Walp.) O.F. Cook, and of associated crops of maize (*Zea mays* L.) and beans (*Phaseolus vulgaris* L.) were compared over 6 years. *G. sepium* was planted at 6666 trees/ha and *E. poeppigiana* at 555 trees/ha. Biomass accumulation in the trunks was greater with *G. sepium*. Without N fertilization, yields of maize and beans were lower and yields of pruned biomass higher with *G. sepium* than with *E. poeppigiana*. Application of 150 kg/ha/yr of N as NH_4N0_3 increased bean yields with both species but reduced maize yields and increased pruned biomass production with *G. sepium*. With *E. poeppigiana*, application of NH_4N0_3 increased maize yields but reduced pruned biomass production. N application increased P accumulation in the *G. sepium* trunks resulting in a significant reduction of Olsen extractable P in the soil after 5 years.

Biomass Yield; Hedgerow Species; Crop Production; Soil Fertility; Weeds

116
BCDG
Salazar, A.A., L.T. Szott, and C.A. Palm. 1988.
Alley cropping in alluvial soils of the upper Amazon basin. Agronomy Abstracts (1988): 61.

Seven consecutive crops of a rice/corn/cowpea rotation were grown in a hedgerow intercropping system on a low P status Typic Tropudalf. Survival, biomass production, and coppicing ability of hedges of *Inga edulis*, *Erythrina* sp., and *Leucaena leucocephala* grown 4 m or 8 m apart and the effect of their pruning additions on topsoil chemical properties, weed biomass, and crop yields were evaluated. Initial survival of *Inga* and *Erythrina* exceeded 90%; *Leucaena* was replanted due to 24% survival. Cumulative pruning yields at 4 m spacing over 27 months were double that at 8 m spacing and were 43,000 kg/ha in *Inga* and *Erythrina* and 36,000 kg/ha in *Leucaena*. There were few differences among systems in topsoil chemical properties. Weed biomass was lower under *Inga* mulch than in the other systems. Cumulative grain yields were similar among alley cropping systems, but were greater than in controls without hedges.

Biomass Yield; Hedgerow Species; Erosion

117
BCF
Ndayizigiye, F. 1994.
The effect of hedgerow shrubs on erosion and the productivity of strongly sloping tropical highland soils in Rwanda. Erosion Network Bulletin 14: 243–248.

The sharp rise in population levels has led to considerable pressure being put on the land, so that the average farmland per family is no more than 0.8 hectares, with more than 25% of the families living on less than 0.4 hectares. The consequences are:

shorter fallow periods, reduced soil fertility due to constant cultivation, and a reduction in livestock numbers due to the lack of grazing ground. These have all resulted in increased erosion and falling crop yields. An experiment was carried out using nitrogen-fixing leguminous hedgerow shrubs (*Calliandra* and *Leucaena*), both to reduce erosion and to produce biomass as a source of organic matter to improve soil fertility. Results obtained after a 4-year period show that runoff was reduced by more than 80% (KR 1.7 to 2.5), while erosion was reduced by more than 98% (soil losses 0.9 to 2 t/ha/yr) in relation to the control; crop yields remain low if deficiencies are not corrected (especially by increasing pH levels) using organic matter and chemical fertilizers. The soil pH was successfully raised from 4.9 to 5.7 and yields increased by 90% during the 1st season and 250% during the 2nd season in relation to the previous year by using 2.5 t/h of lime, 10 t/ha of farm manure, and 300 kg/ha of NPK (triple 17). Biomass production increased consistently and gave 2.6 to 3.6 kg of dry matter per linear meter for *Leucaena* and *Calliandra*, respectively.

Adaptation; Germplasm; Insect Damage; N-Fixing Trees

118
BCG
Glover, N. and J.L. Brewbaker. 1988.
***Gliricidia sepium:* uses, management, and genetic improvement. Agronomy Abstracts (1988): 55.**

Gliricidia sepium (Jacq.) Walp. is a fast-growing, N-fixing tropical tree grown in agroforestry systems to provide fuelwood, animal feed, green manure, shade, and poles. In 1983, collaborative research was initiated among the University of Hawaii, the Nitrogen Fixing Tree Association, the Centro Agronomico de Investigacione y Ensenanza (CATIE, Costa Rica), the Oxford Forestry Institute (UK), and the Visayas State College of Agriculture (VISCA, the Philippines) to study the extent and pattern of genetic variations in *G. sepium* provenances. Provenance trials were established at five locations under a range of ecological conditions. The evaluation of these provenances clearly indicates the existence of significant variation in growth rates between provenances, with considerable variation within provenances. A two-stage method of selection for *G. sepium* improvement is recommended that involves provenance selection followed by individual tree selections. A significant provenance × environment interaction was detected, with some provenances exhibiting superior growth rates at all sites. Degree of insect damage (*Adoretus sinicus* and *Aphis* spp.) and variation of bark color were noted between provenances.

Crop Production; Hedgerow Species

119
BD
Bill, M., B. Jama, K. Reshid, and A. Getahun. 1988.
Results of alley cropping experiments with *Leucaena leucocephala* and *Zea mays* at the Kenya Coast. *Leucaena* Research Report 9: 6–64.

Maize (*Zea mays* L.) yields in the Kenyan coastal zone are typically low (1–2 t/ha), largely due to poor sandy soils. In 1982 research on hedgerow intercropping was initiated with 8 different tree species at the Mtwapa Agricultural Research Station to identify ways to improve these yields. The major objectives of the trials were to get information on best tree species, planting spacings, and management practices to give maximum economic benefits to local small-scale farmers. Species evaluated were *Anacardium occidentale, Casuarina equisetifolia, Eucalyptus camaldulensis, Faidherbia albida* (syn. *Acacia albida*), *Gliricidia sepium, Leucaena leucocephala, Psidium guajava*, and *Sesbania grandiflora*. Results presented were from the 1985 and 1986 planting seasons for the *Leucaena leucocephala* (Lam.) de Wit (K28) plots.

Crop Production; Hedgerow Species

120
BD
Budelman, A. 1990.
Woody species in auxiliary roles in food cropping systems. Royal Tropical Institute, The Netherlands. 21 pp.

This paper summarizes a series of publications that appeared earlier in the Journal of Agroforestry Systems. The subject of the collected papers refers to the use of three nitrogen-fixing, woody perennials—*Leucaena leucocephala, Gliricidia sepium,* and *Flemingia macrophylla*—in relation to the cultivation of the climbing, tuberous food crop, water yam, *Dioscorea alata*. Subsets of questions concerned the application of the leaf mass produced by the perennials as a mulch, useful in cropping system microclimate management, and the use of the woody species as live stakes to support the yam crop. The study took place in the subhumid climate of Côte d'Ivoire (Ivory Coast), West Africa. The general objective of the study was to contribute to the development of a sustainable, low, external input food cropping system.

Ultisol; Hedgerow Species

121
BD
Gichuru, M.P. and B.T. Kang. 1990.
Potential woody species for alley cropping on acid soils. Pages 85–86 *in* Agroforestry land-use systems, edited by E. Moore. NFTA, Hawaii, USA.
The alley cropping system can be used for sustained low input production on nonacid soils. Since woody legume species such as *Leucaena* and *Gliricidia* do not perform well on acid soils, research efforts are underway to select other woody species suitable for alley cropping on acid soils which have low nutrient supply. Trials were performed at the IITA high rainfall station at Onne, Nigeria, to evaluate the potential of native and exotic woody species for alley cropping. Two indigenous species, *Acioa barteri* and *Anthonatha macrophylla*, and two exotic species, *Cassia siamea* and *Inga edulis*, appeared to be promising for alley cropping on acid soils. *Anthonatha macrophylla* showed slow initial growth. All four species coppiced well. All four species showed similar levels of K, Ca, and Mg. However, *Acioa barteri* tops had lower levels of N and P. It appears that *Acioa* is well adapted to grow under low N and P conditions. *Acioa barteri* and *Anthonatha macrophylla* are both widely used in the traditional farming system as fallow crops planted on acid soils and under high rainfall conditions in southeastern Nigeria. *Acioa* fallow can produce large amounts of pruned biomass. During the 9-month-long alley cropping trial, *Acioa* prunings produced over 6 tonnes of dry material, while *Cassia* produced only 3 tonnes. *Gmelina arborea*, on the other hand, produced more wood than leafy biomass. The suitability of *Acioa barteri* for alley cropping in acid soils is also seen from the results of the long-term alley cropping trial. Cassava showed slightly better yields when alley cropped with *A. barteri* than under the control treatment. Cassava top and tuber yields per plant were also higher when alley cropped with *A. barteri.* A similar trend was observed when cassava was alley cropped with *Cassia siamea*; however, cassava yield was depressed when alley cropped with *Gmelina arborea* because of subterranean and area competition.

Biomass Decomposition; Crop Production

122
BD
Karinge, P.G. 1989.
Effect of alley cropping with *Calliandra calothyrsus* (Meissn) on sequentially grown maize and cowpea. MSc thesis, University of Nairobi, Nairobi, Kenya. 137 pp.

The growth, biomass, and nutrient yields of *Calliandra* and the yield of sequentially grown maize and cowpea were assessed in alley cropping. The experiment was set

up in a randomized complete block. Treatments were three nitrogen rates (0, 45, and 95 kg N/ha), and pruning applications (with and without pruning). The decomposition rates and N release in *Calliandra*, maize stover, *Leucaena*, *Senna*, and *Dactyladenia* prunings were compared. A greenhouse experiment was also undertaken to determine the N-manuring value and residual effects of dry and green leaves of *Calliandra* and *Gliricidia* on maize growth. Results indicated that *Calliandra* attained height growths of 3.2 m, 35 coppices per tree, biomass yield of 5.0 t/ha, nutrient yield of 185 N, 13 P, 64 K, 55 Ca, and 16 Mg kg/ha from four prunings. The effect of *Calliandra* pruning was equivalent to the application of 45 kg N/ha. Hedgerows significantly reduced grain field of maize at the adjacent row, but increased N accumulation compared to the mid-alley. Cowpea growth and yield were not affected by prunings. Plants near hedgerows also showed higher nutrient status than those at the mid-alleys. *Calliandra* prunings decomposed four times more than maize stover at rates proportional to their C/N ratios. The order of decomposition among species was *Leucaena, Calliandra, Gliricidia, Senna*, and *Dactyladenia.*

Root Pruning; Crop Yield

123
BD
Korwar, G.R. and G.D. Radder. 1994.
Influence of root pruning and cutting interval of *Leucaena* hedgerows on performance of alley cropped *Rabi sorghum*. Agroforestry Systems 25: 95–109.

The experiment was set up to investigate the effect of root pruning and cutting interval of *Leucaena* hedgerows on alley cropped *Rabi sorghum*. Paired (60 cm) *Leucaena* hedgerows spaced 6.6 m wide were subjected to either root pruning, using a country plough during mid-kharif season, or no-root pruning. The cutting frequency of *Leucaena* hedgerows ranged from 1 month to 6 months during the *rabi* cropping period. The effect on soil moisture, crop growth, yield, and yield components of *Rabi sorghum* were examined. Root pruning of *Leucaena* hedgerows increased grain by 33% (by ploughing) and stover yields of *Rabi sorghum* by 17%, over root not pruned hedgerows. Similarly, shorter cutting intervals (1 and 2 months) increased crop yields as compared with longer cutting intervals (3 and 6 months). The growth of sorghum was also affected in the same way. Soil moisture studies indicated that the competition between crop and hedgerows was considerably reduced by the root pruning. The results clearly showed that the competition between hedgerows and arable crops can be reduced significantly by both root pruning and frequent hedgerow pruning (at 1–2 month intervals).

Hedgerow Species; Crop Production

124
BD
Rai, R.S.V. and K.K. Suresh. 1988.
Agrisilvicultural studies: optimum species combinations. The International Tree Crops Journal 5: 1–8.

Agrisilvicultural studies indicated that arable crops grown under canopies of scattered trees of *Acacia* spp. and *Azadirachta indica* had increased plant height and dry matter production more than crops grown in the open. Similarly, alley cropping trials conducted to examine the optimum species combinations with *Casuarina equisetifolia, Leucaena leucocephala,* and *Eucalyptus equisetifolia* indicated that these hedgerow species had little detrimental effects on the associated crop. *Eucalyptus tereticornis* had the most detrimental effect on alley cropped sorghum, maize, and cowpea.

Crop Production; Hedgerow Species

125
BD
Rosecrance, R.C., J.L. Brewbaker, and J.H. Fownes. 1992.
Alley cropping of maize with nine leguminous trees. Agroforestry Systems 17: 159–168.

An alley cropping system was studied on N-deficient soils in Hawaii to determine mulch effects of leguminous trees on maize yields. *Calliandra calothyrsus, Cajanus cajan, Cassia siamea, Gliricidia sepium,* KX1-*Leucaena* hybrid (*L. pallida* XL. *diversifolia), L. leucocephala, L. pallida, L. salvadorensis,* and *Sesbania sesban* were evaluated for green manure and yield of intercropped maize. *S. sesban, G. sepium, L. pallida,* and KX1 produced between 5 and 12 dry t/ha/yr green manure with nitrogen yields between 140 and 275 kg N/ha in four prunings. Maize grain yields responded linearly to nitrogen applied as green manure regardless of tree species. Maize yield increased by 12 kg for each kg of nitrogen applied. Additions of prunings from hedgerows maintained maize grain yields at about 1800 kg/ha for two consecutive cropping seasons, while control plot yields averaged less than 600 kg/ha. However, in March, maize yields decreased by 34% in the row spaced 40 cm from the hedge, compared to those spaced 110 cm away. In July, increasing the distance away from the hedge to 60 cm and coppicing the hedge during the earlier period of maize growth significantly improved grain yield. Grain yields decreased by only 10% in the maize row closest to the trees.

Hedgerow Species; Crop Production

126
BD
Ruhigwa, B.A. 1993.
Alley cropping of plantain with *Dactyladenia barteri, Alchornea cordifolia, Senna siamea,* and *Gmelina arborea* hedgerows on an Ultisol of Rivers State, Nigeria. PhD thesis, Rivers State University of Science and Technology, Nkpolu, Port Harcourt, Nigeria. 178 pp.

An experiment was conducted on an Ultisol at the International Institute of Tropical Agriculture (IITA), Onne Station to compare the potential of alley cropping in supplying in-situ mulch with mulching in a cut-and-carry system with elephant grass *(Pennisetum purpureum)* for plantain production. *Alchornea cordifolia, Dactyladenia barteri, Gmelina arborea,* and *Senna siamea* were selected as hedgerow species while *P. purpureum* served as the no-tree control. Plantain was intercropped with maize during the first cropping season. Plantain performed best with *P. purpureum* mulch resulting in fast growth, a short cropping cycle, and high bunch yield (17.8 t/ha) of the plant crop. In addition, the ratoon crop mulched with this mulch produced 21.5 t/ha representing an increase of 21% yield relative to plant crop yield. These performances can be attributed to high nutrient contribution from large amounts of mulch applied which improved soil nutrient content, particularly available phosphorus and exchangeable cations (Ca, Mg, and K). They may also be due to reduced diurnal soil temperature fluctuations and moisture depletion during the dry season, and reduced weed infestation recorded under plantains mulched with *P. purpureum.* Among the in-situ mulches, *D. barteri* produced the best results as the plant crop growth and cycle were similar to that of plantains mulched with *P. purpureum.* In addition, *D. barteri* plots produced 85, 57, and 60% bunch yields relative to the yield obtained with *P. purpureum* mulch for the first and second crops, and cumulative yield over 3 years and 3 months. Relative yields, however, ranged between 77 and 38% for other in-situ mulches at these different yield evaluations. Contrary to the increase of the ratoon crop yield in *P. purpureum* mulched plots, the yield of the ratoon crop declined in the alley cropped plots. The decline was, however, 19% in *D. barteri* plots against 27–41% in other alley cropped plots. The leaves of *D. barteri* decomposed slowly resulting in similar effects on soil temperature and moisture depletion, and weed control as *P. purpureum* mulch. In addition, *D. barteri* showed the potential of reducing soil acidity by its higher leaf calcium content, and reduced below-ground compe-

tition. In contrast, superficial rooting of the hedgerow species, high diurnal soil temperature fluctuations and moisture depletion, and high weed infestation due to fast decomposition of leaves were observed in *A. cordifolia, G. arborea*, and *S. siamea* alley cropped plots with accompanying poor plantain performances. Mulch which decomposes rapidly such as the leaves of the three hedgerows, offers a high risk of nutrient loss through erosion and leaching to the disadvantage of perennial food crop(s) such as plantain. *Alchornea cordifolia, G. arborea*, and *S. siamea* had a rapid regrowth which can result in high labor demand for pruning compared to slow regrowing *D. barteri*. This species, however, showed the advantage of producing higher amounts of biomass from fewer prunings. Similar to plantain crops, the maize crop performed better with *P. purpureum* and *D. barteri* mulch treatments than with other treatments. Although *P. purpureum* was the best mulch, the high labor requirement for cutting, transportation, application, and management in addition to extra land needed for its production cannot be compensated for by the increased yields. *Dactyladenia barteri* is, therefore, considered as a promising species for in-situ mulch source for plantains on acid Ultisols.

Biomass; Crop Yield; Hedgerow Spacing; Fertilization

127
BDCF
Sanchez, J.F. and G.A. Sanchez. 1988.
Effect of spacing of *Erythrina poeppigiana* (Walp.) O.F. Cook on maize yield in an alley cropping system. Agronomy Abstracts (1988): 62.

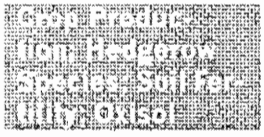
In 1985, an alley cropping trial was established in Turrialba, Costa Rica to determine the effect of the planting density of *Erythrina poeppigiana* on the yield of maize on a Typic Humitropept. All plots received 50 kg of P_2O_5 as triple superphosphate. The treatments were a control without trees but with NPK fertilization and four treatments planted at 6 x 1 m, 6 x 2 m, 6 x 4 m, and 6 x 3 m. After 5 continuous crops of maize and 3 years of tree establishment, the average yields of grains were 4666 kg/ha/yr in the 6 x 4 m plot and 3898 kg/ha/yr for the 6 x 1 m plot. The fertilized control plot was not significantly higher than the best alley cropping treatment. The DM yields of the trees, cut at the end of every harvest period of the maize were 10,756 kg/ha/yr in the 6 x 1 m plot and 4056 kg/ha/yr in the 6 x 4 m plot. The trees biomass furnished 296 kg/ha/yr of N in the 6 x 1 m plot and 102 kg/ha/yr in the 6 x 4 treatment. In the soil, an increase of Olisen extractable K was observed in the first upper 30 cm. The results show that the most appropriate distance for this association is 6 ¥ 4 m, although DM and N yields were higher in closer spacings.

Crop Production; Hedgerow Species; Soil Moisture

128
BDF
Chirwa, P.W., P.K.R. Nair, and C.S. Kamara. 1991.
Soil moisture changes and maize productivity under alley cropping in Zambia. Agronomy Abstracts (1991): 59.

Soil moisture changes during crop growth were monitored with field-installed tensiometers in an alley cropping trial involving *Leucaena leucocephala* and *Flemingia macrophylla* as hedgerow species in the semiarid (900 mm, unimodal rainfall), upland plateau (1200 m) region of Zambia. Moisture depletion was similar under the hedgerows and maize rows, but was significantly higher in fertilized plots than in unfertilized plots. *Leucaena* produced more biomass than *Flemingia* prunings; but, in unfertilized alleys, the application of *Flemingia* prunings resulted in higher crop yields than did the application of *Leucaena* prunings. Maize growth was poorer in the row nearest to the hedgerow than in rows further away, especially in the unfertilized plots. The study showed that under conditions of low soil fertility, *Leucaena* was a stronger competitor than *Flemingia* for soil resources, and caused greater suppression of growth and

yield of alley cropped maize; thus *Flemingia* was a better hedgerow species than *Leucaena* for alley cropping under those conditions.



129
BDF
Evensen, C.I., T. Dierolf, and R.S. Yost. 1991.
Alley farming on highly weathered soils: cumulative effects on field and soil properties. Agronomy Abstracts (1991): 60.

An alley farming study has been conducted for almost 7 years in West Sumatra on an acid and high A1 Tropeptic Haplorthox soil to determine yield response of upland rice and cowpea. Three tree species, *Parserianthes falcataria, Calliandra calothyrsus,* and *Gliricidia sepium* and a no-tree control were planted at three lime rates with low annual inputs of 20 kg P and 50 kg K ha^{-1}. Initially, *Paraserianthes* and *Calliandra* grew vigorously, while *Gliricidia* grew poorly. After 4 years, *Paraserianthes* yields declined due to tree mortality. Rice and cowpea crops initially responded to lime and paraserianthes green manure, but yields and soil cations (Ca, Mg, and K) declined until fertilizer inputs were increased in 1989. Thereafter, yields increased. Soil cations returned to original levels while soil C and N increased on plots with trees. These results indicate little buildup of nutrient cations due to recycling by the trees and suggest that successful alley farming requires maintenance of soil fertility with external inputs.

130
BDF
Evensen, C.I. and R.S. Yost. 1990.
The growth and lime replacement value of three woody green manures produced by alley cropping in West Sumatra. Pages 109–112 *in* Agroforestry land-use systems, edited by E. Moore. Nitrogen Fixing Tree Association (NFTA) Special Publication 90-02, Waimanalo, Hawaii, USA.

Alley cropping was studied as a means of improving crop production and reducing lime requirements on an acid and infertile soil in a transmigration area in Sitiung, West Sumatra, from 1984 to 1988 as part of an effort to develop improved soil management methods for farmers with limited resources. Performance of three hedgerow species *Paraserianthes falcataria, Calliandra calothyrsus,* and *Gliricidia sepium* and three lime rates were studied. Cowpea and rice were used as test crops. Results showed that: (1) *Paraserianthes falcataria* and *Calliandra calothyrsus* were better adapted to the acid and infertile soils than *Gliricidia sepium*; (2) *Paraserianthes* was the most effective alley cropping species at improving rice and cowpea yields, while *Paraserianthes* + moderate (low) lime application (750 kg/ha) was the most profitable treatment. However, mortality of *Paraserianthes* increased with time; (3) less frequent pruning (less than four times per year) and increased hedge cutting height should be studied as possible ways to increase the longevity of paraserianthes hedges, while more frequent pruning and lower cutting height should be studied as possible ways to reduce competition of Calliandra hedges with food crops; and (4) crop yields where green leaf manure was applied were similar to those with lime application only. This substitution of green leaf manure for lime may involve reduced aluminium toxicity from the complexing of mobile Al with the added organic matter, resulting in improved crop nutrition.

Crop Production; Hedgerow Species; Soil Fertility; Ultisol

131
BDF
Gichuru, M.P., B.T. Kang, and S. Hauser. 1990.
Alley cropping with *Acioa barteri, Cassia siamea, Flemingia congesta,* and *Gmelina arborea* on an Ultisol. Agronomy Abstracts (1990): 57.

Studies on intercropping trees/shrubs with food crops in an alley cropping system on nonacid soils have shown good results with *Leucaena leucocephala* and *Gliricidia sepium*. These species performed poorly on acid soils. Research efforts have been directed toward use of species adapted to Ultisols. Four woody species plus a no-tree control, and two fertilizer rates applied to a companion crop were studied. Results indicate that *A. barteri, C. siamea*, and *F. congesta* maintained soil productivity. *G. arborea* depressed cassava and maize yields. Fertilizer application increased crop yield particularly in *G. arborea* and control treatments. Yield gap between alley cropping widens with continuous cropping. Hedgerows have differential effects on soil nutrient and moisture status. Results suggest that this farming system has a potential for acid soils if suitable trees/shrubs are used.

Crop Production; Hedgerow Species; Staking

132
BDJ
Budelman, A. 1990.
Woody legumes as live support systems in yam cultivation I. The tree-crop interface. Agroforestry Systems 10: 47–59.

Three woody legumes (*Leucaena leucocephala, Flemingia macrophylla*, and *Gliricidia sepium*) were tested as live support systems in yam cultivation. In a planting arrangement in which yam rows alternated with rows of the woody species, the tuber yields per ha were 3.4 for *Leucaena*, 5.3 for *Flemingia*, and 10.1 tonnes fresh weight for *Gliricidia* (TUKEY's LSD.2.9 t.) *Leucaena leucocephala* is unsuitable as live support with strong competitive ability in terms of high leaf productivity and relative density of the root mass in the upper soil stratum, the zone explored by the yam crop. *Flemingia macrophylla* is unsuitable as support species mainly because of its low structural value: its branches were too weak to carry the yam leaf mass. The significantly higher tuber yield of the yam crop grown with *Gliricidia sepium* is related to its low leaf productivity, a relatively weakly developed root system, and an open architecture, which leaves sufficient space for a yam crop grown in association.

Crop Production; Hedgerow Species

133
BDL
Chiyenda, S.S. and S.A. Materechera. 1989.
Effect of incorporating prunings of *Leucaena leucocephala, Cassia siamea,* and *Cajanus cajan* on yield of maize in an alley cropping system. Pages 119–128 *in* Nutrient management for food crop production in tropical farming systems, edited by J. Van der Heide. Institute of Soil Fertility, Haren, The Netherlands.

Experiments were conducted with maize intercropped with *Leucaena leucocephala, Cassia siamea*, and *Cajanus cajan* at several plant densities. The experimental results suggest that the incorporation of tree prunings had an ameliorating effect on the soil. The use of *Cajanus cajan* in association with maize is not only promising as a source of nitrogen, but also for fuelwood supply.

Crop/Woody Species; Interface; Crop Yields

134
BE
Pinney, A.Y. 1986.
Alley cropping: a consideration of some tree/crop interfaces. MSc thesis, University of Reading, UK. 100 pp.

Performance of alley cropped maize and cowpea were tested using *Gliricidia sepium* and *Leucaena* hedgerows at two sites in southwestern Nigeria. Results showed that cowpea suffered initial reduction in growth close to hedgerows. In addition, it was shown that under favorable soil fertility and moisture conditions, there was no yield response for both crops. *Gliricidia* biomass was negatively correlated with crop yield and was attributed to light competition. On the other hand, significantly positive microsite enrichment was observed at the adjacent row for both crops.

Hedgerow Species; Decomposition

135
BF
Budelman, A. 1988.
The decomposition of the leaf mulches of *Leucaena leucocephala, Gliricidia sepium,* and *Flemingia macrophylla* under humid tropical conditions. Agroforestry Systems 7: 35–45.

Leaf decomposition of *Leucaena leucocephala, Gliricidia sepium,* and *Flemingia macrophylla* were studied under field conditions. Mulch samples were analyzed over a period of 70 days on carbon, nitrogen, phosphorus, potassium, calcium, and magnesium. Loss rates for the elements show similar patterns for the three mulches. Losses of mulch material are caused by decomposition as well as removal by soil fauna (insects, arthropods, etc.) feeding on the mulch. Based on the data, decomposition and nutrient release functions are developed for the three mulches, which are considered in alley cropping system analysis and modeling.

Hedgerow Species; Mulching

136
BF
Budelman, A. 1989.
The performance of selected leaf mulches in temperature reduction and moisture conservation in the upper soil stratum. Agroforestry Systems 8: 53–66.

The effect of the leaf mulches of *Leucaena leucocephala, Gliricidia sepium,* and *Flemingia macrophylla* on moisture content and temperature in the first 5 cm of the soil. The mulches were applied at the rate of 5 t/ha DM. In order to characterize a mulch material two parameters are distinguished; the initial impact (Ii) and the effective lifetime (Te) of a mulch material. I is expressed in terms of percentage surplus moisture or average temperature reduction (degrees centigrade). T quantifies the duration of the effect. Of the three mulch materials, that of *Flemingia macrophylla* performed best in terms of moisture retention and lowering soil temperatures and the longevity of the effect. *Leucaena leucocephala* mulch shows the smallest impact over the shortest period.

Germplasm; Evaluation; Spacing; Soil Fertility

137
BF
Kwesiga, F. and R. Coe. 1994.
The effect of short rotation *Sesbania sesban* planted fallows on maize yield. Forest Ecology and Management 64: 199–208.

Two provenances of *Sesbania sesban* (Kakamega and Chipata) were planted in 1988 as nursery grown seedlings in fallows at Msekera Research Station, Chipata, Zambia. Trees were grown for 1, 2, and 3 years at 0.5 ¥ 0.5 m, 0.7 m ¥ 0.7 m, and 1 ¥ 1 m spacings. Maize variety 604 was grown after fallow periods, and supplied with 0,

37, 75, and 112 kg N/ha in order to evaluate the effects of fallow and N on maize grain yield. The two provenances did not differ in height, diameter growth, and branch numbers, however, the Chipata provenance had significantly more leaves at 3 months. Woody biomass at 1, 2, and 3 years fallow at close spacing were 8.3, 17.6, and 21.4 t/ha, respectively, for Kakamega provenance, while the Chipata provenance had 10.8, 14.5, and 21.2 t/ha at 1, 2, and 3 years fallow, respectively. Litterfall ranged from 0.6 t in June to 0.01 t/ha in November. Stand mortality increased with stand density and fallow length, ranging from 27 in the first year to 90 at the end of the third year. Maize grain yield without N increased from 2.27 t/ha to 6.02 t/ha after 1 and 3 years fallow, respectively, compared to 1.6–1.8 t/ha in the control plot without fallow. Yield decline was observed in the control even with addition of 112 kg N/ha, while maize yield in the planted fallows increased with fallow length. It was concluded that short fallow rotations with *Sesbania* has great potential of increasing maize production even without supplemental inorganic N input.

Root Barrier; Soil Moisture

138
BF
Ssekabembe, C.K., P.R. Henderlong, and M. Larson. 1994.
Soil moisture relations at the tree/crop interface in black locust alleys. Agroforestry Systems 25: 135–140.

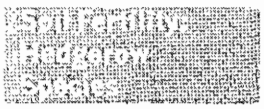
An experiment was conducted in Ohio to determine the effect of black locust hedgerows on water shortage in crop land. Water was applied to bare soil which had carried sole maize stands in the previous growing season, and to the previously established alley cropped plots, some of which had 100 cm deep fiberglass root barriers to prevent root competition for soil moisture in the alleys. Direct soil evaporation was reduced by covering the soil with a black polyethylene sheet. Soil moisture remaining in the top 45 cm soil depth was monitored for 8 days. Soil 1 had a higher organic carbon content and contained more moisture than Soil 2, which had more gravel than Soil 1. In Soil 2 there was significantly less water in alleys without below-ground partitions than on bare soil. In alleys without below-ground partitions, the hedgerows reduced soil moisture content of the alleys by about 8% on Soil 1 and 32% on Soil 2, at 8 days after water application. In the top 45 cm depth of Soil 1, the influence of the hedgerows in the same treatment was large within 76 cm of the hedgerows but declined farther inside the alleys. For Soil 2 which had more gravel in the lower soil layers (which prevented deep growth of black locust roots) the influence of the hedgerows was pronounced throughout the alleys but was highest within the 76 cm distance from the hedgerows.

Nutrient Use; Root Distribution

139
BF
Van Noordwijk, M. 1989.
Rooting depth in cropping systems in the humid tropics in relation to nutrient use efficiency. Pages 129–144 *in* Nutrient management for food crop production in tropical farming systems, edited by J. Van der Heide. Institute of Soil Fertility, The Netherlands.

A simple model is presented for calculating the rooting depth of a crop or crop combination required to intercept leaching nutrients for different climatic and soil conditions. Important parameters in this model are the amount of water moving through the soil, which depends on the amount of rainfall left after evapotranspiration, and the apparent adsorption constant, which depends on the nutrient and soil type involved. Calculations for three time patterns of nutrient supply in relation to nutrient demand show moderate effects of the degree of synchronization on rooting depth required if a high interception fraction is desired. In shifting cultivation systems a deep-rooted fallow vegetation can recover nutrients leached to the subsoil during the cropping phase. The simple leaching model can indicate the combinations of climate zone and

apparent adsorption constant for which such interception is possible. It appears that recovery of leached nitrate is only possible in the subhumid zone. In the humid tropics the continuous presence of a deep root system as part of the crop combination on the field is necessary to use nitrogen efficiently, except when acid soil conditions keep all nitrogen in the ammonium form or when an almost ideal synchronization exists of nitrogen supply and demand during the growing season. Some data are discussed on the root distribution of food crops and on the possibilities to establish a "safety net" under the crops grown in alleys between deep-rooted hedgerow trees.



140
BF
Yamoah, C.F., K. Mulongoy, and A.A. Agboola. 1985.
Decomposition and nitrogen contribution by prunings of selected legumes in alley cropping systems. Pages 482–485 *in* Proceedings of the First Conference of the African Association for Biological Nitrogen Fixation (AABNF), 23–27 Jul, 1995, MIRCEN, Nairobi, Kenya.

Nitrogen (N) contribution from prunings of *Gliricidia sepium* (Jacq.), *Flemingia congesta,* and *Cassia siamea* Lam. was evaluated in an alley cropping system with maize as the test crop at the International Institute of Tropical Agriculture (IITA) in Nigeria. For the cutbacks from 2-year old plants, the extent of leaf decomposition was 96, 58, and 46 dry-matter loss for *Gliricidia, Flemingia*, and *Cassia*, respectively during the 120 days of maize growth. Dry-matter losses for the subsequent *Gliricidia*, *Flemingia*, and *Cassia* prunings were 100, 73, and 83, respectively. During the cropping season, the prunings released 252, 70, and 120 kg N per hectare for *Gliricidia*, *Flemingia*, and *Cassia*, respectively. However, maize grain yield increased by 15% for *Gliricidia*, 25% for *Flemingia*, and 50% for *Cassia* relative to the control without prunings.

141
BFC
Tambi, J.A.M. 1984.
The effect of pruning on nodule shedding in cowpea and *Gliricidia* and the availability of the shed nodules as N-source. BSc project report, Njala University College, University of Sierra Leone. 42 pp.

Two potted trials were set up to investigate the effect of pruning on nodulation using *Gliricidia* and cowpea as test crops. The design was a randomized complete block with five replications. Treatment was with and without inoculation, and days after pruning (2, 5, 10, 15, and 20 days). The second experiment involved combinations of N rates with fresh and dried nodules of *Gliricidia* and cowpea. Early pruning was found to increase nodule number, but reduced nodulation in cowpea. Pruning decreased total biomass production in shoots and roots. Regrowth of leaflets following defoliation was 5 days in cowpea and 10 days in *Gliricidia*. When urea fertilizer and fresh and dried nodules of cowpea and *Gliricidia* were used as N-sources for rice, fresh cowpea nodule was slightly, but not significantly, better than urea. Dried *Gliricidia* was comparable to cowpea nodules and urea. Field observation showed that earthworm activity was higher under *Dactyladenia* and *Alchornea* hedgerows than *Leucaena* and *Gliricidia*, and more close to hedgerows than at the middle of alleys.

142
BFG
Akinnifesi, F.K. 1990.
Phytosociology of woody volunteers under on-farm alley cropping in a forest ecosystem. MSc thesis, University of Ibadan, Nigeria. 117 pp.

An agroecological approach was employed to investigate interspecific volunteer species under alley cropping. Woody volunteers within hedgerows of *Senna siamea* (Irwin

& Barneby) and *Leucaena leucocephala* (Lam.) de Wit were surveyed from 16 dispersed alley cropping fields. A total of 31 different volunteer species were found with varying frequencies of occurrence. *Antiaris africana* (Linn.), *Albizia zygia* (D.C.) Macbr., *Alchornea cordifolia* (Schum and Thonn.), *Alchornea laxiflora* (Benth.), *Ficus exasperata* (Vahl.), and *Newbouldea laevis* (P. Beauv.) were more frequent than other species. Their associations with each other and hedgerow species in different fields were discussed. Woody volunteers were more abundant under *Senna* than *Leucaena* hedgerows. An average of 8 and 7 different woody volunteer species occurred under *Senna* and *Leucaena*, respectively, and both hedgerows were similar in type of species occurring under them, though slight variations occurred among fields. In general, weed suppression and soil microsite conditions (including nutrient buildup) were better under alley cropping than in plots without hedgerow species. Dominant weed species and nutrient cycling efficiencies of hedgerow species were affected by periods of establishment. Associations of woody volunteers with hedgerow species and with soil microsite conditions could be useful in determining adaptations of native species to prevailing agrosystems.

Insect Resistant; Germplasm Evaluation

143
BG
Austin, M.T. and J.L. Brewbaker. 1994.
Breeding *Leucaena* spp. for forage and biomass in the tropics. Agronomy Abstracts (1994): 74.

Major constraints to expanded use of *Leucaena* as a forage legume include susceptibility to psyllid insects and cold temperatures. Research in Hawaii has identified elite *Leucaena* hybrids for forage based on dry matter yield, psyllid resistance, digestibility, and cold tolerance. Dry matter forage yields of the interspecific F1 hybrid k748 × k636 (*L. pallida* × *L. leucocephala*) in lowland Hawaii ranged from 13 to 31 MG ha/yr. This hybrid also produced the best forage yield at a higher, cooler elevation in Hawaii (900 m) producing 2.4 MG ha^{-1} after one harvest in the establishment season. *Leucaena pallida* spp. and hybrids had better psyllid resistance ($P<0.05$) than *L. leucocephala* K636 in lowland Hawaii. Psyllid damage was negatively correlated ($r = -0.55$, $P<0.01$). Digestibility is expected to be lower for the L. *pallida* F1 hybrids. In Florida, *L. leucocephala* genotypes had superior digestibility ranging from 510 to 550 g/kg while *L. pallida* K376 and the interspecific hybrid Kx2 (K376 x K8) had lower in vitro organic matter digestion (IVOMD) ranging from 470 to 500 g/kg. Hybrids with *L. pallida* show improved yields, psyllid resistance, and quicker seedling establishment than *L. leucocephala* genotypes.

Weeds; Hedgerow Species

144
BG
Getahun, A. and B. Jama. 1989.
Alley cropping in the coastal area of Kenya. Pages 163–170 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. International Development Research Centre (IDRC), Ottawa, Canada.

On-station and on-farm trials were carried out using multipurpose or leguminous trees and shrubs. The research partly focused on testing these woody species for enhancement of crop and livestock-feed production and improvement of soil fertility. This paper reports some of the results obtained with *Leucaena, Sesbania, Casuarina, Gliricidia,* and *Acacia albida* in the coastal area of Kenya. Woody species established well in the coastal region. Maize intercropped with woody species in the second and third years showed low yields, particularly at higher tree densities. Prunings of *Leucaena* and *Gliricidia* hedgerows produced substantial amounts of biomass and nitrogen. In the 3rd year after establishment and following hedgerow prunings, maize alley cropped with *Leucaena* yielded more than the control plot. Tree establishment improved soil fertility and reduced weed infestation. In 3 years, *Leucaena* and *Casuarina* can produce 175 t/ha and 86 m^3/ha of commercial wood, respectively.

Hedgerow Species; Fodder Production; Forage Production

145
BH
Adjei, M.B., A. Sotomayor-Rios, and D.B. Bates. 1991.
Production of sorghum silage from alley cropping systems in the Caribbean. Agronomy Abstracts (1991): 58.

Forage from grass-legume systems conserved as silage provides an option for resolving dry season feed deficiency for livestock in the semiarid tropics. Three varieties of sorghum and a millet-elephant grass (M-E) hybrid were evaluated for dry matter yield, head/stover ratio, disease resistance, nutritive value, and silage pH and organic acids. Grasses were grown in both monoculture and an alley cropping system with two native legumes (*Leucaena leucocephala* and *Desmanthus virgatus*). Total (grass + legume) dry-forage yield of sorghums from two harvests was not affected by cropping system. Seasonal sorghum yield was higher (R0.04) for Puerto Rico 5BR (14.3 mg/ha) than for Dekalb FS25A or Haygrazer Sudangrass (12.5 mg/ha). Comparative M-E hybrid yield was reduced from 15.7 mg/ha for monoculture to 12.3 mg/ha for alley crops. The hybrid also perennated to provide two additional harvests in the dry season. Approximately 10% of total dry forage from alley crops was contributed by legumes. The head/stover ratio was highest ($P<0.001$) for PR 5BR (0.40) and lowest for the M-E hybrid (0.13). Incidence of sorghum rust and target spot was negligible on M-E hybrid, slight on PR 5BR, but moderate to heavy on Haygrazer and Dekalb. Forage digestibility of *Leucaena* alley crops was superior ($P<0.001$) than *desmanthus* alley crops. Silage characteristics were significantly improved by the addition of molasses before ensiling. The preliminary data indicate a potential for selecting from available grass-legume mixtures for silage production.

Fodder; N-Fixing Woody Species

146
BH
Brewbaker, J.L. 1989.
Nitrogen-fixing trees for fodder and browse in Africa. Pages 55–70 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. International Development Research Centre (IDRC), Ottawa, Canada.

Several outstanding nitrogen-fixing tree species are widely known, although basic information on their genetic potentialities is lacking. Many other species or genera deserve serious evaluation, particularly for dry matter digestibility, site (stress) adaptability, and tolerance of regular coppicing for use in alley farming. Many nitrogen-fixing trees and shrubs remain to be identified, making any review of this type only a progress report. Of the 640 known N-fixing trees and shrubs, however, about 80 are of good browse-fodder value. Data for dry-matter digestibility are available for relatively few of these species and are often disappointing, although protein values for these species are often high. Finally, a few of these remnant species have been evaluated in some type of continuously coppiced, alley crop system. *Gliricidia* and *Leucaena* provide outstanding fodder species for alley farming, and their germplasm deserves continued expansion, hybridization, and evaluation.

Fodder; N-Fixing Woody Species

147
BH
Brewbaker, J.L. and B. Macklin. 1990.
Nitrogen-fixing trees for fodder in agroforestry systems. Pages 53–61 *in* Agroforestry land-use systems, edited by E. Moore. Nitrogen Fixing Tree Association (NFTA), Hawaii, USA.

About 75 trees and shrubs of Africa serve as browse for the continent's diverse animal species. The term "fodder trees" can thus be applied very broadly. However, most fodder from trees is of poor or atrocious quality, and is often toxic or "armed" to protect it from herbivore depredation. It is thus the uncommon tree that offers high-

quality fodder, uncomplicated by poor digestibility, toxins, or armor. Most of these superior fodder species are nitrogen-fixing legumes. Agroforestry systems have been developed to exploit the multiple land-use by animals, crops, and trees. Fodder trees are found most commonly in linear border plantings, but also as hedges of scattered individuals in pasture or crop lands. The animal or crop is usually perceived by small farmers as the important component in this system, and the tree is almost always considered a minor one. This is reflected by the limited research literature on the improvement and management of fodder trees and shrubs. The present paper reviews experiences with N-fixing fodder trees that have current use or apparent promise in agroforestry systems. The focus is on tropical ecosystems, where fodder trees play a major role.

Woody Species; Fodder Production

148
BH
Ghani, A.N. and K. Awang. 1990.
Development and evaluation of agroforestry systems for fodder production. Pages 319–330 *in* Shrubs and tree fodders for farm animals, edited by C. Devendra. International Development Research Centre (IDRC), Ottawa, Canada.

Agroforestry, which integrates tree management, food production, and environmental conservation, has a potential role in rural development. This paper outlines how agroforestry systems that incorporate fodder production as a main objective can be developed. It focuses on the basic criteria to use species selection, management practices, and the advantages and constraints involved. A method of evaluation and strategies for future consideration are also discussed.

Fodder; Livestock Production; Hedgerow Species

149
BHI
Atta-Krah, A.N. 1990.
Availability and use of fodder shrubs and trees in tropical Africa. Pages 140–162 *in* Shrubs and tree fodder for farm animals, edited by C. Devendra. International Development Research Centre (IDRC), Ottawa, Canada.

Generally, trees occupy a significant niche in the farming systems and overall way of life in tropical Africa. Fodder shrubs and trees (browse) in this region play a significant role both in farming systems, where they are protected as fallow species, and in livestock production. Livestock in this zone depend largely on browse for their dietary protein. Compared with tropical grass, browse is generally richer in protein and minerals. The importance of browse increases with increasing aridity and is generally most essential in the dry seasons when most other feed resources depreciate in quality and quantity. Browse intake increases total dry-matter intake, increases crude protein intake, and improves the digestibility of low-quality forage. The effect of browse feeding on livestock is shown in increased survivability (i.e., lower mortalities, especially over the dry season) and increased productivity. Traditionally, throughout tropical Africa, processing and conservation of tree fodder is uncommon and cultivation is minimal and insignificant. This paper advocates the need for increased cultivation and integration of fodder trees (especially leguminous ones) into local farming systems through agroforestry. It also stresses the need for increased research support for the efficient cultivation, management, and use of fodder shrubs and trees for improved livestock production.

Hedgerow Species; Mulching; Staking

150
BJF
Budelman, A. 1991.
Woody species in auxiliary roles. Royal Tropical Institute, Amsterdam, Netherlands. 151 pp.

A collection of published papers dealing with research on live staking of water yam (*Dioscorea alata*) with *Leucaena leucocephala, Gliricidia sepium,* and *Flemingia macrophylla*. Trials were conducted in the subhumid zone of Côte d'Ivoire. The paper deals with (1) productivity and composition of leaf material, (2) use of leaf as mulch, and (3) use of woody species in annual crop production.

HEDGEROW HUSBANDRY

Hedgerow Establishment

151
C
Atta-Krah, A.N. and G.O. Kolawole. 1987.
Establishment and growth of *Leucaena* and *Gliricidia* alley cropped with pepper and sorghum. *Leucaena* Research Reports 8: 46–47.

Establishment and growth of *Gliricidia* and *Leucaena* in alley farms vary widely from one farmer's farm to another. Many factors: soil fertility, shading, weed infestation, may be implicated for the variation. The paper reports on the effect of sorghum (*Sorghum bicolor*) and pepper (*Capsicum* sp.) on the establishment and growth of *Leucaena leucocephala* and *Gliricidia sepium* when alley cropped. Seeds of the tree species were sown direct on every fourth or fifth ridge on which the food crop was planted 10 days earlier. Heights of each tree species in two rows each of *Leucaena* and *Gliricidia* were measured and grouped into classes at maturity of the food crops. Dry-matter yields of the trees were estimated at 9 months after planting. Sorghum had a greater adverse effect on growth and establishment of the two tree species than pepper. *Leucaena* appear more tolerant of the adverse effect than *Gliricidia*. The authors explained the more negative effects of sorghum as due to intense shading and competition for moisture and nutrients.

Hedgerow Evaluation

152
C
Bohringer, A., M. Tamo, and H.M. Dreyer. 1994.
Growth and productivity of pigeon pea (*Cajanus cajan*) genotypes for use in alley cropping and their interactions with the environment. Experimental Agriculture 30: 207–215.

About 21 genotypes of pigeon pea were evaluated for their potential in alley cropping in two different environments on the island of Oahu, Hawaii. Hedgerows were planted in August 1986 and were cut 1 m above ground level 229, 290, and 342 days after sowing. Dry matter yields for seven selected genotypes from the three cuttings combined ranged from 691 to 4083 g/m^{-2}, with significant differences between genotypes and significant genotype ¥ environment interactions. Genotypes rarely combined more than two desirable alley cropping characteristics. This suggests a distinct role for selected genotypes in different alley cropping environments.

N-Fixing Trees

153
C
Brewbaker, J.L. and W.M. Macklin. 1988.
Fodder trees and shrubs for tropical land-use systems. Agronomy Abstracts (1988): 52.

Fodder is a major product of trees in tropical agroforestry systems, and is often valued more than coproducts such as wood and green manure. Research and development have been focused on trees that coppice well and which can be managed in low hedges that also serve for erosion control and as a source of green manure and fuelwood. Of about 100 tropical fodder trees considered important commercially, about 70 fix nitrogen, lending them especially to sustained multiple cropping land-use systems. Coevolution with herbivorous animals equipped most tropical perennials with feeding deterrents and high insect resistance, notably spines, odors, toxins, and low digestibility related to fiber, tannins, and other factors. Thus relatively few genera include species with highly digestible, high-protein fodder. These are largely American legumes and include *Albizia, Desmanthus, Gliricidia, Leucaena,* and *Sesbania.* Species hybridization is opening avenues for major steps in genetic improvement in *Leucaena* and other leguminous genera. Recent advances in agronomic, nutritional, and agroforestry research with tropical fodder trees will be reviewed.

Hedgerow Species

154
C
Chiyenda, S. and S.A. Materechera. 1989.
Some results from alley cropping *Leucaena leucocephala, Senna siamea,* and *Cajanus cajan* with maize at Bunda College of Agriculture. Pages 135–142 of proceedings of a Symposium on Trees for Development held by the International Foundation for Science, Nairobi, Kenya.

An experiment was conducted at Bunda, Lilongwe, Malawi in 1983 to investigate the effect on soil fertility and crop yield of incorporating prunings from 3 tree species into soil under alley cropping with maize. The experiment consisted of three alley widths (2.7, 5.4, and 10.8 m) and inorganic fertilizer split-applied to maize at planting, at 0, 50, and 100 kg/ha, and when plants were 45–50 cm tall. Prunings were incorporated at 3 weeks before planting at the time of ridging. Results indicated that incorporation of prunings improved soil fertility and could supply about 50 kg N/ha to maize. Although *Cajanus* seemed most promising, it was susceptible to fusarium wilt.

Hedgerow Establishment

155
C
Cobbina, J., B.T. Kang, and A.N. Atta-Krah. 1989.
Effect of soil fertility on early growth of *Leucaena* and *Gliricidia* in alley farms. *Agroforestry Systems 8:* 157–164.

Observed variability in growth of young *Leucaena leucocephala* and *Gliricidia sepium* alley cropped with food crops in an Alfisol between farms was studied. A field study was undertaken to determine whether or not the differential growth of the two tree species was due to variation in soil fertility. Plant height of *Leucaena* and *Gliricidia* at 6 and 9 months after planting had significantly correlated with soil organic C and total N. Dry-matter yield at 12 months after planting also had strong correlation with plant height, soil organic C, and total N for *Leucaena*, but not for *Gliricidia.*

Hedgerow Husbandry: Seed Dormancy

156
C
Duguma, B. 1985.
Studies on factors affecting establishment of selected tree species of potential importance in agroforestry. MSc thesis, University of Ibadan, Nigeria. 413 pp.

The effect of hot water, sulphuric acid, and hand scarification on germination percentage of *Gliricidia sepium, Leucaena leucocephala,* and *Sesbania graniflora* seeds and the effect of stage of development on germinability of *Leucaena* were studied to assess level of dormancy and stage of development at which dormancy begins in *Leucaena* seed and to identify suitable treatment techniques to enhance germination of the seeds. The germination percentage of acid treated and untreated *Leucaena* seeds at different stages of development as affected by cold room, refrigerator, laboratory, and screenhouse storage was also studied to select the best storage facilities for maintaining viability of seeds for at least 9 months. Percentage germination of *Gliricidia* and *Sesbania* decreased with increasing water temperature and sulphuric acid concentration. Highest germination percentages of 98 and 71 were recorded for untreated *Gliricidia* and *Sesbania* seeds, respectively. Similarly, the percentage germination of green, light, and dark brown *Leucaena* seeds was significantly high (73, 98, and 97% respectively) without any treatment while germination of the untreated dry seed was less than 20%. Germinability of the last group of seeds was significantly improved by hot water and sulphuric acid treatments and hand scarification.

Seed Treatment

157
C
Duguma, B., B.T. Kang, and D.U.U. Okali. 1988.
Factors affecting germination of *Leucaena* (*Leucaena leucocephala*) (Lam.) de Wit seed. Seed Science and Technology 16: 489–500.

The effects of seed treatment, storage, and stage of seed development on the germination percentage of *Leucaena* seeds were studied in order to economize and improve existing seed-treatment methods. Freshly harvested mature green, light brown, and dark brown seeds showed high germination percentages of 73, 98, and 97, respectively, while dry seeds showed low a germination percentage (20). Mechanical scarification improved the germination (98%) of dry seeds. The germination percentage of dry seeds was improved by hot water, sulphuric acid treatments, and by mechanical scarification. Hot water (initial temperature of 100 °C) treatment at a volume ratio of one seed to two of water, increased the germination percentage. Sulphuric acid treatment was effective only with concentrated (98%) acid. The effectiveness of acid treatment depends on the seed:acid (w/v) ratio and treatment time. The highest germination percentage (95%) was obtained with excess sulphuric acid treatment for 30 minutes. A one to one seed:acid ratio and 10 minutes treatment gave the same result as a 10 to one seed:acid ratio with 60 minutes treatment. These treatments increased germination to over 80. A higher seed to acid ratio would economize the use of acid. Seed stored in a refrigerator (2 °C) or in a cold room (6 °C) gave the best result. Dry seeds stored well under room temperature or in a screenhouse without losing germinability for at least one year.

Establishment: Hedgerow Evaluation

158
C
Earnest-Schaeben, R. 1994.
Potential of alley cropping maize and cassava in south Benin, West Africa: evaluation of the establishment phase. Verlag Ulrich E. Grauer Wendlingen. 131 pp.

A field trial was conducted on a clayey, kaolinitic, isohyperthermic Paleustalf at the Benin station of IITA. The design was a split-split plot experiment with four replica-

tions. Two alley cropping treatments with *Leucaena leucocephala* hedgerows, pigeon pea (*Cajanus cajan*) hedgerows, and no-tree controls were the main plots. Hedgerows were spaced 4 m apart. Two fertilizer levels, N, 90 and 40 P, 75 K kg/ha were used in the subplots. Three cropping systems, sole cassava, maize-cassava intercrop, and sole maize were used in the sub-subplots. Results showed that *Leucaena* established slowly then picked up, and coppiced rapidly. In contrast, the *Cajanus* established more quickly and initially yielded twice the amount of mulch material than *Leucaena*. However, *Cajanus* could not withstand frequent prunings, and had a survival rate of only 40% 3 years after establishment. Preliminary root observation and analysis of soil properties indicated that below-ground competition between trees and crops may be strong in the zone. Results further indicated that alley cropping can reduce, but not completely eliminate, the use of supplemental fertilizer. Cassava yield was not diminished by alley cropping. Cassava was suggested as a stronger competitor for growth factors than maize and would therefore suffer less competition. The land use efficiency measured by land equivalent ratios (LER) was not depressed by alley cropping. The modification of the spatial arrangement of cassava-maize intercropping under alley cropping warrants further investigation.

Hedgerow Management

159
C
Erdmann, T.K., P.K.R. Nair, and B.T. Kang. 1993.
Effects of cutting frequency and cutting height on reserve carbohydrates in *Gliricidia sepium* (Jacq.) Walp. Forest Ecology and Management 57: 45–60.

The effects of cutting frequency and cutting height on reserve carbohydrates in *Gliricidia sepium* were examined. Sample cores of major lateral roots and lower stems, taken from plants cut at 3- and 6-week intervals and from uncut (control) plants, as well as plants that were cut at 0, 25, and 100 cm above the ground, were analyzed for soluble sugars and starch using the perchloric acid method. Results indicate that *G. sepium* utilized the stem starch to support initial coppice shoot growth after cutting and that this carbohydrate fraction was present in sufficient concentrations to preclude the use of root reserve carbohydrates. The result demonstrated that deciduous trees in the seasonally dry tropics accumulate reserve carbohydrates early in the dry season.

Hedgerow Establishment

160
C
Ezenwa, I.V. and A.N. Atta-Krah. 1992.
Early growth and nodulation in *Leucaena* and *Gliricidia* and the effects of pruning on biomass productivity. Pages 171–178 *in* Biological nitrogen fixation and sustainability of tropical agriculture, edited by K Mulongy, M. Gueye, and D.S.C. Spencer. John Wiley, Chichester, UK.

Patterns of early root and shoot growth and nodulation, and the effects of increasing frequency of pruning on leaf dry-matter yield, root dry weight, and nodulation of *Leucaena leucocephala* and *Gliricidia sepium* were studied in two pot experiments. In *G. sepium* the emphasis during early growth was on the production of lateral roots and nodulation; in *L. leucocephala* it was on the elongation of the tap root. This may have been the cause of delayed nodulation in *L. leucocephala* as the lateral roots (the major point of attachment of nodules) were observed only at 12 weeks after planting. Increasing the frequency of pruning from 12-week to 4-week intervals significantly reduced leaf and root dry-matter yields and nodulation in both species. The highest leaf dry-matter yields were produced with 8-weekly and 12-weekly pruning regimes, while the highest root weight was produced by the uncut plants. For all nodulation parameters measured, uncut plants performed better than plants cut every 4 weeks, but were inferior to those cut every 8 weeks which, in turn, were inferior to those cut every 12 weeks, indicating that a lenient pruning regime may enhance nodulation and/or nodule longevity.

Biomass Production: Hedgerow Husbandry

161
C
Friday, J.B. and K.S. Friday. 1990.
Production of foliar biomass in hedgerows in the Philippines. *Leucaena* Research Reports 11: 115–117.

For more than a decade farmers in the uplands of the Philippines have been using densely spaced hedgerows of legume trees planted along soil contours for soil conservation and fertility management. The system was originally developed using *Leucaena leucocephala* (Lam.) de Wit as the hedgerow species, but the psyllid (*Heteropsylla cubana*) infestation which began in 1985 in the Philippines made it important to investigate other species. An additional constraint to the hedgerow system is the difficulty of procuring the large amounts of seed needed to plant dense hedgerows. This study compared *Leucaena leucocephala* with *Gliricidia sepium* (Jacq.) Walp., another species naturalized in the Philippines, for green manure production from double and single tree row hedgerows.

Pruning Management

162
C
Jama, B. and P.K.R Nair. 1989.
Effect of cutting height of *Leucaena leucocephala* hedges on production of seeds and green leaf manure at Machakos, Kenya. *Leucaena* Research Reports 10: 46–48.

The trial investigated the effects of cutting heights of *Leucaena* on the production of leaf manure and flower/seed at Machakos field station. Ten meter long hedges were pruned back to 30, 60, and 90 cm above ground 2 years after establishment. Results showed an increased percentage of plants and green leaf manure the greater the cutting height.

Hedgerow Establishment

163
C
Kang, B.T., R. Vadivel, O.A. Osinubi, and F.M. Gatmaitan. 1986.
Establishing and managing alley cropping plots. International Institute of Tropical Agriculture, Ibadan, Nigeria. 6 pp. (English and French editions.)

This pamphlet provides a practical guideline for establishing and managing woody hedgerows and alley cropping plots.

N-Fixation

164
C
Ladha, J.K., M.B. Peoples, D.P. Garrity, V.J. Capuno, and P.J. Dart. 1993.
Measurement of the N-fixation of hedgerow vegetation in an alley crop system using 15N natural abundance method. Agronomy Abstracts (1993): 253.

This study evaluated the 15N natural abundance 15N method to estimate N-fixation by *Gliricidia sepium*, a multipurpose tree common in alley cropping systems in the tropics, and assessed the suitability of the non-nodulating legume *Cassia spectabilis* as a non-fixing reference. The 15N of total N of *Cassia* and *Gliricidia* was determined from 6 prunings between January 1990 and July 1991. Variation in the 15N of extractable soil N with depth, and in different plant parts of the trees was also examined. Data on the proportion of plant nitrogen derived from N-fixation using *Cassia* compared to Napier grass and maize as alternative references are presented.

Nitrogen Fixation

165
C
Liya, S.M., C.T.I. Odu, A.A. Agboola, and K. Mulongoy. 1991.
Estimation of N-fixation by nitrogen-fixing trees in the subhumid tropics using 15N dilution and different methods. Pages 240–242 *in* The use of stable isotopes in plant nutrition, soil fertility and environmental studies. International Atomic Energy Agency (IAEA), Vienna, Austria.

Nitrogen fixation by leguminous trees contributes N to agroforestry systems and enables farmers to grow their own N fertilizer. Estimation of the amount of N fixed is necessary to assess the value of leguminous trees. The amount of N fixed in the first year by *Leucaena leucocephala* with and without inoculation with Rhizobium strain TAL 1145 was compared with that of *Gliricidia sepium* and *Albizia lebbeck* without inoculation. The non-N-fixing reference plant was *Cassia siamea*. The legumes were grown in the field, without irrigation, at the International Institute of Tropical Agriculture, Ibadan, in concrete cylinders, of 0.28 m^{-2} surface area and 1 m deep, sunk in the ground and filled 16 years earlier with a sandy, high base status Entisol. Two-month-old seedlings of each species were transplanted into the cylinders in a completely randomized design with four replications. Two months before transplanting, 15N had been incorporated into the soil organic matter by applying N (10.2 kg/ha) as a solution of ammonium sulphate with 5% at 15N enrichment and sucrose. The C:N ratio was 10. At harvest, 13 months after planting, leaves, stems, roots, pods, and litter were collected separately, dried, ground, subsampled, and analyzed for N and 15N excess by the International Atomic Energy Agency in Vienna. Nitrogen fixation was calculated (a) using the difference method, by comparing the N uptake of the N-fixing species with that of the non-N-fixing control, and (b) using the 15N dilution method, by calculating fixed N in the different plant organs, with the corresponding organ of the non-fixing species as a control. The percentage atom enrichment of *Cassia* leaves was used as the control for *Leucaena* pods, and total fixed N was calculated by summation of the fixed N in the different plant parts.

Nutrient Yield

166
C
Lulandala, L.L.I. and J.B. Hall. 1990.
Nutrient removals in harvesting of *Leucaena* hedgerows at Mafiga, Morogoro, Tanzania. Forest Ecology and Management 35: 207–216.

Studies were undertaken to determine the effects of nutrient removal and nutrient balance in production systems involving *Leucaena* hedgerows in monoculture and in intercropping with fertilized maize and fertilized beans, at Mafiga, Morogoro, Tanzania from 1980 to 1984. *Leucaena* foliage was being harvested for fodder which was being taken away from the production sites four times each year over a period of 41 months. Nutrients removed with the fodder and the corresponding nutrient balance in the soils of production sites were monitored. Overall nutrient drains of 88 kg N, 48 kg K, 20 kg Ca, 8 kg Mg, and 5 kg P/ha/year were estimated. The implications of these results in sustaining the productivity of the areas involving *Leucaena* are discussed and relevant management approaches are suggested.

General

167
C
Mansary, S.D. 1987.
Report on a selected use system in Sierra Leone. Training course on agroforestry research for development 11–29 May 1987, Nairobi, Kenya. 9 pp.

The predominant form of land use in Sierra Leone is shifting cultivation or rotational agriculture. The problems associated with the system are highlighted. Even though carefully designed agroforestry research work in the country is inadequate and in the

rudimentary stage, it is focused on finding alternative land use systems to shifting cultivation which has been observed to be unproductive and impracticable for the country. Alley cropping, which is identified in other countries as a suitable alternative to shifting cultivation, is also being tried. Present agroforestry research work is described together with proposed land-use research in agroforestry.

Nitrogen Contribution; Nitrogen Fixation

168
C
Mulongoy, K. and N. Sanginga. 1990.
Nitrogen contribution by *Leucaena* in alley cropping. IITA Research 1: 14–17.

The paper describes three related experiments to assess N cycling in alley cropping, using *Leucaena* (*Leucaena leucocephala*) as the hedgerow tree. Experiment I assessed the amount of N fixed, Experiment 2 monitored the fate of N from prunings, and Experiment 3 monitored the N contribution of below-ground plant parts. All three experiments were conducted on research plots at IITA. The results showed that integration of trees, especially nitrogen-fixing trees into alley cropping systems can contribute to low-input, sustainable agriculture through the maintenance of soil fertility and the addition of soil organic matter.

Biomass and Nutrient Yield

169
C
Mwenye, R.W. 1984.
Study of biomass production and nutrient and crop performance of four woody species alley cropped with maize. Research Report, Farming System Program, IITA, Ibadan. 37 pp.

In order to study the suitability of woody species for alley cropping with maize, a field experiment was conducted on an Egbeda soil series (Oxic Paleustalf) at the International Institute of Tropical Agriculture, Ibadan to determine biomass production, and nutrient and crop performance. *Leucaena* gave the highest grain yield of 3700 kg/ha followed by *Gliricidia* at 3696 kg/ha with 4-m spacing and fertilizer application. *Leucaena* also gave the highest dry matter yield of prunings at 5.3 t/ha. In terms of nutrient recycling, *Leucaena* and *Gliricidia* recycled the highest level of N, P, and Ca, while *Alchornea* recycled the highest levels of Mn. Alley cropping maize with *Leucaena, Gliricidia,* and *Alchornea* on the Egbeda soil appears to be a promising alternative to the traditional bush fallow. These selected woody shrubs also produce significant amounts of mulch material which suppresses weeds and the shrubs produce significant amounts of staking material.

Hedgerow Species; Nodulation; N-Fixation

170
C
Okogun, J.A. 1994.
Agronomic and microbiological factors influencing hedgerow tree establishment in alley cropping. PhD thesis, University of Ibadan, Ibadan, Nigeria. 251 pp.

Field and greenhouse studies were undertaken on an Alfisol at Ibadan and an Ultisol at Onne to evaluate fifteen woody species (indigenous and exotic) for use in alley cropping and to determine the effects of planting crops at different intervals (0, 25, 50, 75, 150 cm distance from hedgerows). Four levels of weeding regimes were tested on early growth of trees, with and without fertilizer application. Growth parameters, N-fixation nodulation, and microrrhizal fungi infection were measured. Results showed that fertilizer application improved nodulation in all nodulating legumes, by as much as 80% in *Albizia lebbeck* on the nonacid soil and by 56% on the acid soil. Nitrogenase activity in *Gliricidia sepium* ILG 55 was improved by fertilization by 82–85%. N-

fixation in *Leucaena* was depressed by fertilizer application. Although, the biomass of the woody species was positively responsive to fertilizer application, the microrrhizal infection of the roots was depressed. Regardless of fertilizer addition, *Afzelia bella*, *Senna spectabilis*, and *Dialium guianense* performed poorly in 46% both soils. *Albizia lebbeck* was superior to other woody species in all parameters measured. Trees generally had no adverse effect on the yield of food crops in this cropping system. Weed competition reduced biomass in *Senna* by 78%. Early weeding seemed to be a more critical factor affecting the performance of *Gliricidia* and *Leucaena* than fertilizer application.

Biomass Yield: Woody Species

171
C
Rao, D.L.N., H.S. Gill, and I.P. Abrol. 1990.
Regional experience with perennial *Sesbania* in India. Pages 189–198 *in* Perennial *Sesbania* species in agroforestry systems, edited by B. Macklin and D.O. Evans. Proceedings of a workshop held at International Center for Research in Agroforestry (ICRAF), Nairobi, Kenya, 27–31 Mar 1989, NFTA, USA.

Biomass production, nutrient cycling, and nitrogen fixation by perennial *Sesbania* species for farm forestry applications in alkaline soils were evaluated in four field experiments during 1982–8. *Sesbania grandiflora* grew fast, but could not tolerate the severe winter; *Sesbania formosa* yielded 38 t/ha of dry biomass in 28 months in 2 ¥ 2 m plantation geometry. Provenances of *Sesbania sesban* grew fast, had favorable wood distribution, and had high biomass production and nitrogen fixing ability. Fuelwood (dry) was 83–127 t/ha, 20 months after transplantation in 2 ¥ 2 m. About 90% of the roots were confined to the surface (0–30 cm) soil layer. Fuelwood production was 44.5 t/ha in 3 ¥ 1 m and 1 ¥ 1 m, respectively, 30 months after transplanting. In direct seeded (5–20 kg/ha), high density plantations, fuelwood was 12 t/ha in the first year, but coppices in the subsequent 3 years yielded 25–32 t/ha/yr and 1–1.2 t/ha foliage with a green leaf manuring (kg/ha) capacity of 46 N, 2.5 P, 14 K, and 5.5 S. There was excellent nodulation and nitrogen fixation in the three experiments, ranging from 312 to 466 kg/ha/yr. Average minimum N-fixation rate was 346.5 kg/ha/yr.

Nitrogen Fixation

172
C
Sanginga, N., K. Mulongoy, and A. Ayanaba. 1985.
Effect of inoculation and mineral nutrients on nodulation and growth of *Leucaena leucocephala*. Pages 419–427 *in* Biological nitrogen fixation in Africa, edited by H. Ssali and S.O. Keya. Proceedings of the First Conference of the African Association for Biological Nitrogen Fixation held 23–27 Jul 1985, MIRCEN, Nairobi, Kenya.

Experiments were conducted at the International Institute of Tropical Agriculture (IITA) and at Fashola, southwestern Nigeria, to identify and characterize indigenous rhizobia nodulating *Leucaena leucocephala* (Lam.) de Wit, and to monitor the influence of some mineral nutrients on the effectiveness, survival, and competitive ability of the most promising strains. Establishment of *Leucaena* was poor at both locations as a result of low soil fertility and the presence of only few native rhizobia capable of nodulating *Leucaena*. Isolates IRc 1045 and 1050 obtained from *Leucaena* grown at Fashola and IITA were found to be the most effective rhizobia for *Leucaena*. At IITA, only inoculated plants nodulated, while at Fashola all the plants produced nodules. At the latter location, nodulation in uninoculated plots was partly 69% due to the presence of rhizobium IRc 1050 introduced strains and indicated that indigenous rhizobia were poor competitors. Inoculation with IRc 1050 and 1045 combined with phosphorus improved plant growth and nitrogen fixation. The amount of N fixed symbiotically by *Leucaena* was estimated at IITA by the difference method; it ranged between 225 and 350 kg/ha in 6 months, representing about 58% of the plant N.

Hedgerow Establishment

173
C
Tonye, J. 1986.
Alley cropping in Cameroon. Pages 158–162 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. Proceedings of an international workshop held 10–14 Mar 1986. IITA, Ibadan, Nigeria, International Development Research Centre (IDRC), Canada.

The Cameroon Institute of Agronomic Research introduced alley cropping to lowland farmers of the high-rainfall forest zone in 1984. Preliminary results from on-station trials show differences in growth rates between *Leucaena* species and cultivars.

Crop Production; Nitrogen Contribution

174
C
Xu, Z.H., P.G. Saffigna, R.J.K. Myers, and A.L. Chapman. 1992.
Nitrogen fertilizer in *Leucaena* alley cropping. I. Maize response to nitrogen fertilizer and fate of fertilizer 15N. Fertilizer Research 33: 219–227.

Experiments were conducted in the semiarid tropics of northern Australia to evaluate the response of maize (*Zea mays* L.) growth to the addition of N fertilizer and plant residues and to examine the fate of fertilizer 15N in a *Leucaena leucocephala* alley cropping system in which supplemental irrigation was used. *Leucaena* prunings, maize residues, and N fertilizer were applied to alley cropped maize grown in 15N microplots which were installed in the alleys formed by *Leucaena* hedgerows spaced 4.5 m apart. The 15N-labelled fertilizer was used to examine the fate of fertilizer N applied in the presence of mulched *Leucaena* prunings and maize residues. Application of *Leucaena* prunings increased maize yield while addition of N fertilizer in the presence of the prunings produced a further increase in maize production. There was a positive interaction between N fertilizer and *Leucaena* prunings in increasing maize production. The addition of maize residues in the presence of N fertilizer and *Leucaena* prunings decreased maize yield and N uptake and increased fertilizer 15N loss from 38% to 47%. Maize recovered 24–79% of fertilizer 15N in one cropping season, depending on the application rate of N fertilizer and field management of plant residues. About 20–34% of fertilizer 15N remained in the soil. More than 37% of fertilizer 15N was apparently lost from the soil and plant system largely through denitrification when N fertilizer was applied at 40 kg N ha^{-1} or more in the presence or absence of plant residues. The contribution of mulched *Leucaena* prunings to crop production in the alley cropping system was enhanced by N fertilizer application.

Hedgerow Establishment

175
C
Yamoah, C.F., P. Ay, and A.A. Agboola. 1986.
The effects of some methods of establishing *Gliricidia sepium* on food crop performance, growth, and survival rate of *Gliricidia.* The International Tree Crops Journal 4: 17–31.

Establishment of *Gliricidia sepium* in an alley cropping system with arable crops was studied in the Guinea savanna zone of Nigeria. Maize height, grain yield, and percent ear leaf nutrient content were not adversely affected by *Gliricidia* during the establishment phase. Maize grain yield and *Gliricidia* growth rate were significantly improved by the application of N fertilizer but not the survival rate of *Gliricidia* which declined with time in all the establishment methods used due to the erratic rainfall pattern, especially in the case of 0.5 m cuttings. The use of longer (1.2 m) cuttings gave the highest survival rates during the dry season especially when rainfall was erratic. It can be concluded that when intercropping *Gliricidia* with food crops, it is safe to plant both at the same time.

Hedgerow Species

176
C
Yamoah, C.F., R. Grosz, and E. Nizeyimana. 1989.
Early growth of alley shrubs in the highland region of Rwanda. Agroforestry Systems 9: 171–184.

Early growth of some woody shrubs used in alley cropping were studied in the Buberuka Highland and Central Plateau region of Rwanda. The two agroecological zones have altitudes in the range of 1800–2400 m and 1500–1900 m, respectively. The effect of intercropped bean, potato, pea, and wheat on early growth of *Sesbania sesban (Sesbania)* was studied; the effect of lime and manure applications on growth of *Sesbania, Leucaena* spp. (*Leucaena*), *Calliandra Calothyrsus (Calliandra),* and *Markhamia lutea (Markhamia)* was investigated; and growth of *Sesbania* and *Leucaena* were examined at selected locations. Bean grown in association with *Sesbania* enhanced the growth of the shrub in the Central Plateau region. At both sites, growth of *Sesbania* was reduced by intercropped pea. A significant increase in the growth of *Sesbania* was observed during the dry season in June and July. Biomass and height after one years' growth of *Sesbania* were higher in the Buberuka than in the Central Plateau region. Growth of the shrubs ranked as *Sesbania, Leucaena, Calliandra,* and *Markhamia* in the Buberuka Highlands. Application of farmyard manure also increased the growth rates of the shrubs. *Calliandra* and *Leucaena* were most responsive to liming. *Leucaena* responded less to liming with manure application, *Calliandra, Sesbania,* and *Markhamia* showed no definite trends. *Sesbania* and *Markhamia* were least influenced by the application of lime. Their respective LRIs were 0.35 and 0.46. The average growth rates for *Sesbania* ranged between 26.4 and 62.2 cm/month and for *Leucaena* 13.1–27.4 cm/month.

Establishment; Hedgerow Biomass

177
CB
Duguma, B. 1985.
Studies on factors affecting establishment of selected tree species of potential importance in agroforestry. PhD thesis, University of Ibadan, Ibadan, Nigeria. 413 pp.

The effects of seed treatment including hot water, sulphuric acid, and hand scarification were tested on the germinability of *Gliricidia sepium, Leucaena leucocephala,* and *Sesbania grandiflora.* The best storage facilities that can maintain viability of seeds were studies under cold room, refrigerator, laboratory, and greenhouse storage for different stages of seed development in *Leucaena.* The influence of planting depth and angle of planting on sprouting potential of cuttings of *Gliricidia* and *Leucaena* were assessed in the field. Pot experiments were also set up to assess the lime and phosphorus requirements of acid soils. Rhizobium inoculation on growth of *Leucaena* in five soils was supplemented with lime and phosphorus. Field trials were conducted to determine the effect of pruning regimes on the biomass production, N yield, the survival of three species, and on the yield of alley cropped maize and cowpea. Results indicated that germination of *Gliricidia* and *Sesbania* decreased with increasing water temperature and acid concentration. *Gliricidia* gave the highest (98%) germination rate and *Sesbania* (77%) when seeds were not treated. The germination rate of fresh *Leucaena* seeds was higher (73–98%) than dry seeds (20%). However, germination of dry seeds was improved by hot water, acid or hand scarification; a seed ratio of 2:1 at 100 °C for 24 hours was best for *Leucaena* (80% germination). Angular planting (47) of *Gliricidia* and *Leucaena* cuttings was better than perpendicular planting, with generally higher sprouting for *Gliricidia.* Shallow planting (10–20 cm) lower, i.e., basal portions of stem were better for *Gliricidia.* Liming and P applications improved the growth of *Leucaena* in all acid soils. Nodulation of *Leucaena* was also enhanced by inoculation. Biomass and N yield of the species increased with increasing pruning height. Biomass yield increased in the order of *Leucaena, Gliricidia, Sesbania.* Dry-matter yield of *Leucaena* was higher in the wet than in the dry sea-

son. The yield of alley cropped maize and cowpea increased with decreasing pruning height, and increasing frequency of pruning. Pruning frequency did not affect the survival rate of *Leucaena*, slightly reduced the survival rate of *Gliricidia*, and completely killed *Sesbania*.

Hedgerow Species; Soil Fertility

178
CB
Kang, B.T. and O. Onafeko. 1989.
Spatial chemical soil variability in alley cropped plots. Agronomy Abstracts (1988): 55.

Alley cropping is an agroforestry system in which arable crops are grown between hedgerows of planted shrubs and trees which are periodically pruned to prevent shading of the companion crop(s) and to provide mulch and green manure. The study was carried out in alley cropped plots that had been continuously cropped for 6 years. The experimental area was located on a degraded Alfisol (Oxic Paleustalf). The effect of planting of four hedgerow species (*Acioa barteri, Alchornea cordifolia, Gliricidia sepium,* and *Leucaena leucocephala*) grown at 4-m interhedgerow spacing were compared to a control (no hedgerow) plot. Large lateral variability in surface soil pH, organic C level, and P, K, Ca, and Mg status were observed within the alleys. Long-term alley cropping with the four woody species also resulted in differences in soil chemical and nutrient status. Alley cropping with *Leucaena leucocephala* showed the highest soil organic C, extractable P, exchangeable K, and Mg status.

Hedgerow Species; Establishment

179
CB
Nwosu, A.O. 1986.
Germination and establishment of *Acioa barteri* and *Anthonotha macrophylla*: potential of alley cropping trees for Imo State. Higher National Diploma in Forestry. Michael Opara College of Agriculture, Umuagwo-Ohaji, Nigeria. 89 pp.

Eighty seeds each of *Anthonotha* and *Dactyladenia* (syn. *Acioa*) *barteri* were sown at shallow and deep soil depths as treatments with 4 replications. Results showed that germination in *Dactyladenia* started at the same time regardless of treatment. However, *Anthonotha* germination was faster in shallow than in deep sowing. *Anthonotha* had the highest overall germination. Poor germination in *Dactyladenia* was attributed to poor storage of seeds. Height growth of *Dactyladenia* was more than *Anthonotha* when established in alley plots.

Hedgerow Management; Biomass; Weed Control; Spacing

180
CBG
Gathaara, G.N., E.L. Glumac, and P. Felker. 1991.
Three-year growth studies of *Leucaena leucocephala* (1094) and *L. pulverulenta* (1001) at two spacings in Texas. Forest Ecology Management 40: 189–198.

The performance of *Leucaena leucocephala* and a superior *L. pulverulenta* family were examined over a 3-year period at spacings (1.5 m ¥ 1.5 m and 1.5 m ¥ 3.0 m) in order to compare two mechanical weeding operations. *Leucaena pulverulenta* was examined since faster-growing families of this cold-hardy, low-mimosine *Leucaena* species were recently identified. There was no significant difference in yields between the species but there was a significant difference between spacings. The annual growth rates for the first, second, and third seasons' growth for *L. leucocephala* were 3.73, 10.11, and 6.00 t/ha for the close spacing and 3.03, 7.14, and 5.04 for the wider spacing, respectively. The annual growth rates for the first, second, and third seasons' growth for *L. pulverulenta* were 2.03, 8.35, and 8.31 t/ha for the close spac-

ing and 1.25, 9.38, and 5.29 for the wider spacing, respectively. The *L. leucocephala* had greater coppice than the second year's growth for *L. pulverulenta*, despite its higher susceptibility to frost during the first and second winters.

Alfisol; Crop Production; Hedgerow Husbandry

181
CD
Kang, B.T. and B. Duguma. 1985.
Nitrogen management in alley cropping systems. Pages 269–284 *in* Nitrogen management in farming systems in the humid and subhumid tropics, edited by B.T. Kang and J. Van der Heide. Institute for Soil Fertility, Haren, The Netherlands.

Although nitrogen is known to be a very important element for increasing food crop production in the tropics, use of fertilizer nitrogen is limited in many areas of the tropics due to its high cost and lack of availability. Hence the need to find technically feasible and viable alternative nitrogen sources for the resource-poor farmers in order to reduce dependency on commercial fertilizer nitrogen. There has been a great deal of interest in recent years on the use woody leguminous species as potential sources of nitrogen due to their high nitrogen fixing capacity. Woody legumes grown in hedgerows can be successfully intercropped with food crops in alley cropping systems. Regular prunings of the woody legumes produce large quantities of green manure for the companion food crops. *Leucaena leucocephala* and *Gliricidia sepium* grown in 4-m spaced hedgerows on an Alfisol can produce over 200 and 100 kg N/ha/year with five prunings, respectively. The use of woody legumes in alley cropping with food crops, therefore, needs to be recommended for adoption by farmers in the tropics as a low input but stable method of food farming.

Crop Production; Spacing

182
CD
Karim, A.B., P.S. Savill, and E.R. Rhodes. 1993.
The effects of between-row (alley widths) and within-row spacings of *Gliricidia sepium* on alley cropped maize in Sierra Leone. Growth and yield of maize. Agroforestry Systems 24: 81–93.

The effects of inter- and intrahedgerow spacing of *Gliricidia sepium* were investigated on growth and grain yield of maize at Senehun in southern Sierra Leone. Four between-row spacings (2, 4, 6, and 8 m) were combined with three within-row spacings (0.25, 0.50, and 1.00 m) in a split block design. Maize was planted at populations of 20,000, 40,000, and 53,333 plants ha^{-1} in alleys and as a monocrop. All plots were fertilized with N, P, and K before pruning of the trees. When pruning started, only the pure maize plots received fertilizer; prunings from the hedgerows were returned to the appropriate alleys in the other plots. Plots with the highest maize populations gave the best yields before pruning, but lower populations gave improved yields after pruning. Yields of maize increased with increasing alley widths before the start of pruning, after which the narrower alleys of 2 and 4 m outyielded the wider ones by almost double, probably due to the large amount of nutrients applied in prunings. Alleys of 2–4 m wide, planted not closer than 0.50 m within rows, resulted in more than twice the yields of maize than in the 8-m alleys planted at 0.25 m within rows. Hedgerow shading reduced grain yield of maize before the start of pruning.

Hedgerow Species: Crop Yield

183
CD
Kass, D. and D.L. Kass. 1987.
Alley cropping of annual food crops with woody legumes in Costa Rica. Proceedings of a Symposium on Advances in Agroforestry held at Turrialba, Costa Rica, 1–11 Sep 1985, edited by J.W. Beer, H.W. Fassbender, and J. Heuveldop. Informe Tacnico Centro Agronomico Tropical de Investigacion y Ensenaza 117: 197–208.

Investigations were conducted in Informe Tacnico Centro Agronomico Tropical de Investigacion y Ensenaza (CATIE) in 1982 to test the performance of maize, cassava, and *Phaseolus vulgaris* (beans) in an alley cropping system using *Erythrina poeppigiana* and *Gliricidia sepium* for 3 years. Yields of maize and beans could be maintained at 2.6 t/ha and 0.8 t/ha, respectively, under *Erythrina*. *Gliricidia* yield could not be sustained at 40 t/ha in alley cropping or with fertilizers. Differences in growth habits and biomass production of woody legumes are causes of differences observed in yield.

Nitrogen Fixation

184
CD
Ladha, J.K., M.B. Peoples, D.P. Garrity, V.T. Capuno, and P.J. Dart. 1993.
Estimating dinitrogen fixation of hedgerow vegetation using the Nitrogen-15 natural abundance method. Soil Science Society of America Journal 57: 732–737.

Leguminous trees are known to play a major role in alley farming due to their ability to increase soil organic matter and recycle N. Information is scarce on their N fixing under field conditions because of methodological difficulties. This study examined whether the 15N natural abundance (+15N) method could be applied to an alley cropping system to estimate N-fixation by *Gliricidia sepium* (Jacq.) Walp. The study also assessed the suitability of the nonnodulating legume, *Senna spectabilis* (DC.) Irwin and Barneby as a suitable reference for investigations with N-fixation studies. The hedgerow species were planted in double rows, 3 m long with 5-m-wide alleyways, at an acid upland site in the Philippines. The +15N of total N of *Senna* and *Gliricidia* prunings was determined from six samplings between January 1990 (17 months after establishment) and July 1991. The 15N of the total N of samples from nonfixing *Senna* ranged from 4.47 to 7.28 with an average and standard error of 6.16 and 0.41. These values were similar to those of extractable N of soil from different soil depths, ranging from 4.66 to 7.33, suggesting that *Senna* is a suitable nonfixing reference species. The changes in 15N of total N of prunings were similar in both tree species; therefore, the observed variation was considered not to have interfered with estimation of N-fixation (Ndfa). At four of the six sampling times *Gliricidia* had an Ndfa close to 50, whereas at the other two sampling dates the Ndfa dropped to 30 and 35. This study also provides the first quantitative data demonstrating that *Senna* is a non-N-fixing legume.

Crop Production: Hedgerow Husbandry

185
CD
Nyenti, T.E. 1991.
The relationship between pruning intensity of *Leucaena leucocephala* and the performance of associated mixed cropped maize and cassava. MSc thesis, University of Ibadan, Nigeria. 32 pp.

Some farmers in southern Nigeria have been observed to apply late pruning of the *Leucaena* hedgerow in alley cropping with intercropped maize and cassava. An experiment was therefore initiated at IITA, Ibadan to investigate the effect of delayed pruning of *Leucaena* hedgerows in an alley cropping system with maize and cassava.

Only the performance of the main crop was used in this thesis. The intercropped observation was conducted from June to September 1991. The trial was carried out using a randomized complete block design with four replications and the following five treatments. *Leucaena* hedgerows were pruned at five different frequencies (every 2, 4, 6, 8, and 10 weeks) with "no pruning" treatment serving as the control. It was observed that soil moisture was higher near the hedgerows than in the middle of the plot. In the control (unpruned) plot the reverse was observed. No consistent pattern was observed between the pruning cycles (2–10 weeks) and surface soil moisture. *Leucaena* pruning yield leaf area index, plant height, and maize stover yield did not show any significant differences among the pruning cycles. Maize grain yield decreased with delayed pruning or longer pruning cycles, although differences were not statistically significant. Delayed pruning shades the crops.

Crop Production; Hedgerow Management

186
CD
Riley, J. and S. Smyth. 1993.
A study of alley cropping data from northern Brazil: I. Distribution properties. Agroforestry Systems 22: 241–258.

Trees and plants of a Brazilian *Inga*/maize/beans alley cropping experiment were assessed for their distributional properties over 3 years. Results for the crop data demonstrated similarities between the distributions for alley crops and sole crops, abnormality shown by positive skewness and peaked distributions. Year-to-year changes in the distributional shapes were demonstrated as soil nutrient depletion increased and as climatic variables fluctuated. Between-row variation across the alleys was often of a similar size to within-row variation. Initial recommendations for analysis of such data are given on the basis of these results.

Crop Production; Nitrogen Fixation

187
CD
Sanginga, N., K. Mulongoy, and A. Ayanaba. 1986.
Inoculation of *Leucaena leucocephala* (Lam.) de Wit rhizobium and its nitrogen contribution to a subsequent maize crop. Biological Agriculture and Horticulture 3: 347–352.

The N contribution from *Leucaena leucocephala* inoculated with two elite strains of Rhizobium, IRc 1045 and 1050, was examined at the International Institute of Tropical Agriculture (IITA) Ibadan and at Fashola, southwestern Nigeria. Only inoculated plants nodulated at Ibadan, but at Fashola, all the plants produced nodules regardless of inoculation treatments. At both locations, Rhizobium inoculation increased total N and dry matter of *Leucaena* as compared to the uninoculated plants. The effect of inoculation was statistically equal to the nitrogen treatment. The amount of N fixed annually was estimated at IITA by the difference method. It ranged between 448 and 598 kg N/ha and represented 52% and 61% of total N in the plant. After 6 months, *Leucaena* was cut at IITA, and maize TZESRW was grown in the same plots to assess the influence of previous inoculation treatments on N contribution of *Leucaena*. Maize yield data indicated that nitrogen in *Leucaena* prunings from inoculated plots was 87% as efficient as 80 kg urea N/ha but prunings from uninoculated plots were equivalent to 38 kg urea N/ha. In plots where the prunings were removed, the leaf litter and decaying roots and nodules contributed N equivalent to 42 kg urea N/ha. In order to maximize the benefits from *Leucaena* in farming systems, more studies are needed on N recovery and appropriate management strategies.

Biomass Production; Crop Production; Shading

188
CDE
Hocking, D. and D.G. Rao. 1990.
Canopy management possibilities for arboreal *Leucaena* in mixed sorghum and livestock small farm production systems in semiarid India. Agroforestry Systems 10: 135–152.

The chronic shortage of fodder for draft animals is a major problem for small farmers in the semiarid tropics. *Leucaena leucocephala* has improved productivity in many places in India and in various cropping systems, usually as either a pure crop or in a hedgerow alley cropping configuration. Mixed cropping with arboreal forms is seldom seen. For off-season fodder production, hedgerows have the disadvantage of being open to unmanaged browsing when unfenced (as is usual). Arboreal forms of fodder are generally far less vulnerable to animal damage. In this paper, the components of production of sorghum and arboreal *Leucaena* are measured under different intensities of canopy lopping. Pollarding of the *Leucaena* at the time of under-sowing with sorghum gave the best management option. In a year with less than 50% of average seasonal rainfall, this system gave a yield of 4.6 t/ha/yr fresh wt fodder and 3.8 t/ha/yr dry wt of fuel harvests, while increasing the standing crop of wood by 1.8 t/ha/yr and retaining a yield of sorghum grain equivalent to 46% of pure sorghum cropping; the LER of this system was 1.35. Maximum cash value was attained with an unlopped pure crop *Leucaena* followed by pollarded *Leucaena* with sorghum; pure crop sorghum achieved a lower value and stability of production. These results demonstrate both the high productivity of *Leucaena*/sorghum based systems, even in poor rainfall conditions. Pollarding transferred the high future timber value of *Leucaena* to the present value of sorghum grain and fuelwood.

Biomass Yield; Crop Production; Inceptisols; Soil Fertility

189
CDF
Alvarez-Lopez, S. 1986.
Effect of poro *Erythrina poeppigiana* (Walpers) O.F. Cook, planted at four spacings on the production of maize (*Zea mays*) in an alley cropping system. MSc thesis, Universidad de Costa Rica/Centro Agronomico Tropical de Investigacion y Ensenaza (CATIE), Turrialba, Costa Rica. 87 pp.

The influence of the poro tree, *Erythrina poeppigiana*, planted at four spacings, on the production of maize, *Zea mays*, was evaluated in an alley cropping system. The experiment was carried out in an Typic Humitropepts. The poro trees were planted vegetatively by large stakes, 6 m apart. Maize was planted between the trees in lines of ten; maize (Tuxpeno C-7) was sown. Treatments were four planting densities of poro and one control without trees. Two entire cycles (pollarding/corn harvest) of this system were evaluated. The largest biomass production and the highest nitrogen content of the poro was found in the 6 ¥ 1 m planting density. The annual amount of organic matter recycled to the soil through two pollardings was 6.69 t/ha dry weight, with the 6 ¥ 1 m treatment, with an N content of 3% of which 73% came from the leaves. The treatments with the highest grain and nitrogen production were the control, the 6 ¥ 4 and the 6 ¥ 3 m plots, all of them were statistically different ($P<0.05$) from the 6 ¥ 2 m and the 6 ¥ 1 m plots. The yields were 7.43, 6.18, 6.08, 4.22, and 4.19 t/ha/yr of grain, respectively. Up to 40% of the total corn nitrogen was found in the grain. As for the nitrogen balance in this cropping system, the effect of poro in the different treatments was considered positive. The measurements over one experimental year showed that the generated 200 kg N/ha to the system in the 6 ¥ 1 m treatment. In the same treatment, the grain extracted 63 kg of N/ha from the system so that there was an excess 137 kg/year of nitrogen supplied by the poro to the system. There was an increment in extractable acidity and a corresponding lowering of the soil pH as well as a gradual decrease of the carbon/nitrogen ratio over time.

Crop Production; Decomposition; Soil Fertility

190
CDF
Haggar, J.P., E.V.J. Tanner, J.W. Beer, and D.C.L. Kass. 1993.
***Nitrogen dynamics of tropical agroforestry and annual cropping systems.* Soil Biological Biochemistry 25: 1363–1378.**

The processes of active soil organic matter maintenance (SOM) and synchrony (timing of release of organically bound nutrients to coincide with crop demand) were assessed for their contribution to the maintenance of crop nitrogen availability in alley cropping. Two maize alley cropping treatments with *Erythrina poeppigiana* and with *Gliricidia sepium* were compared to sole-cropped maize in an 8-year-old experiment at Centro Agronomico Tropical de Investigacion y Ensenaza (CATIE) in Costa Rica. Maize yield, N uptake, and N release from mulch and crop residue decomposition were measured each month during one cropping cycle. The effects of changes in active soil organic matter (SOM) on available N were assessed by measuring field N mineralization and the size of the microbial N pool through the cropping season. Two subtreatments were introduced to assess the contribution of a current mulch application to maize N uptake; (1) removing the mulch and (2) applying N labelled mulch. Monthly sampling of 15N in the mulch, microbial biomass, and maize allowed assessment of the synchrony of mulch N release and crop uptake. The alley cropping treatment doubled maize biomass and N content, N release from mulch and residue decomposition, and N mineralization compared to the sole. Soil microbial N was not significantly different between treatments, but increased by 80% during the cropping season. Maize grown in the alley plot with the mulch removed contained only 3–15 less N at maturity. Similarly 15N labelled mulch only contributed about 10% of maize N. The percentage contribution of mulch 15N to the maize declined from 13 to 14% 30 days after planting to 8–11% 100 days after planting. Total recovery of mulch N by the maize was only about 10 kg/ha^{-1} and almost all of this was taken up by 60 days after planting. The contribution of mulch N to weed N content declined from 15 to 24% 7 weeks after mulch application to 2–6% at 9 months after application. Mulch N contributed only 3–5% of the microbial N pool at 40 days and this fell to zero by 105 days. Higher rates of N mineralization resulted in alley cropping from the build up of readily mineralizable organic N in the soil over the 7 years of tree mulch application. The size of the microbial N pool was not to be related to nitrogen availability or organic residue inputs. Mulch N released during a cropping season increased maize N uptake by 15% over sole plots. The long-term buildup of the SOM reserve of mineralizable organic N was more important than the synchrony of mulch N release and crop uptake in determining the higher productivity and N uptake in the alley crop compared to the sole crop.

Crop Production; Hedgerow Management; Entisol; Soil Fertility

191
CDF
Kang, B.T., H. Grimme, and T.L. Lawson. 1985.
***Alley cropping sequentially cropped maize and cowpea with Leucaena* on a sandy soil in southern Nigeria. Plant and Soil 85: 267–277.**

The potential of alley cropping maize and cowpea with the giant *Leucaena (Leucaena leucocephala* (Lam.) de Wit) cultivar K-28 was studied on an Entisol (Psammentic Ustorthent) in southern Nigeria. In this trial, the crops were grown in 4-m wide alleys formed by periodically pruned *Leucaena* hedgerows. The effect of application of *Leucaena* prunings, nitrogen fertilizer, and tillage was studied. Despite the very intensive pruning regime (five prunings/year) for a 6-year period, the *Leucaena* hedgerows continued to produce substantial amounts of prunings, nitrogen yield, and stakes. The application of nitrogen to the maize crop increased dry matter and nitrogen yield from the *Leucaena* prunings. Although high nitrogen yield was obtained from the prunings, the application of low nitrogen rates was still needed for obtaining a high maize yield. Maize grain yield can be sustained at about 2.0 t/ha with continuous application of *Leucaena* prunings only. Without the application of *Leucaena* prunings

and nitrogen, maize yield continued to decline with subsequent croppings. Cowpea grain yield was not affected either by *Leucaena* prunings or by residual nitrogen. Tillage (rototilling) resulted in either higher or the same maize and cowpea yields as compared with no-tillage. The application of *Leucaena* prunings resulted in higher soil moisture retention, organic matter, exchangeable K, Ca, Mg, and also nitrate levels in the soil solution. *Leucaena* and maize appear to extract soil moisture from different zones in the soil. Timely pruning of hedgerows is necessary to minimize shading.

Crop Production; Hedgerow Management; Soil Fertility

192
CDF
Karim, A.B. 1987.
Alley cropping in the uplands of Sierra Leone. PhD thesis, Oxford University, Oxford, UK. 272 pp.

In Sierra Leone, impending food shortages are apparent. An increasing population and its associated pressure on agricultural land has led to forest destruction through increasing intensity of shifting cultivation resulting in declining soil fertility and crop yields. In an attempt to improve or sustain crop production without costly inputs, such as chemical fertilizers, low input crop production technologies using leguminous trees were investigated. Special emphasis was placed on the use of tree prunings as sources of manure either from intercropped trees or from outside the system. Four field experiments were conducted in the "uplands" of Sierra Leone. The term is used to describe well-drained areas, to distinguish them from swamps. They are not necessarily at high elevations. They are well-drained areas and make up about 60% of the total arable land. The effectiveness of tree prunings as sources of nitrogen for maize and the effects of intercropping *Leucaena* and *Gliricidia* with maize, cowpea, and sweetpotato on yields were examined. The effects of between-and within-row spacings of *Gliricidia* on growth and relative productivity, and its competitive interactions with maize were investigated. Twenty t/ha of prunings of *Albizia lebbek, Gliricidia sepium*, and *Leucaena leucocephala* increased yields of maize by 29, 54, and 85%, respectively, over that from an application of 120 kg N/ha. Smaller quantities of *Leucaena* and *Gliricidia* (5–10 t/ha) produced lower yields by themselves but the addition of 50–100 kg N/ha increased them. *Cassia siamea, Samanea saman, Delonix regia*, and *A. lebbek* were very effective in conserving soil moisture and reducing soil temperature. *Leucaena* did not adversely affect the yields of intercropped maize, cowpea, or sweetpotato. The *Leucaena* grown among maize were taller than those grown with cowpea, sweetpotato, or those clean weeded. Growth and productivity of *Gliricidia* were primarily affected by planting pattern, whereas those of the intercropped maize were, in addition, affected by the distance from the hedgerow. The number of branches and biomass production of *Gliricidia* decreased with wider spacing. Biomass production per hectare with 2-m alleys (46 t) was about 3–4 times that produced with alleys wider than 4 m (15 t). Before the start of pruning, maize yields increased with increasing alley widths and within row spacings. At the start of pruning, the narrower alleys out-yielded the wider ones. Light was a crucial limiting factor for grain yield, but this was apparent only before the start of pruning. Phosphorus and nitrogen were identified as the most important nutrients for maize and *Gliricidia* grown in the soil used. Maize was more competitive than *Gliricidia*, especially for phosphorus. Cutting *Leucaena* at 75–100 cm at 3 monthly intervals produced the highest dry matter (754 g/plant) and yielded more nitrogen.

Crop Production; Hedgerow Species; Soil Fertility

193
CDF
Matthews, R.B., S.T. Holden, J. Volk, and S. Lungu. 1992.
The potential of alley cropping in improvement of cultivation systems in the high rainfall areas of Zambia: I. *Chitemene* and *Fundikila*. Agroforestry Systems 17: 219–240.

The potential of alley cropping to improve the traditional systems of cultivation, *chitemene* and *fundikila*, in the Northern Province of Zambia are investigated. *Flemingia congesta, Tephrosia vogelii,* and *Sesbania sesban* were grown in association with finger millet, groundnut, cowpea, and maize in various traditional cropping sequences. The indigenous species *Tephrosia vogelii* and *Sesbania sesban* were not able to withstand repeated pruning following the dry season, and were replaced with *Calliandra calothyrsus* and *Cassia spectabilis*. Alley cropping with these species for 4 years did not improve crop yield; the alley crop treatments even dropped significantly below the control treatments in the fourth year casting doubt on the potential of alley cropping for sustainable production. Alley cropping also had no consistent effect on soil chemical characteristics in any of the trials. This lack of positive crop response to alley cropping was attributed to low tree biomass production, low quality of prunings, and an inappropriate cropping sequence. Despite high pools of soil nutrients in the *chitemene*, the effectiveness of the alley cropping to recycle nutrients was not evident in the trials.

Crop Production; Hedgerow Species; Soil Fertility

194
CDF
Matthews, R.B., S. Lungu, J. Volk, S.T. Holden, and K. Solberg. 1992.
The potential of alley cropping in improvement of cultivation systems in the high rainfall areas of Zambia: II. Maize production. Agroforestry Systems 17: 241–261.

The potential of alley cropping for maize production on the low fertility, acidic soils in northern Zambia is described. *Leucaena leucocephala, Gliricidia sepium, Sesbania sesban, Albizia falcataria, Flemingia congesta,* and *Cassia spectabilis* were grown in alley crops with hybrid maize and soybean. All trials received recommended rates of P and K fertilizer; N fertilizer was applied at three rates as a subplot treatment. One trial received lime before establishment. Significant improvement in maize yields through alley cropping only occurred in the lime trial: when no N fertilizer was applied, incorporation of *Leucaena leucocephala* prunings resulted in an increase of up to 95% in yields with a smaller improvement being produced by *Flemingia congesta*. Increase in maize yields over the control treatment correlated with amount of biomass applied. Low biomass production in most of the other tree species used was responsible for the lack of crop response to alley cropping. An economic analysis showed that alley cropping with limed *Leucaena* was only profitable when fertilizer costs were high in relation to maize prices. It is suggested that future alley cropping research focus on screening a wider range of tree species including other species of *Leucaena* for acid tolerance and higher biomass production. Since lime is expensive and difficult to obtain and transport for most small-scale farmers in the region, it is therefore not a practical recommendation.

Hedgerow Species; Crop Yields; Inceptisols

195
CDF
Odongo, J.C.W., C.K. Ong, and M.M. Sharma. 1994.
***Gliricidia sepium* and *Cajanus cajan* in alley cropping systems. Nitrogen Fixing Tree Research Reports 12: 6–9.**

The study was undertaken in a semiarid zone at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Center near Hyderabad (17° 30'N, 78°

16'E, altitude 549 m) to compare the effects of *Gliricidia* and erect pigeon pea on yields of maize and sunflower grown in 9–10-m wide alleys during 1989–1991. Rainfall ranged from 780 to 1050 mm. The soil is a Vertic Inceptisol. The experimental design was a randomized block with three replications. Treatments were sole maize planted at 75 ¥ 15 cm, sole pigeon pea at 75 ¥ 25 cm, maize grown at 100 ¥ 50 cm in *Gliricidia* alleys, and 75 ¥ 25 cm in pigeon pea alleys. Plot size for sole treatments was 12 ¥ 10 m and 26.8 ¥ 12 m for alleys. An interface effect was reduced by separating intercropping from sole using 2-m strips. Sunflowers were also planted during the postrainy season. Maize yield was not significantly affected by hedgerows during the first year. Yield of sunflower was adversely affected by drought, and was more pronounced in alleys than sole plots, due to below- and above-ground competition. Fodder yield of pigeon pea was more than *Gliricidia*. *Gliricidia* and pigeon pea were found to be more compatible with alley cropped maize in the first than in the second year. *Gliricidia* also seemed to be less aggressive than pigeon pea. Long-term studies are needed to confirm the benefits or adverse effects of these legumes in alley cropping under semiarid conditions.

Crop Production: Biomass Production: Nutrient Yield: Weeds

196
CDG
Siaw, D.E.K. 1989.
Alley cropping for sustainable crop production on an Alfisol, using a combination of the woody species *Leucaena leucocephala* (Lam.) de Wit and *Acioa barteri* (Hook F. Ex. Oliv.) Engl. PhD thesis, University of Ibadan, Ibadan, Nigeria. 208 pp.

The growth, biomass, and nutrient yields of *Leucaena (Leucaena leucocephala* and *Acioa (Acioa barteri)* intercropped in the same hedgerow or grown in alternating hedgerows at a interhedgerow spacing of 4 m, and alley cropped with food crops, were studied on an Alfisol in the humid zone of southwestern Nigeria, with bimodal rainfall. Sequentially cropped maize and cowpea were used as test food crops. Uncut *Acioa* and *Leucaena* hedgerows, grown as planted fallow for about 2 years, recorded slightly increased surface soil (0–15 cm) pH, organic carbon, phosphorus, and calcium status than the control plot with no hedgerows. With the exception of pH and potassium, which decreased, the nutrient status of the soils after 4 croppings improved over the initial state before prunings were applied. *Leucaena* produced large amounts of dry pruning biomass (5–9 t/ha) and wood (4–7 t/ha) in 1986. In contrast, *Acioa* produced 0.25–4.41 t/ha of pruning biomass, and 0.07–144 t/ha of wood. *Leucaena* prunings had higher nutrient status and yield than *Acioa*, with means of 4.1 and 1.6 nitrogen (N), respectively, in the prunings. The N contribution ranged from 167 to 324 kg N ha/yr for *Leucaena* and 3 to 65 kg/ha/yr for *Acioa* in 1986. The highest yields of *Acioa* and *Leucaena* hedgerows were obtained with monocropping. Intercropping *Leucaena* and *Acioa* in the same hedgerow suppressed *Acioa* growth, biomass production, and nutrient yield more than it affected *Leucaena*, due to the latter's faster growth. When both species were intercropped in the same hedgerows, total biomass yield declined with increasing proportion of *Acioa* in the combination, ranging from 6 to 10 t/ha in 1986. *Acioa* hedgerows produced an insignificant amount of wood with repeated prunings. Whereas the growing of *Leucaena* and *Acioa* in alternating hedgerows may have merits for the mulch and green manure they provide, intrarow combination of the two species showed that they are incompatible if both objectives are to be met simultaneously. Longer-term observations in different localities, as well as with various species combinations are needed. The percent dry matter decrease per week, as a result of decomposition, was 1.7 for *Acioa*, 4.0 for the 1.1 mixture, and 4.6 for *Leucaena*. Estimated nitrogen released from prunings during the decomposition period was 11 kg N ha^{-1} from *Acioa*, 40 kg from the 1.1 mixture, and 110 kg from *Leucaena*. The surface application of prunings and inorganic N significantly increased crop growth, N uptake, and yield of maize and cowpea. Maize yields were higher in the alley cropped treatments than in the control without woody species. The control yielded 2.7 and 1.5 t/ha maize grain in 1985 and 1986, respectively, while the alley cropping treatments

yielded 4.2–5.1 t/ha in 1985 and 2.7–3.5 t/ha in 1986. The *Leucaena* (75) + *Acioa* (25) treatment had the highest grain yield in both years. The grain yield of cowpea exhibited similar trends to that of maize; the alley cropped treatment yielded 640–830 kg/ha grain, while the control averaged 500 kg. During fallow periods, weed suppression increased with increasing proportions of *Leucaena*; during cropping, *Acioa* mulch demonstrated better weed suppression than *Leucaena* mulch, at the same rate of application.

Competition; Hedgerow Husbandry

197
CE
Huxley, P.A. 1989.
Hedgerow intercropping: some ecological and physiological issues. Pages 208–219 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. International Development Research Centre (IDRC), Ottawa, Canada.

Productive and useful woody species as in managed agroforestry systems have arisen through evolutionary adaptations in response to environmental stresses. Some relevant aspects are discussed. The limits to exploitation and regrowth capacity of woody species are discussed. The limits to biomass production have been modeled and can be assessed. It is now known that the proportion of assimilates assigned to fine-root turnover can, in some cases, equal litter fall; however, total carbon budgets for hedgerow intercropping have yet to be investigated. Where plant biomass is removed from the site (e.g., as crop yields, leafy fodder, etc.), long-term benefit to the soil will be diminished with no inputs. This trade-off needs thorough investigation. In much of hedgerow intercropping, yield sustenance is probably because of the short-term effects of soil and environment. This is made apparent if the effects of tree cover in space and time are compared and contrasted by modeling the situation.

Biomass Production; Crop Production

198
CE
Yamoah, C.F., A.A. Agboola, and G.F. Wilson. 1986.
Nutrient contribution and maize performance in alley cropping systems. Agroforestry Systems 4: 247–254.

The potential contribution of N, P, and K and biomass yield of some woody perennials on maize performance were assessed in an alley cropping trial at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Results indicated that dry matter yield was highest for *Senna*, followed by *Gliricidia* and *Flemingia*. Dry matter yields of *Senna* varied more at the various pruning times, than those of *Gliricidia* and *Flemingia* which were relatively uniform. *Gliricidia* contributed the highest amount of N from the cutback (first pruning) and three subsequent prunings. Dry wood yield at cutback was 14.5 t/ha for *Gliricidia*, 6.8 t/ha for *Flemingia*, and 29.7 t/ha for *Senna*. *Gliricidia* coppiced at a faster rate than *Flemingia* and *Senna*. Maize height, stover, and cob weights in rows close to the shrub hedgerows were slightly lower but not significantly different from those grown at the middle of the alleys. In the alley cropping plots without N application and prunings removed, the maize near the hedgerows performed better than those in the middle of the alleys. The results indicate that supplementary N is needed to optimize yield in the alley cropping system. The amount of N required is higher in *Flemingia* alleys than for *Gliricidia* and *Senna*. Root growth of maize was found to be restricted in control plots without hedges; uptake of the major nutrients (N, P, and K) was also found to be similarly affected in those plots.

Modelling; Soil Fertility

199
CF
Babcock, B. and A.S.R. Juo. 1988.
Modelling an alley cropping system. Agronomy Abstracts (1988): 51.

The alley cropping system is greatly extending the productive life of land after clearing in some parts of the world where slash and burn agriculture is traditional. The reason for the success of the system is not fully understood, partly because it has never been examined as a complete system. Specialists from various disciplines have each examined their part of the system in isolation. Modelling offers a way of integrating their knowledge, finding the gaps in that knowledge, directing further research, revealing which part of the system is successful, and predicting the circumstances under which it might fail. The model used must describe the soil, hedgerow, and crop plants and must describe competition between hedgerow and crop for light, water, and nutrients. The decay of organic matter laid on the soil surface and the result this has on arthropod activity and hence soil macroporosity must be simulated. The model must also deal realistically with deep rapid drainage through macropores. The progress of the modeling system will be described.

Hedgerow Species; Micronutrients

200
CF
Dikko, A.U. 1990.
Micronutrient status and cycling in an alley cropping system with four woody species on an Alfisol. MSc thesis, University of Norway, Norway. 90 pp.

An investigation was carried out in an alley cropping field with *Gliricidia sepium*, *Alchornea cordifolia*, *Leucaena leucocephala*, and *Dactyladenia barteri*. Four N fertilizer rates (0, 45, 90, and 135 kg, N/ha) were applied in the control, and two N-rates (0 and 45 kg N/ha) in alley plots. Maize and cowpea were grown in the main and minor seasons, respectively. Results showed that all the treatments including the control had sufficient amounts of these four micronutrients in the soil, with higher amounts in the alley plot than in the control. Plant analyses indicated that *Leucaena* added highest amounts of Fe, Zn, and Cu, while *Alchornea* added the most Mn. Maize had the highest Fe content, *Gliricidia* the most Cu, *Alchornea* the most Zn, and the control the most Mn with 135 kg N/ha. These trends however differed in the cowpea crop. The highest grain yield was obtained in the control with 135 kg N/ha, alley cropped plots were however not significantly different when fertilized at 45 kg N/ha, except for the *Dactyladenia* plot. The residual effects of N in the control plot reduced cowpea yield but this was reversed in the alleys.

Rhizobium Inoculation; Soil Fertility

201
CF
Gichuru, M.P. and K. Mulongoy. 1990.
Effect of inoculation with rhizobium P application and liming on early growth of *Leucaena* (*Leucaena leucocephala* Lam. de Wit), edited by M. Gueye, K. Mulongoy, and Y. Dommergues. Maximizer la FBA pour la Production Agricole et la Forestière en Afrique. IIIeme Conference de l'AABNF, 7–12 Nov 1988. Pp. 72–80.

The effects of P application (0 and 50 mg/kg soil), inoculation with soil from a field with well nodulated plants of *Leucaena leucocephala*, and of a water suspension of rhizobium strain IRC 1045 specific for *Leucaena* on establishment of *Leucaena* were studied in four soils, two Psammentic Ustorthents, one Oxic Paleustalf, and one Typic Paleudult. Application of P resulted in improved *Leucaena* growth and nodulation in all four soils. The sharpest response was obtained in the Psammentic Ustorthent from a farm where *Leucaena* established poorly. Soil inoculation with Rhizobia resulted in improved *Leucaena* growth, increased dry-matter yield, and nodulation ex-

cept on the Oxic Paleustalf from the International Institute of Tropical Agriculture (IITA) on which *Leucaena* normally performs well. The soil inoculant performed better than the water suspension of strain IRC 1045. Dicalcium phosphate affected the early growth of *Leucaena* on the Typic Paleudult because of its liming properties.

Hedgerow Species; Soil Fertility; Ultisol

202
CF
Gichuru, M.P., B.T. Kang, and S. Hauser. 1990.
Alley cropping with *Acioa barteri, Cassia siamea, Flemingia congesta,* and *Gmelina arborea* on an Ultisol. Agronomy Abstracts (1990): 57.

Studies on intercropping trees/shrubs with food crops in an alley cropping system on nonacid soils have shown good results with *Leucaena leucocephala* and *Gliricidia sepium*. These species performed poorly on acid soils. Research efforts have been directed toward using species adapted to Ultisols. Four woody species plus a no-tree control, and two fertilizer rates applied to a companion crop were studied. Results indicate that *A. barterii*, *C. siamea*, and *F. congesta* maintained soil productivity. *G. arborea* depressed cassava and maize yields. Fertilizer application increased crop yield particularly in *G. arborea* and control treatments. The yield gap between alley cropping widens with continuous cropping. Hedgerows have differential effects on soil nutrient and moisture status. Results suggest this farming system has a potential for acid soils if suitable trees/shrubs are used.

Hedgerow Species; Soil Fertility

203
CF
Onafeko, O.O. 1992.
Performance of selected woody species in relation to soil factors and rhizobium inoculation in the humid zone of Nigeria. PhD thesis, University of Ibadan, Nigeria. 201 pp.

Three related investigations were carried out: (1) on an Alfisol at Ibadan to compare the effects of 6-years' continuous alley cropping on soil properties, using *Dactyladenia barteri*, (syn. *Acioa barteri*), *Alchornea cordifolia, Gliricidia sepium,* and *Leucaena leucocephala* hedgerows with the control (no hedgerow); (2) the effects of N and P and/or rhizobium inoculation on establishment of *Gliricidia* and *Leucaena* were also evaluated at 15 months in three locations (Alabata, Ajaawa, and Zaki-biam); (3) a complementary study was done on six farmers' fields at Alabata using 1-year old *Leucaena* hedgerows. Alley cropping with *Leucaena* showed the highest soil organic carbon, available P, exchangeable K, and Mg status compared to other species. Highest Ca status was found in *Gliricidia*, while *Dactyladenia* showed the lowest Ca and K levels. *Leucaena* responded more to rhizobium inoculation than fertilizer application. P fertilizer increased the uptake of N by 131%, P by 145% in *Gliricidia*, and N uptake by 70% in *Leucaena*. Biomass yield of *Gliricidia* and *Leucaena* differed with location. In addition, the critical nutrient levels (in plant) established were 2.68 N for *Gliricidia*, and 2.95 N for *Leucaena*. The critical P and K levels for both species were 0.1 and 1.83, respectively.

Nitrogen; Biomass Yield

204
CF
Vijayakumar, K.R., G. Mammen, G.G. Pillai, and V.K. Vamadevan. 1986.
Alley cropping of *Leucaena* in coconut gardens in Western Ghats of India. *Leucaena* Research Reports 7: 72–74.

In a trial established in 1983 at Calicut, 4-month-old *Leucaena* seedlings were planted as 1 or 2 double-row hedges between 2 rows of coconuts. Biomass and N yield from seven prunings showed that *Leucaena* can meet the requirements of coconut for green manure and mulch.

Hedgerow Species; Weed Control

205
CG
Rippin, M., J.P. Haggar, D. Dass, and U. Kopke. 1994.
Alley cropping and mulching with *Erythrina poeppigiana* (Walp.) O.F. Cook and *Gliricidia sepium* (Jacq.) Walp.: effects on maize/weed competition. Agroforestry Systems 25(2): 119–134.

This study examined the potential of alley cropping systems to sustain high productivity with low external inputs and reduce weed competition in Costa Rica at Centro Agronomico Tropical de Investigacion y Ensenaza (CATIE). Data were recorded 8 years after establishment of the experiment. Plant residues of *Erythrina poeppigiana* trees (10 t/ha dry matter) planted at 6 by 3 m reduced weed biomass by 52% compared to *Gliricidia sepium* trees (12 t/ha) planted at 6 by 0.5 m which reduced weed biomass by 28% compared to controls without trees. *Erythrina* was more effective in controlling grass weeds, while *Gliricidia* reduced some dicot weeds. Weed maize grain yield under *Erythrina* and *Gliricidia* were higher (3.8 t/ha) than the unmulched control (2.0 t/ha). This difference was attributed to weed suppression by these hedgerow species.

Crop Production; Fodder; Livestock Production

206
CHI
Atta-Krah, A.N. and J.E. Sumberg. 1988.
Studies with *Gliricidia sepium* for crop/livestock production systems in West Africa. Agroforestry Systems 6: 97–118.

The results of four years (1982–1986) of research on *Gliricidia sepium* conducted by the Humid Zone Program (HZP) of the International Livestock Centre for Africa (ILCA) at Ibadan in southwest Nigeria are presented in this paper. The biological characteristics of the species with respect to growth, flowering, and seed production and its potential for improving crop production (through soil fertility maintenance) and livestock production are examined. Integration of *Gliricidia* into cropping systems is needed for optimum realization of its crop improvement quality. The paper presents the alley farming system as one means of achieving sustainability in crop production through integration of trees, such as *Gliricidia*, into cropping systems. The use of *Gliricidia* in intensive feed gardens for production of leguminous fodder is also described as an alternative production system. On-farm experiences with local farmers in the integration of *Gliricidia* and *Leucaena* into local farming systems are also described. Suggestions for more research, targeted specifically at improvement of the species and its utilization, are indicated.

Fodder Production; Hedgerow Establishment; Land Tenure; Livestock Production; Seed Production

207
CHIL
Reynolds, L., A.N. Atta-Krah, and P.A. Francis. 1988.
Alley farming with livestock guidelines. Humid Zone Research Site, International Livestock Centre for Africa, Ibadan, Nigeria. 30 pp.

The background of the International Livestock Centre for Africa's (ILCA) research on alley farming in southern Nigeria is presented. Problems and constraints of alley farming and potential solutions are discussed. Detailed information and guidelines on successful establishment and management of alley farms and intensive feed gardens are provided. Discussions on integration of livestock into alley farming concentrate on sheep and goats which are more prevalent among settled smallholder farmers in the humid zone. Quantitative performance data are given for West African dwarf breeds. The agronomy and extension of alley farming and the effect of land tenure systems are considered. The booklet also contains information on seed production, handling, and rhizobium inoculation.

Hedgerow Establishment; On-Farm Trial

208
CM
Ezeribe, A.C. and M.C. Palada. 1988.
An agronomic evaluation of farmer-managed alley cropping trials in southwest Nigeria. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 53 pp.

Alley cropping, which is a system of growing food crops in alleys between rows of fast growing leguminous trees or shrubs, has been proven to be a viable alternative to the century-old bush fallow system of subsistence farming. Before the system can be adopted by farmers, on-farm trials are needed to truly validate this finding and adapt it to the farmers managerial competence. To do this *Leucaena* was identified as a suitable leguminous species that had proved useful in the sandy Entisol of southwestern Nigeria. An on-farm trial was designed and a number of farmers in Alabata started testing the technology in 1985 and were joined by others in 1986. Activities on these alley cropping farmers' plots were monitored till the end of the 1987 cropping season. Results so far have shown that farmers in the test area were able to establish the alley cropping, food-production systems in their fields where there was no water logging and the soils free draining. Established *Leucaena* hedgerows grew very well and were able to record a fresh biomass yield of over 10 t/ha in the second year after establishment with four prunings. Not only was substantial biomass produced in the farmers' fields, the growing of the traditional food crops of maize + cassava intercrop was also feasible as well as sole maize followed by a new legume cropping system. The latter system introduced cowpea and later soybean to the farmers in the test area. Whereas soil pH, available P, and Ca decreased in the trial, organic C, Mg, K, and total N slightly increased. The farmers' reaction to alley cropping so far has not given a definite direction. Their enthusiasm for the system is manifested by the interest many of them showed in regularly maintaining (weeding) the alley cropping plots. Some however, do not appear to have grasped the system as is manifested by their allowing the alley cropping plots to remain fallow over an extended period in the cropping season.

CROP HUSBANDRY

Modeling

209
D
Anderson, L.S., R.I. Muetzelfeldt, and F.L. Sinclair. 1993.
***An integrated research strategy for modeling and experimentation in agroforestry.* Commonwealth Forestry Review 72: 166–174.**

A strategy for the integration of modeling and experimental work in agroforestry research is presented. The approach, in which modeling is perceived as a central feature determining and coordinating process-based experimental studies, aims to achieve a functional understanding of how agroforestry systems work. The underlying context concerns the effects of placing a variable number of trees into cultivated fields and the mechanisms involved in the resultant interactions between tree and crop species. Four elements of the strategy are described; the modeling approach, the priority research areas, a knowledge base, and necessary organizational structures.

Crop Performance

210
D
Bheemaiah, G., M.V.R. Subramanyam, and S. Ismail. 1992.
Performance of arable crops with *Acacia albida* under different alley widths in dry lands, edited by P. Tauro and S.S. Narwal. Pages 120–122 of Proceedings of 1st National Symposium on Allelopathy in Agroecosystems, 12–14 Feb 1992, CCS Haryana Agricultural University, Hisar, India.

The first 2-year data from alley cropping trials conducted in Andhra Pradesh, India during 1989–90 are reported in this paper. *Acacia albida* hedgerows planted at 3 different widths were alley cropped with castor (*Ricinus communis*), sunflower (*Helianthus annuus*), and red gram (*Cajanus cajan*). Crop growth in all the 3 alley widths were superior to solecrops. Height and biomass of trees were not reduced by intercrops, but were better under castor and red gram than with sunflower.

Crop Production

211
D
Gunasena, H.P.M. 1989.
Agricultural sustainability through alley cropping in Sri Lanka. Indian Journal of Dryland, Agricultural Research and Development 4: 55–61.

In an experiment conducted at Dodangolla, maize cv. Thai composite, winged bean (*Psophocarpus tetragonolobus*) cv. SLS 40, and *Dioscorea alata* cv. Rasawalli were grown as pure stands or intercrops between single rows of *Leucaena leucocephala* or *Gliricidia maculata* (*G. sepium*) spaced 3.6 m apart. The sole crop yield of *D. alata* was 3.6 t/ha, of maize 3.5 t, and of winged bean 3.1 t. Maize + *D. alata* and winged bean + *D. alata* produced yields of 4.2 t compared with the yield of 3.0 t for the maize + winged bean intercrop. The poor performance of the maize + winged bean intercrop was related to heavy shading by both crops. *G. sepium* and *L. leucocephala* produced 7.4 and 4.8 t/ha leaf mulch, respectively. *G. sepium* performed better during prolonged drought periods and produced more fuelwood (7.1 t) than *L. leucocephala* (4.3 t). *G. sepium* and *L. leucocephala* prunings and crop residues of maize, winged bean, and *D. alata* increased soil N and organic matter content.

Crop Production

212
D
Gunasena, H.P.M. 1989.
Integration of tree legumes in cropping systems in the intermediate zone of Sri Lanka. Pages 327–330 *in* Nutrient management for food crop production in tropical farming systems, edited by J. Van der Heide, Institute for Soil Fertility (IB), Haren, The Netherlands.

A long-term experiment was initiated in 1985 at the University Experimental Station, Dodangolla in the intermediate agroecological zone of Sri Lanka to study the effect of integration of tree legumes in cropping systems, their effect on crop yields, and changes in soil fertility. The loppings of the alley crops and the residues were incorporated in the same plots at the end of each season. Among sole crops, yam (*Dioscorea alata*) recorded the highest yield (3.6 t/ha) followed by corn (3.5 t/ha). Corn + yam and winged bean + yam performed better than the corn + winged bean intercrop. The latter was incompatible due to heavy mutual shading by both crops. The crop residues added by corn were the highest (6.6 t/ha) as compared to other crops, and ranged from 0.62 to 1.7 t/ha. The tree legumes added considerable amounts of biomass during and at the end of the growing season. The total biomass produced by both crops was approximately 3.5 t/ha. *Gliricidia* showed better growth than *Leucaena* particularly during prolonged periods of drought. *Gliricidia* also produced more fuelwood (4.7 t/ha) than *Leucaena* (2.7 t/ha) which could provide the subsistence farmers with energy for cooking, as 80% of their energy supply is fuelwood. The soil fertility in-

creased due to the addition of crop residues and loppings of leguminous trees as indicated by changes in soil N and organic matter contents. The results showed the multiple advantages in the use of tree legumes and the potential of their extensive use in the intermediate zone of Sri Lanka.

Crop Production
Entisol

213
D
Kang, B.T., L. Sipkens, G.F. Wilson, and D. Nangju. 1981.
***Leucaena* (*Leucaena leucocephala* (Lam.) de Wit) prunings as nitrogen source for maize (*Zea mays* L.). Fertilizer Research 2: 279–287.**

In field and pot trials at Ibadan, southern Nigeria, the effectiveness of *Leucaena leucocephala* de Wit prunings as N source for maize was evaluated using an N deficient, sandy Apomu soil (Psammentic Usthorthent). The N uptake of seedlings, and N percentage in ear leaves of maize, and grain yield were increased by the application of 10 t of fresh prunings or a combination of 5 t of fresh prunings and N at 50 kg N/ha. The prunings were more effective as N source when incorporated in the soil than when applied as mulch. In the pot trial, prunings applied 2 weeks before planting were better than when applied at the time of maize planting. The apparent N recovery from prunings with early incorporation under greenhouse conditions was similar to that of fertilizer N.

Crop Production

214
D
Kardell, O. 1993.
A theoretical study for North Vietnam of alternative agroforestry systems to pure cassava. Agroforestry Systems 21: 251–262.

Cassava is recognized in North Vietnam as the second most important crop after paddy rice. It is usually grown on highly erodible slopes of the small hills surrounding paddy fields. Cassava crop land is generally in annual use until the yield is less than 3–4 t fresh tubers/ha. This constant cropping system rapidly depletes the soil as fertilizers are infrequently used and crop residues are usually removed from the fields. Erosion is a major problem as the soil is exposed through hand cultivation and regular weeding during a cropping season which coincides with the wet season. Sustainable and productive cropping systems are needed. As a first step towards sustainability this paper presents several possible agroforestry systems in which cassava could be intercropped with a number of nitrogen fixing trees and shrubs. Several theoretical combinations have been examined assuming a critical lower production limit of 3–4 t fresh tubers/ha. Agroforestry systems with sustained high potential yields are recommended for future field experimentation.

Crop Production

215
D
Karim, A.B., P.S. Savill, and E.R. Rhodes. 1991.
The effect of young *Leucaena leucocephala* (Lam.) de Wit hedges on the growth and yield of maize, sweetpotato, and cowpea in an agroforestry system in Sierra Leone. Agroforestry Systems 16: 203–211.

The effects of *Leucaena leucocephala* on the growth and productivity of maize, cowpea, and sweetpotato were studied at Senhum-Kamajei, a high rainfall region in Sierra Leone. The experiment was laid out in a completely randomized design with four replicates of each treatment. The treatments and controls were: pure crops of maize, cowpea, sweetpotato, and *Leucaena* clean weeded and unweeded; and intercrops of *Leucaena* with the food crops, both with and without applied fertilizers after the first year. The growth of *Leucaena* was slow but tended to reduce grain yields of maize,

and tuber and vine yields of sweetpotato in the rows next to the trees, especially in the nitrogen-treated plots. The maize seems to increase the early height growth of the trees.

Crop Production

216
D
Kass, D. 1985.
Alley cropping of annual food crops with woody legumes in Costa Rica. Pages 197–208 *in* Advances in agroforestry research, edited by J.W. Beer, H.W. Fassbender, and J. Heuveldop. *Proceedings of a seminar held in Turrialba*, Costa Rica, 1–11 Sep 1985, Centro Agronomico Tropical de Investigacion y Ensenaza (CATIE).

Research in alley cropping of annual food crops with woody legumes began on the Centro Agronomico Tropical de Investigacion y Ensenaza (CATIE) station in 1992. Results of associating a food crop production system consisting of maize (*Zea mays* L.), common bean (*Phaseolus vulgaris* L.), and cassava (*Manihot esculenta* Crantz) with the woody legumes *Erythrina poeppigiana* (Walpers) O.F. Cook and *Gliricidia sepium* (Jacq.) Steud for 3 years are presented. Yields of *Z. mays* and *P. vulgaris* could be maintained at over 2600 kg/ha/a and 800 kg/ha/a, respectively, by association with *E. poeppigiana* in an alley cropping system. Even higher yields of *P. vulgaris*, but not of *Z. mays*, could be obtained with *G. sepium*. *M. esculenta* yields could not be maintained over the 3 years either with the application of up to 40 t/ha/a of manure and mulches, with the application of mineral fertilizers (N-P-K-Mg-S), or with alley cropping with *G. sepium* or *E. poeppigiana*. Differences in the growth habits and seasonal biomass production by the woody legume species are considered the causes of the differences observed. Work on farms in Puriscal and San Carlos, begun in 1983 and 1984, has not progressed sufficiently for a final evaluation but establishment of *G. sepium* from seeds instead of the more costly stakes was successful on a farm in San Carlos.

Crop Production

217
D
Kass, D.L., A. Barrantes, W. Bermudez, M. Jimenez, and J. Sanchez. 1988.
Results of six years research into alley cropping in La Montana, Turrialba, Costa Rica. EL Chasqui 19: 3–4.

The results are reported of alley cropping experiments carried out from 1982 to 1987 with *Erythrina poeppigiana* or *Gliricidia sepium* and maize or beans as crops. Other treatments included monocropping with the application of cattle dung or mulching with prunings from *Gmelina arborea* or *E. poeppigiana*, intercropping with *Vigna sinensis* (*V. unguiculata*) + mulching with *Gliricidia sepium*, and a control (monocropping with none of these other treatments). The *Gmelina arborea* mulch treatment was applied from year 2 onwards after intercropping with *Mucuna pruriens* in year 1 only. All treatments were fertilized with P, K, Ca, and Mg with and without N. Data presented include changes in soil properties, nitrogen balances, yields of crops and of biomass prunings of *E. poeppigiana* and *Gliricidia sepium*, and economics. Crop yields were greatest in the *E. poeppigiana* mulch treatments and were also high in the *Gmelina* arborea and *Gliricidia sepium* mulch treatments; they were lowest in the alley cropping treatments (for maize) and the control (beans).

Crop Production

218
D
Kass, D.L., H. Jimenez, and D.C.L. Kass. 1986.
Effect of applying prunings of *Gliricidia sepium* to maize and beans on an Oxic Dystropept in San Carlos, Costa Rica. Nitrogen Fixing Tree Research Reports 4: 11–12.

In an alley cropping system with *Gliricidia sepium*, beans and maize were grown in plots receiving no treatment (control), *Gliricidia* prunings (at 2 kg/m2), or *Gliricidia* hedgerows at 6 or 9 m spacings. Each plot was further divided into subplots receiving 0, 100, and 200 kg N/ha. *Gliricidia* prunings increased the yield of both crops in the absence of fertilizer. Yield of crops was lower in alley cropped plots where trees were unpruned.

Crop Production

219
D
Kass, D., J. Sanchez, P. Ferreira, G. Sanchez, and J.F. Araya. 1990.
Yield stability as an indication of sustainability in alley farming systems. Agronomy Abstracts (1990): 59.

Stability analysis in which "stability" was defined as "the square root of the mean square of deviations around a linear time trend divided by the mean over time", was applied to the results of several alley cropping experiments carried out in Costa Rica. In general, bean yields showed the greatest stability in mulch treatments although bean yields over time were higher in the mulch treatments. In all cases, mean yields and stability were higher for mulched and alley farming treatments than for unmulched controls without N fertilization. Fertilization with mineral N generally increased bean yields and stability in all treatments but only increased maize yields and stability in the non-alley farming treatments.

Biomass Production; Crop Production

220
D
Kaudia, A. and A. Getahun. 1990.
Effect of density on biomass yields of *Sesbania sesban* under alley cropping systems. Pages 211–215 *in* Perennial *Sesbania* species in agroforestry systems, edited by B. Macklin and D.O. Evans. Nitrogen Fixing Tree Association (NFTA) Special Publication. 90-01, Waimanalo, Hawaii, USA.

Locally collected *Sesbania sesban* (L.) Merril was planted at eight different planting arrangements in association with agricultural crops at the Ngong/Jamhuri Agroforestry/ Energy Centre, Nairobi. The tree planting densities ranged form 10,000 trees/ha (2 x 0.5 m) to 833 trees/ha (4 x 3 m). Trees were cut back at the age of 1.5 years and biomass yields were assessed. Green leaf manure (GLM) was measured separately from wood yields. Yields of GLM and wood were both highly correlated to tree plant density. Crop yield response over the study period 1986–1988 is briefly discussed.

Crop Production

221
D
Kpomblekou-Ademawou, K. 1989.
Alley cropping maize with *Leucaena leucocephala* in southern Togo. Pages 139–140 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. International Development Research Centre (IDRC), Ottawa, Canada.

A field trial was carried out at Glidji in southern Togo using *Leucaena* hedgerows. Yield data from maize showed that, even under low-rainfall conditions, the addition of *Leucaena* can reduce nitrogen fertilizer use.

Crop Production

222
D
Lal, R. 1989.
Agroforestry systems and soil surface management of a tropical Alfisol. I. Soil moisture and crop yields. Agroforestry Systems 8: 7–29.

Field experiments were conducted on a tropical Alfisol at Ibadan, Nigeria, to evaluate the effects on soil moisture and crop yields of three agroforestry systems. Treatments were two perennial shrubs (*Leucaena leucocephala* and *Gliricidia sepium*) each at 2-m and 4-m row spacings and were compared with no-till and plow-till systems of seedbed preparation. Measurements were made for soil properties, runoff and erosion, nutrient losses in runoff, and crop growth and yield for a uniform maize and cowpea rotation. All of the six plots, each measuring 70 ¥ 10 m, were established on a natural slope of about 7°. Alterations in soil properties and effects on crop growth were evaluated for 6 consecutive years from 1982 through 1987. Seed germination and seedlings gave satisfactory establishment of *Leucaena* hedgerows while establishment of *Gliricidia* from stem cuttings was poor. Maize germination and crop stand were normal while that of cowpea were suppressed by both *Leucaena* and *Gliricidia*. Maize growth and yield were suppressed only in the vicinity of hedgerows. Maize grain yield in agroforestry systems averaged about 10% lower than that of the control. In contrast with maize, agroforestry systems drastically suppressed cowpea grain yield. The average cowpea yield in agroforestry systems was higher than that of the control. The average cowpea yield in agroforestry systems was 30 to 50% of the control. Regardless of the management system, grain yields declined over time at the rate of 340 kg for maize and 96 kg ha/yr for cowpea. Consequently, soil moisture content in the top 0–5 cm layer in agroforestry systems was generally higher than that in the control during both wet and dry seasons. In addition, hedgerows of *Leucaena* and *Gliricidia* acted as windbreaks.

General

223
D
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.

The available research data clearly show that existing knowledge of biophysical processes in alley cropping and other agroforestry systems is much less than that of agricultural and forestry-based systems. The choice of appropriate species and their management still constitutes crucial knowledge gaps in agroforestry systems. Most experiments have been conducted with intensive and monocropping systems. There is a need to evaluate agronomic and economic aspects of agroforestry using traditional cropping systems, e.g., mixed cropping at lower plant populations. More studies are needed on interactions among species, specifically in relation to competition for water, nutrients, and light. The synchronization of nutrients released by the pruning and the period of maximum nutrient demand by the food crop are still unknown. In addition to the biophysical processes, economic feasibility of the system needs to be assessed in the context of the on-farm situations. Agroforestry has the potential to be a sustainable alternative to shifting cultivation. Presently, there is no workable system for major soils and ecological regions of the tropics. Alley cropping has shown some advantages in relatively fertile Alfisols but not in other soils and harsh environments. Innovative agroforestry systems await development. Agroforestry data that can withstand the scrutiny of systems performance indicators on a sustainable basis still constitute a major challenge to research.

Crop Production

224
D
Leihner, D.E. 1988.
Cassava alley cropping project in Benin, West Africa. Cassava Newsletter 12: 12–13.

A regional research program, designed to generate and validate agricultural production technologies for the small-farm sector in West Africa, was initiated recently by the University of Hohenheim, West Germany in collaboration with the International Crops Research Institute for the Semi-Arid Tropics' (ICRISAT) Sahelian Center in Niamey, Niger, and with the International Institute of Tropical Agriculture (IITA) in Nigeria. The largest of IITA's five projects is carried out in the subhumid zone at IITA's station in the People's Republic of Benin. The project's present status is to obtain basic information on resource usage in cassava/maize alley cropping systems, with a view to stabilizing the declining cassava and maize yields in this fragile ecosystem. For the research, improved varieties of cassava (TMS 30572) and maize (TZESRW) are grown in a 3-year rotational scheme either in monoculture or intercropped. The intercropping system includes two alley crops grown with the food crops: *Leucaena leucocephala,* a tropical leguminous tree, and pigeon pea, *Cajanus cajan*, also a legume, which, besides fixing N, produces a small-grain yield for consumption by humans. Initial observations, from the first growth cycle which was completed in April 1987, show that *Leucaena* has slow initial growth, is quickly covered by food crops, and shows symptoms of nutrient deficiency in the acid, red, terre de barre Oxisols of the area. Pigeon pea, however, looks very promising—it shows healthy growth and rapid, dry-matter buildup. The regenerative capacity of both species has been confirmed by earlier research done at IITA headquarters for *Leucaena* and at the Carder de l'Atlantique research farm in Benin by a West German technical aid program. A holistic approach is taken to monitor as many parameters as possible to track the system's efficiency in using nutrients, water, and light, and transforming them into biomass and food. Soil/water status is recorded with tensiometers. It is expected that the alley crops, which are cut regularly to provide mulch for the food crops, will help conserve soil moisture and reduce water stress under conditions of uncertain rainfall, and will slowly decompose to provide plant nutrients from the mineralization of organic matter. Weed problems are also expected to be notably reduced under alley-crop mulch cover. This in-depth analysis of the food-crop/alley crop system is expected to contribute to the understanding of the physiological and agronomic bases of the potential of alley cropping systems to stabilize food crop yields. Once these bases are better understood, alley cropping may be extended to a much larger variety of ecological zones and farming systems. Consequently, it will help overcome the food deficits which periodically plague the African continent.

Crop Production

225
D
Leihner, D.E., R. Ernst, and B.T. Kang. 1990.
Effect of alley cropping with *Leucaena leucocephala* and *Cajanus cajan* on growth and yield of cassava in Benin, West Africa. Pages 278–286 *in* Proceedings of the 8th Symposium of the International Society of Tropical Root Crops held in Bangkok, Thailand, 30 Oct–5 Nov 1988, edited by R.H. Howeler, Bangkok, Thailand.

An alley cropping trial was carried out on an Oxic Paleustalf in the subhumid zone of the People's Republic of Benin. A split-plot design with four replications was used. There were three main plots (alley cropping with *Leucaena*, alley cropping with *Cajanus*, and no alley cropping), two subplots (no fertilizer and 90, 40, and 77 kg/ha of N, P, and K, respectively), and three sub-subplots (sole cassava, cassava-maize intercop, and sole maize). *Leucaena* and *Cajanus* hedgerows with interrow spacing of 4 m were established in 1986. Results of observations on cassava during the 1987–1988 cropping period are presented in this paper. Cassava top dry-matter yield and leaf

area index (LAI) increased with fertilizer application, which also increased the radiation interception. An optimum LAI for root weight increase was maintained for a longer period in unfertilized cassava resulting in larger root yields than in fertilized cassava. Without fertilizer application, root yield of cassava was reduced more by alley cropping with *Leucaena* (33) than with *Cajanus* (22). Loss in root yield when alley cropped with *Cajanus* was mainly due to a reduction in cultivated area. There appeared to be stronger competition between the *Leucaena* hedgerows and cassava grown adjacent to the hedgerows than between *Cajanus* and cassava. With fertilizer application, root yield of cassava alley cropped with *Cajanus* was greater than root yield of cassava alley cropped with *Leucaena* or when grown without alleys. This could be related to the maintenance of a large photosynthetically active leaf area of cassava in the *Cajanus* alley cropping system during the last 3–4 months of the cassava growth cycle.

Crop Production

226
D
Limon, A., D. Kass, and J. Jimenez. 1993.
Cultivar selection of the crop component in agroforestry systems. Agronomy Abstracts 1993: 58.

Most of the emphasis in the improvement of agroforestry systems has concentrated on proper selection of the tree component while ignoring selection of the crop and the animal component. Results of a 3-year trial on a Typic Humitropept indicate considerable differences in the performance of different cultivars of maize (*Zea mays* L.) and beans (*Phaseolus vulgaris* L.) when grown in monoculture or when associated with *Erythrina poeppigiana* (Walpers) O.F. Cook, *Calliandra callothyrsus* Benth., or *Gliricidium sepium* (Jacq.) Walp. A maize hybrid, H-3, from El Salvador with a maturity of about 8 days less than other materials out yielded these materials when associated with woody legumes. Bean cultivars, Negro Guasteco, and DOR 364, performed better when associated with trees than in monoculture.

Crop Production

227
D
Matthews, R.B., J. Volk, and S. Lungu. 1991.
The potential of alley cropping in improving cultivation systems in northern Zambia: the evidence so far. Forest Ecology and Management.

In the northern province of Zambia, traditional forms of shifting cultivation, the *chitemene* and *fundikila*, crops are grown for only 3–4 years before fertility decline and weed encroachment necessitates the abandonment of the field and cultivation of new plots. In all three cultivation systems, there is a need to explore alternative strategies for maintaining and improving soil fertility. Initial diagnostic surveys suggested alley cropping as a possible agroforestry intervention. Trials were subsequently initiated to evaluate the potential of alley cropping to maintain or improve crop yields in the three systems. In the low input traditional systems of *chitemene* and *fundikila*, there was a decline in crop yields and no difference in soil fertility. Four years of alley cropping with *Flemingia congesta* produced a small improvement in the same trial, but *Gliricidia sepium* had no effect. An economic analysis showed that alley cropping with limed *Leucaena* was only profitable when fertilizer costs were high. However, lime is both expensive and difficult to obtain for most small-scale farmers in the region, and is therefore not a practical recommendation. It is suggested that the general lack of response to alley cropping is due to low tree biomass production compared to regions where alley cropping has been successful. Screening of a larger number of tree species and techniques to increase biomass production in the northern province are further needed.

Crop Production

228
D
Mittal, S.P. and P. Singh. 1989.
Intercropping field crops between rows of *Leucaena leucocephala* under rainfed conditions in northern India. Agroforestry Systems 8: 165–172.

Investigations were conducted for 6 years on a sandy loam soil on intercropping hedgerows of *Leucaena leucocephala* (Lam.) de Wit with three field crops viz. maize (*Zea mays* L.), black gram (*Vigna mungo* L.), and cluster bean (*Cyamopsis tetragonoloba* L. Taub.). In treatments 1 and 2, *Leucaena* hedges were planted as pure crops at close (25 cm × 75 cm) and wide (25 cm × 375 cm) spacings. In treatments 3, 4, and 5, the three field crops were intercropped between the hedgerows of *Leucaena* at the wide spacing, and in treatments 6, 7 and, 8 the field crops were raised as pure crops. *Leucaena* was pruned to 75 cm each time it attained a height of 175 cm. The pure crop of *Leucaena* at close spacing produced an average, over the 6 years, of 34 t/ha/yr of green fodder and 9.4 t/ha/yr of air dry fuelwood. The *Leucaena* at wide spacing produced 18.9 t/ha/yr of green fodder and fuelwood. The yield of all the field crops was less when raised as intercrops than as pure crops. Mean maximum net returns were obtained from intercrops of *Leucaena* and cluster bean (Rs 3540 t/ha/yr) which were significantly higher than the returns from pure crop of *Leucaena* at wide spacing but similar to the returns from pure crops of cluster bean. *Leucaena* with maize (Rs 3273 t/ha/yr) and black gram (Rs 3125 t/ha/yr) gave significantly higher net returns over pure crops of *Leucaena* at wide spacing, maize, and black gram.

Modeling

229
D
Muetzelfeldt, R.I. and F.L. Sinclair. 1993.
Ecological modeling of agroforestry systems. Agroforestry Systems 6: 207–247.

Three models are used to describe a system (descriptive models); to generate management recommendations (prescriptive models); and to predict system behaviour and the consequences of management actions (predictive models). A set of agroforestry relevant prototype models are reviewed. The modeling elements that are used in their construction and alternatives to conventional programming for their implementation are then discussed. Three categories of problems encountered in modeling agroforestry systems include gaps in knowledge about particular processes and relationships; deficiencies in how particular aspects of agroforestry systems are modeled; and deficiencies in the modeling environment within which models are constructed, used, and communicated to others. In this review, the deficiencies in modeling particular aspects of agroforestry systems are discussed and then the shortcomings of current modeling environments are considered.

Crop Production

230
D
Mulongoy, K. and B.T. Kang. 1986.
The role and potential of forage legumes in alley cropping, live mulch and rotation systems in humid and subhumid tropical Africa. Pages 212–231 *in* Potentials of forage legumes in farming systems of sub-Saharan Africa, edited by I. Hague, S. Jutzi, and R.J.H. Neate. Proceedings of a workshop held 16–19 Sep, 1985. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.

Fragile, low activity clay soils which are prone to erosion and are characterized by inherently low fertility are common in humid and subhumid tropical Africa. On these soils, forage legumes play an important role in developing sustainable and low input

crop production systems. Woody and herbaceous species such as *Leucaena leucocephala, Gliricidia sepium, Flemingia congesta,* and *Sesbania rostrata* have shown good potential for inclusion in alley cropping systems. *Mucuna pruriens* var. *utilis* is one of the most promising sources of in situ mulch in small- and large-scale crop production. Live mulches of *Psophocarpus palustris* and *Centrosema pubescens* smother weeds effectively and have been shown to sustain high maize yields with little fertilizer N input. Despite the encouraging results obtained with forage legumes on less acid soils, further research is needed to select species that can be included in low-input crop production systems on strongly acid soils.

Crop Production

231
D
Palada, M.C. and B.T. Kang. 1990.
Alley cropping intercropped maize and cassava and sequentially cropped maize and cowpea in southern Nigeria. Pages 89–90 *in* Agroforestry land-use systems, edited by E. Moore. Proceedings of a special session on Agroforestry Land-Use Systems in International Agronomy, American Society of Agronomy Annual Meeting, 28–29 Nov 1988, Anaheim, California. Nitrogen Fixing Tree Association (NFTA), Hawaii, USA.

Data are presented on the effect of alley cropping on crop yield during the early establishment period of woody hedgerows. As expected during the first establishment year, there was no apparent effect of alley cropping on maize yield. In the second year, mean yield of maize with *Leucaena* hedgerows was lower than maize yield with *Gliricidia* hedgerows mainly due to shading. Maize yield with *Gliricidia* hedgerows was similar to that observed in the control plots. There appears to be some positive effect from the addition of *Gliricidia* prunings on maize yield. Alley cropping significantly reduced yield of the second season cowpea crop mainly due to shading by the unpruned hedgerows. Second year cowpea yields were better than first year yields. Yield in the *Gliricidia* plot was higher than in the *Leucaena* plot and equal to that in the control. During the early hedgerow establishment period, there was no apparent effect of alley cropping on cassava yield.

Fallow

232
D
Rao, M.R., C.S. Kamara, F.R. Kwesiga, and B. Duguma. 1990.
Agroforestry field experiments: methodological issues for research on improved fallows. Agroforestry Today 2(4): 8–12.

There is a need for new land-management systems that allow more intensive cropping while at the same time maintaining soil fertility. One option could be rotational systems with planted fallows that improve the soil more quickly than natural vegetation. Like any other rotational system, an improved fallow takes land out of crop production for a certain period. This agroforestry technology may not be appropriate in situations where cropping is continuous as in the high-density areas of Asia and the African highlands. A tree fallow benefits subsequent crops by recycling nutrients from deeper layers up to the top soil. Nitrogen-fixing trees also enrich the soil with nitrogen from the air. Two agroforestry technologies involve the use of multipurpose trees during fallow periods: (1) a system in which planted tree fallows alternate with crops; (2) rotational hedgerow-intercropping systems, in which a period of hedgerow intercropping is followed by a period of uninterrupted hedge growth without crops. Although still at an early stage, this research has highlighted a number of technical issues of particular importance in improved-fallow experiments. These include the choice of tree species, timing of fallow periods, size and arrangement of experimental plots, and management practices including the need for chemical inputs.

Experimentation

233
D
Rao, M.R. and J.H. Rogers. 1990.
Agroforestry field experiments: discovering the hard facts Part 2: agronomic considerations. Agroforestry Today 2(2): 11–15.

The promise of agroforestry lies in hard data coming out of well-planned and properly conducted field experiments. If the 1980s were the period of conceptualization, hypothesizing the potentials of agroforestry, and identifying research needs, then the 1990s should see field experimentation changing those potentials into realities. Numerous projects are already being implemented with the aim of extending and promoting agroforestry technologies. If these are to achieve their goals, there must also be an emphasis on agroforestry experimentation based on well-founded scientific principles. We hope that the ideas and guidelines presented in this two-part article will be helpful to those engaged in this work.

Crop Production

234
D
Reshid, K., A. Getahun, and B. Jama. 1989.
The influence of rainfall distribution on the yield of maize under *Leucaena leucocephala* alley cropping at Mtwapa, Coast Province, Kenya. Pages 383–390 *in* Meteorology and agroforestry, edited by W.S. Reifsnyder and T.O. Darnhofer. Proceedings of an international workshop on the Application Of Meteorology To Agroforestry Systems Planning And Management, 9–13 Feb 1987, Nairobi, Kenya. International Centre for Research in Agroforestry (ICRAF), Nairobi, Kenya.

The study conducted at Mtwapa, Coast Province, Kenya, during the long rains of 1985 and 1986 on the influence of rainfall distribution pattern on the yield of maize under *Leucaena leucocephala* alley cropping showed that the rainfall distribution pattern had a significant effect on the yield of maize even though the total rainfall for both years was the same (1130 mm and 1128 mm for 1985 and 1986, respectively). Maize yields for both years were also consistently higher under high *Leucaena* densities than under low densities or the sole crop. Yields of maize were very low in 1986 as a result of the heavy rains during the early crop growth stage (vegetative) (91%) and little during the pollination and grain-filling stage (reproductive) (9%) as compared to 1985 where rainfall distribution was relatively uniform whereby 58% of the total rainfall fell during the vegetative growth period and 42% during the reproductive period. As the result, yield of maize in 1986 was reduced by about 60% as compared to that of 1985.

Experimentation

235
D
Rogers, J.H. and M.R. Rao. 1990.
Agroforestry field experiments: discovering the hard facts. Part I: statistical considerations. Agroforestry Today 2: 4–7.

The paper outlines some statistical and agronomic considerations that researchers need to take into account when designing field experiments so that they can make valid conclusions leading to recommendations that extension agents and development workers can take to farmers with confidence. It covers the principles of experimentation, special considerations, determining plot size and arrangement, structuring the treatment, choosing the design, and laying out the plots.

Yield Stability

236
D
Sanchez, G., J. Sanchez, and P. Ferreira. 1994.
Mountain immortelle (*Erythrina poeppigiana*) Walp. O. Cook in different tree spacings. Agronomy Abstracts (1990): 62.

A coefficient of stability for each treatment was defined as S_MS/X, S being the stability, MS the mean square of deviations around a linear time trend, and X the mean over time. It is thus analogous to the coefficient of variability with smaller values indicating greater stability. The regression coefficient was also used to determine whether a parameter associated with a particular treatment tended to increase or decrease (degrade) with time. Yields of maize planted twice yearly in association with *E. poeppigiana* at spacings of 6 × 1, 6 × 2, 6 × 3, and 6 × 4 m for 6 years, showed greater stability (lower values of S) but also lower values of X at higher tree densities. Lower values of S and higher values of X occurred in wet season maize plantings. Degradability was lowest in 6 × 2 m tree spacing and greatest with mineral fertilization without trees.

Crop Production

237
D
Selenje, M.B. 1984.
Agroforestry in Lilongwe Agricultural Development Division as a soil conserving and improving approach. Lilongwe Station Report, Lilongwe, Malawi. 9 pp.

Agroforestry is a collective term for land-use systems and practices based on the integration of woody perennials with crops and/or animals. Ecological and socioeconomic reasons for an agroforestry approach include the need to abate the declining land productivity due to erosion, the low adoption rate of conservation practices, monocropping, deforestation, and general environmental degradation, and to meet the needs of the increasing population such as food, fuelwood, and timber. Suitable agroforestry trees in Malawi include *Acacia albida* (*msangu*), *Sesbania* spp. (*mbimu*), *Leucaena leucocephala*, and *Cajanus cajan* (*Nandolo*). The effectiveness of some forms of agroforestry are being tested in the Lilongwe Agricultural Development Division. Maize variety UCA/*Leucaena* alley cropping as a low N-input system was tested during the 1983/84 season at Nkhande in the Ntcheu Project. In this trial, *Leucaena* was planted in ridge furrows during the 1982/83 growing season at 91 cm and 182 cm between rows and was allowed to grow unchecked. In the 1992/93 season UCA maize was grown on the ridges and the *Leucaena* plants were pruned 3 times during the growing season to avoid shading the maize and each time the prunings were laid on the ridges as green manure mulch. Mean maize grain yield of 4511 kg/ha and 4613 kg/ha at the spacing of 91 cm and 182 cm between rows of *Leucaena*, respectively, were recorded compared to 3283 kg/ha from unfertilized pure stands of maize. This apparently shows that maize/*Leucaena* alley cropping can be utilized as a low N-input system. In addition, weed suppression and moisture retention were more noticeable in the maize/*Leucaena* system. In another trial, the effect of *Leucaena* hedgerow as an N-source for maize was studied at Nathenje during the 1983/84 season. The application of 18.5 t/ha fresh *Leucaena* leaf yielded mean maize grain yield of 4259 kg/ha which compared favorably with 412 kg/ha obtained with the addition of 4 bags 20:20:0 as basal dressing and 4 bags calcium ammonium nitrate (CAN) as top dressing. This indicates that *Leucaena* leaf can be utilized as an N-source for crop production. The prunings were more effective with a split application than with a single application. Apart from increasing yield, *Leucaena* leaf is also said to improve soil moisture and structure. The integrated land-use approach whose basic framework consists of boxed crop ridges on the contour; contour buffer strips planted to a variety of perennial crops; and integration of livestock in the farming system is now being implemented and demonstrated at demonstration farms of residential training centers and some EPAs in Ntcheu.

Crop Production

238
D
Shannon, D.A., K.N. Kabaluapa, and M.L. Mpoy. 1989.
Alley cropping: a promising technology for the savanna of Zaire. Agronomy Abstracts (1989): 59.

A trial was conducted in Gandajika, Zaire, to study the effects of alley cropping on yields of maize. Hedgerows of *Leucaena leucocephala* spaced 4 m apart were seeded together with maize in January 1986, on a coarse-textured Alfisol. Treatments were the presence or absence of hedgerows and presence or absence of a low rate of fertilizer. Maize was planted in two seasons per year for 3 years. During the trial, pruning frequency and timing were adjusted to minimize competition with the crop. Fertilizer application increased yields in all seasons. Alley cropping decreased maize yields slightly in the first season and increased yields from the fourth season onward. Without alley cropping, yields generally declined after the third season. Alley cropping without fertilizer resulted in stable yields over time, but with fertilizer, resulted in increased yields over time. Alley cropping is now being tested in on-farm trials.

Crop Production

239
D
Shannon, D.A. and W.O. Vogel. 1994.
The effects of alley cropping and fertilizer application on continuously cropped maize. Tropical Agriculture 71: 163–169.

The long-term effects of alley cropping on maize under continuous cropping with and without fertilizer are reported in this paper. Maize was planted twice a year for 4 years. Maize yields were higher with alley cropping than without alley cropping from the fourth crop onwards. Fertilizer application increased yield for each crop. Average yields over the eight crops were highest when alley cropping was supplemented with a moderate application of inorganic fertilizer. The long-term effects of the treatments on maize yield were estimated by the regression of grain yield on time expressed as consecutive maize crops. A dummy variable was included in the multiple regression equations to account for cropping seasons in which drought or other factors severely reduced yields. Without alley cropping, maize yields declined, while with alley cropping, maize yields increased over time. Alley cropping combined with moderate fertilizer use may be the best option to stabilize yield and increase productivity where long fallow periods are no longer feasible.

Competition; Crop Production

240
D
Singh, R.P., C.K. Ong, and N. Saharan. 1989.
Above- and below-ground interactions in alley cropping in semiarid India. Agroforestry Systems 9: 259–274.

The effect of microenvironment on the growth and yield of cowpea, castor, and sorghum was investigated in a 10-m-wide alley cropping system. A polyethylene root barrier was installed between the root systems of crops and *Leucaena* to examine below-ground interaction and by measurements of both soil moisture and root growth. Microclimate measurements included light, wind speed, humidity, and temperature. Growth and yield of crops declined from 150% to 30% of sole crop as the distance from the hedgerows decreased from 5 to 0.3 m. The presence of the root barrier had a marked effect on crop growth and completely eliminated any reduction in crop yield, although shading by the hedgerow reached 30% to 85% of full sunlight. Microclimate changes in the alleys did not significantly influence crop yield. The substantial increase in crop yield in the middle of the alleys was probably due to the

residual effects of a previous hedgerow, removed 12 months earlier, on the infiltration rate and nutrient status of the soil. These results suggest that alley cropping may induce competition for moisture between the trees and crops which may severely reduce crop yield in the semiarid tropics.

Soil Fertility; Erosion

241
D
Soepardi, G. 1989.
Nitrogen and other nutrients in red/yellow Podzolics of Kumai, Central Kalimantan utilized under an alley cropping system. Pages 177–185 *in* Nutrient management for food crop production in tropical farming systems, edited by J. Van der Heide. Institute of Soil Fertility, The Netherlands.

Research for cultural practices to conserve, and if possible, improve productivity of newly reclaimed red yellow Podzolic soils was undertaken in Central Kalimantan from 1984 to 1987 using lamtoro (*Leucaena leucocephala*) as a hedge crop in an alley cropping system. The lamtoro hedge was maintained at 80 cm height and cuttings were returned to the soil. Crop residues were left in the field and together with the weeds incorporated into the soil during soil preparation for the next crop. Alley cropping in combination with fertilizer application on red/yellow Podzolics was successful in maintaining or improving soil pH, organic C, total N, extractable P, and exchangeable bases. Alley cropping also prevented runoff and erosion from taking place.

Experimentation; Modeling

242
D
Thomas, T.H., P.A. Wojtkowski, P.G. Bezkorowajuyj, D. Nyamai, and R.W. Willis. 1992.
Bioeconomic modeling of agroforestry systems: a case study of *Leucaena* and maize in western Kenya. Pages 153–171 *in* Financial and economic analyses of agroforestry systems, edited by G.M. Sullivan, S.M. Huke, and J.M. Fox. Proceedings of a workshop held July 1991, Honolulu, Hawaii, USA. Nitrogen Fixing Tree Association, Paia, Hawaii, USA.

The paper illustrates how a bioeconomic simulation model and information from a wide variety of sources can be used to provide an assessment of physical and financial performance of an alley cropping agroforestry system in eastern Africa. The structure of the model is described, as are the climatic and topographic features of the area to which the model is applied. The model is used to generate outputs of maize and green and woody biomass under a range of hedge spacings and rainfall levels. These are then combined with data relating to input requirements and input and product prices to determine gross margins and net benefits per hectare from polycultural as opposed to monocultural options under various rainfall and hedge-spacing scenarios. The polyculture option is seen to have a significant advantage over maize monoculture, though this diminishes rapidly as optimal rainfall conditions for the monoculture are approached. Under conditions where the differences in the performance between the two options are marginal, other factors such as varying assumptions relating to labor productivity can have a significant impact. The paper then undertakes an intertemporal analysis to evaluate the economic implications for sustainability of two management options, namely total incorporation and total extraction of biomass for sale as fodder over a long time period. The analysis suggests that both options are viable ones at the chosen discount rate, though, if the farmer can utilize or sell the hedge loppings as animal fodder, the extraction option could be attractive. The paper ends by discussing some methodological implications of bioeconomic modeling for research and extension purposes.

Crop Yield

243
D
Vijayakumar, K.R., G. Mammen, and V.K. Vamadevan. 1986.
Alley cropping of nitrogen-fixing leguminous trees in coconut based cropping systems: a new method of agroforestry. Pages 124–126 *in* Ecodevelopment of the Western Ghats, edited by Nair K.S.S. Proceedings of a symposium held 17–18 Oct at Peechi Kerala, India.

Intensive crop production in the Western Ghats of India has resulted into serious soil-fertility degradation due to a shortage of organic manures. The application of fertilizer nitrogen is also negligible. An exploratory trial was undertaken in Kerala in 1983 using *Leucaena leucocephala* alley cropped with coconut. The *Leucaena* hedgerows were established in staggered double rows (25 x 50 cm) between 2 rows of coconut. The paper reports the positive effect of pruning yields on crop-growth.

Crop Production

244
D
Wardell, D.A. 1991.
Black pepper thrives on living stakes. Agroforestry Today 3(2): 14–15.

The paper describes live staking of black pepper using various multipurpose tree species (MPTS) including *Cedrela odorata* and *Gliricidia sepium* in the Tanga region of Tanzania.

Crop Production; Plantain; Mulching

245
D
Wilson, G.F. and R. Swennen. 1986.
Alley cropping: potential for plantain and banana production. Pages 37–41 *in* Alley farming in the humid and subhumid tropics. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Plantains and cooking bananas are important carbohydrate food sources in the humid tropics. They are traditionally grown in bush-fallow rotational systems, multistorey cropping systems, or backyard gardens. Mulching is shown to be beneficial for plantains and bananas. Alley cropping with leguminous trees and shrubs is proposed as a source of mulch. Three concepts for managing plantains with woody legumes are being tested.

Crop Production

246
D
Yamoah, C.F. 1991.
Choosing suitable intercrops prior to pruning *Sesbania* hedgerows in an alley configuration. Agroforestry Systems 13: 87–94.

Farming is intensive in the northern Rwandan highlands due to scarcity of land. A trial was conducted to choose suitable intercrops with *Sesbania* for alley cropping prior to cutback of the shrub. Potato, pole bean, dwarf, bean, and maize were tested in 4-m alleys. The study indicated that pole bean is most suitable while maize is the least preferred intercrop for a 6-month-old *Sesbania*. Shading by *Sesbania* hedges and competition for nutrients as well as disease incidence are possible causes for the observed yield reduction of intercrops.

Crop Production

247
D
Yamoah, C.F. and J.R. Burleigh. 1990.
Alley cropping *Sesbania sesban* (L.) Merill with food crops in the highland region of Rwanda. Agroforestry Systems 10: 169–181.

In the densely populated Rwandan highlands, food production is constrained by soil erosion and soil fertility decline. Alley cropping leguminous shrubs with food crops on contours can minimize the soil erosion, low fertility, and to its ability to provide wood and forage. The effect of *Sesbania* prunings with moderate levels of N and P on bean (*Phaseolus* sp.) and maize (*Zea mays*) yields were examined in an alley cropping system. The experimental design was a randomized complete block with split-split plots. Main plots were alley widths: 2, 4, 6, and 8 m. Phosphorus (P) at 0.30 and 60 kg P_2O_5/ha were the subplots, and nitrogen (N) at 0.30 and 60 kg/ha were the sub-sub plots. Maize was not supplied with P during the second cropping season. Crop yield in kg/ha included the land space taken by hedgerows. Bean yield in 6 m alleys (1100 kg/ha) was about twice that in 2 m alleys (500 kg/ha). Bean responded to N and P application. Optimum alley width for bean yield was 6 m and was optimum at N 30 kg/ha. Hedgerows provided staking for climbing phaseolus beans. Maize responded to N but not to residual P. Maize yield was highest at 8 m alleys with 40 kg N/ha, but yields from 8 and 6 m alleys with the same N treatment were not significantly different. Maize plants in middle rows were significantly taller than plants in rows adjacent to hedgerows. Alley width and row position had significant effects on maize rust development. There were significantly fewer uredinia in the *Sesbania* alleys relative to the control plots without hedgerow shrubs. Significantly greater rust development was observed in the middle rows than in the border rows.

Crop Production; Hedgerow Species

248
DC
Koudoro, D. 1982.
Evaluation of four woody fallow species for alley cropping with maize and cowpea. Diplôme d'Ingenieur Agronome Specialise. MSc thesis, Université Nationale du Bénin, Benin Republic. 133 pp.

Field evaluation of four woody species (*Alchornea cordifolia, Dactyladenia barteri, Gliricidia sepium*, and *Leucaena leucocephala*) for alley cropping at Ibadan is described. Two row spacings (2 and 4 m) and two N rates (0, 90 kgN/ha) were used. Results indicated that *Leucaena* was the fastest growing at 11 months after planting, while *Dactyladenia* showed the least performance. Cowpea suffered shading from trees during the second season. At 4 m spacing with fertilizer, *Gliricidia* gave the best yield of cowpea (1829 kg/ha) and maize (3471 kg/ha). Maize grain was not significantly affected by spacing. However, yield of maize was low in *Leucaena* without fertilizer application. The general performance of the hedgerows during this early stage was ranked as follows: *Gliricidia, Dactyladenia, Leucaena, Alchornea.*

Vegetable Production;

249
DC
Palada, M.C., J.J. O'Donnell, S.M.A. Crossman, and J.A. Koswalski. 1994.
Influence of four hedgerow species on yields of sweet corn and eggplant in an alley cropping system. Agronomy Abstracts (1994): 72.

Alley cropping systems have been developed to improve long-term soil fertility and productivity in the tropics, thereby increasing and sustaining crop production. While these systems have benefited most agronomic crops, their application to vegetable crops has not been studied extensively. A study is being conducted to determine the applicability of alley cropping for sustainable vegetable production in the Virgin Islands. This paper presents the initial results of experiments conducted in 1993 and

1994 involving hedgerow intercropping of sweet corn and eggplant with four hedgerow species: *Gliricidia*, *Leucaena*, *Moringa*, and pigeon pea. The influence of hedgerows on crop yields, soil moisture, crop competition, and other soil and crop parameters are discussed.

Crop Yield; Pruning

250
DC
Tanyi, E.O. 1991.
The relationship between pruning intensity of *Leucaena leucocephala* and the performance of associated mixed cropped maize and cassava. MSc thesis, University of Ibadan, Ibadan, Nigeria. 32 pp.

An experiment was initiated at the International Institute of Tropical Agriculture (IITA) main station in Ibadan, Nigeria to investigate the effect of delayed pruning of *Leucaena* hedgerows in an alley cropping system with maize and cassava. Only the performance of the main crop was reported in this thesis. The observation of the intercrop was conducted from June to September, 1991. The trial was carried out using a randomized complete block design with four replications and five treatments: five different pruning frequencies (every 2, 4, 6, 8, and 10 weeks) with "no pruning" treatment serving as the control. It was observed that soil moisture was higher near the hedgerows than in the middle of the plot. In the control (unpruned) plot the reverse was observed. No consistent pattern was observed between the pruning cycles (2–10 weeks) and surface soil moisture. *Leucaena* pruning yield, leaf area index, plant height, and maize stover yield did not show any significant differences among the pruning cycles. Maize grain yield decreased with delayed pruning or longer pruning cycles, although differences were not statistically significant. Delayed pruning casts more shade on the crops.

Staking; *Gliricidia Sepium*; On-Farm Trial; Cost and Returns Analysis

251
DCMK
Otu, I.O. 1992.
Effect of *Gliricidia* (*Gliricidia sepium* [Jacq.]) Steud on yam yield in southwestern Nigeria. PhD thesis, University of Ibadan, Ibadan, Nigeria. 264 pp.

The study was designed to (1) assess the suitability of *Gliricidia sepium* as a live stake for white yam (*Dioscorea rotundata*), (2) determine the contribution of *Gliricidia* prunings to soil fertility maintenance, (3) evaluate the effects of *Gliricidia* prunings on soil physical properties, and (4) assess the effects of *Gliricidia* and other mulches on minisett seed yam production technique. The methodology involved an on-farm research (OFR) approach in two locations at Ayepe (a forest zone) and Alabata (a derived savanna zone) in southern Nigeria. The effects of spacings, minisett size, and different mulching materials on the performance and yields of minisetts were examined. Results showed that yam tubers were bigger under bamboo staking than under unpruned *Gliricidia*, due to over 50% shading 6 months after planting. Yield difference was not significant. Three prunings significantly improved yam tuber yield. Additions of prunings also increased yam tubers by 17% in both locations. The soil bulk density was decreased by 13%, soil moisture content increased by 15%, and weed dry matter reduced by 21% due to *Gliricidia* mulch application. Polyethylene (plastic) mulch was however superior to *Gliricidia* and grass mulch in yield and weed suppression. The cost-benefit analysis indicated that using *Gliricidia* stakes is highly profitable.

Competition; Crop Production; Soil Fertility; Oxisol

252
DE
Basri, I.H., A. Mercado, and D.P. Garrity. 1990.
Upland rice cultivation using leguminous tree hedgerows on strongly acid soils. Agronomy Abstracts (1990): 53.

The area of strongly acid, sloping land being cultivated with food crops is expanding rapidly in southeast Asia. Contour hedgerow farming was investigated to reduce soil loss and sustain cereal crop yields in these environments. A field experiment to test the effects of hedgerow management, pruning management, and fertilizer management was established on an Ultic Haplorthox (pH 4.6–5.1, slope 2.5–30%) in two locations at the International Rice Research Institute (IRRI) research site in Claveria, northern Mindanao, Philippines. Terrace formation was well advanced 2.5 years after *Cassia spectabilis* hedgerow establishment. The in situ prunings supplied 132, 7, 45, 39, and 9 kg/ha of N, P, K, Ca, and Mg, respectively, and increased rice yield by 25–35% on a total field area basis. Fertilizer P produced a strong yield response in the presence or absence of prunings. Tree-crop competition reduced rice yield by 50–75% in the 2–3 rows closest to the hedge. Methods to effectively alleviate interspecies competition on strongly acid soils will be a critical agronomic issue on building sustainable contour hedgerow systems.

Crop Production; Soil Moisture

253
DE
Chirwa, P.W. 1991.
Soil moisture changes and maize productivity under alley cropping with *Leucaena* and *Flemingia* hedgerows in semiarid conditions in Lusaka, Zambia, MSc thesis, University of Florida, USA. 120 pp.

The study was conducted at Chalimbana Agricultural Research Station in Lusaka, Zambia. The objective was to study the soil moisture depletion pattern in *Leucaena* and *Flemingia* hedgerow alleys and assess the productivity of alley cropped maize in relation to sole cropped maize. Results showed that maize plants in the second and third rows were taller than those in the first rows (nearer the hedgerows) of both *Leucaena* and *Flemingia* alleys, and maize height was similar in alleys of both species. The fertilized maize was taller than the unfertilized maize in both species' alleys. Maize dry-matter (DM) accumulation and grain yield were lower in the first maize rows than in the second and third maize rows in *Flemingia* alleys but not in *Leucaena* alleys. The soil moisture depletion in fertilized alleys was greater than in unfertilized alleys and there were no differences in moisture depletion among the maize rows in the alleys. The hedgerows had a higher soil moisture content than the maize rows throughout the maize growing season. However, there were no differences in moisture depletion between the hedgerows and the maize rows. The study showed that under low fertility conditions *Leucaena* was a stronger competitor than *Flemingia* for soil resources and caused suppressed growth and low yield of alley cropped maize. Thus, under dry and low fertility conditions, *Flemingia* is a better hedgerow species than *Leucaena*; but, if fertilizer is added, there are no short-term differences between the two species.

Crop Production; Competition; Vertisol

254
DE
Daniel, J.N., C.K. Ong, and M.S. Kumar. 1991.
Growth and resource utilization of perennial pigeon pea (*Cajanus cajan* (L.) Millsp.) at the tree-crop interface. Agroforestry Systems 16: 177–192.

From 1987 to 1989, pigeon pea (*Cajanus cajan* (L.) Millsp.) was grown as a multipurpose tree species in strips with sorghum, sunflower, and chick-pea on a shallow Vertisol. The interaction between the perennial pigeon pea and annual crops was

determined at the tree-crop interface (TCI) by comparing the plants at the interface (I) and in the middle of the block planting (M). Pigeon pea I plants had significantly more branches and bigger stems than M plants at the onset of the following rainy season. The greater number of flowers and grains of the pigeon pea I plants was partly due to a better lateral light level and partly due to a better access to water. On the other hand, the negative effect on annual crops at the TCI extended to 1.5 m during the rainy season and to 2.5 m during the postrainy season. The growth of annual crops significantly reduced 30–40 days after sowing and was associated with the shading by the taller pigeon pea. Root profile data of pigeon pea at the interface indicated that competition for moisture was the major cause for yield reduction of chickpea during the postrainy season but an allelopathetic effect was also suspected. The results are consistent with other TCI studies especially with *Leucaena leucocephala* in the semiarid environment. The possible mechanisms for moisture interaction at the TCI are also discussed.

Crop Production; Root Pruning; Ultisol

255
DE
Fernandes, E.C.M., C.B. Davey, and P. Sanchez. 1990.
Alley cropping on an Ultisol: mulch, fertilizer, and hedgerow root pruning effects. Agronomy Abstracts (1990): 56.

A field experiment was conducted on a Typic Paleudult at Yurimaguas (Peru) to evaluate the effects of mulch (+ M), fertilizer (+ F), and hedgerow root pruning (+ R) on crop yields, weeds, and soil nutrient dynamics in alley cropping. Hedgerows of *Inga edulis* Mart. were planted 4 m apart and the alleys cropped with an annual rotation of upland rice-rice-cowpea. Fertilizers were applied only to alleys. Data for seven consecutive crops show that weed biomass was significantly higher in +F vs –F plots and significantly lower in +M vs –M plots. Crop yields were significantly higher in +M vs –M plots only for crop 2, higher in +F vs –F plots for crops 4 to 7, and higher in +R vs –R plots for crops 5 to 7. Crop yields were reduced close to the hedgerow with a significant quadratic relationship between yield and distance to hedgerow. Available P, exchangeable Ca, and Mg were significantly higher only in +F vs –F plots.

Competition; Crop Production

256
DE
Haggar, J.P. and J.W. Beer. 1993.
Effect on maize growth of the interaction between increased nitrogen availability and competition with trees in alley cropping. Agroforestry Systems 21: 239–249.

Alley cropping experiments with *Erythrina* and *Gliricidia* indicated that maize growing next to *Erythrina* hedgerows had lower biomass (44%) and lower N content (35%) than maize growing in the middle of the alleys. Maize growing next to *Gliricidia* hedgerows had the same biomass but 56% higher N content ($P < 0.1$) than maize growing in the middle of the alleys. However, these differences did not develop until 2 months after sowing the maize. Spatial variability in soil nitrogen mineralization and mulch nitrogen release did not explain any of the differences in growth or N uptake of the maize with respect to distance from the trees. The slower growth of the maize next to the *Erythrina* trees after 2 months is due to increasing light and/or nutrient competition from the trees as the trees recover from pollarding. The apparent lack of competition from *Gliricidia* may be due to different rates of regrowth or different shoot and root architecture. A theoretical model is described demonstrating that crops can only take fuel advantage of the higher nutrient availability under alley cropping if the major part of its growth before the trees recover significantly from pollarding and start competing strongly with the crop.

Crop Production

257
DE
Jama, B., A. Getahun, and D.N. Ngugi. 1991.
Shading effects of alley cropped *Leucaena leucocephala* on weed biomass and maize yield at Mtwapa, Coast Province, Kenya. Agroforestry Systems 13: 1–11.

In an alley cropping trial with *Leucaena leucocephala* at Mtwapa Kenya, reductions of up to 90% in weed biomass were observed under *Leucaena* alley cropping with varying trees between (2, 4, and 8 m) and within-row spacing combinations when compared to a crop-only control. An increase of 24 to 76% in maize yields of alley cropped plots compared to the crop-only control was also estimated. The canopy closed in the 2 m alley width faster than in the 4- and 8-m alley widths, and gave the least weed reduction during the short-fallow period between two cropping seasons. At the end of the short fallow period, substantial fuelwood (up to 8 t/ha) was realized from *Leucaena* stands.

Crop Yield; Competition

258
DE
Khan, G.S. and J.H. Ehrenreich. 1994.
Effect of increasing distance from *Acacia nilotica* trees on wheat yield. Agroforestry Systems 25(1): 23–30.

Some farmers in Pakistan believe that trees may reduce their crop yields so they avoid planting trees in their fields. Many foresters, however, claim that trees are beneficial for crops. This study examined the effect of boundary trees (*Acacia nilotica*) on the growth and yield of associated wheat crops under irrigated conditions in Punjab, Pakistan. Results indicate that the growth and yield of wheat was reduced at close proximity to trees up to 8.5-m distance from the trees. The growth and yield of wheat generally improved as distance from the trees increased. Tree size had no effect on wheat growth. However, the grain yields were slightly lower near the largest trees having a breast height diameter of about 50–55 cm.

Crop Production; Competition

259
DE
Lawson, T.L. and B.T. Kang. 1990.
Yield of maize and cowpea in an alley cropping system in relation to available light. Agriculture, Forestry, Meteorology 52: 347–357.

The incident solar radiation was measured in sequentially cropped maize and cowpea planted between hedgerows of shrubs in an alley cropping pattern. The incident solar-radiation profile was examined and its effect on crop yield determined. The study involved four different species of shrubs; *Leucaena leucocephala* de Wit, *Gliricidia sepium, Alchornea cordifolia*, and *Acioa barteri*, planted at two row spacings (2 and 4 m) and two fertilizer rates (F1 45-20-20 and F2 90-40-40 kg of N/P/K/ha) applied to the maize crop only. The hedgerows were periodically pruned, and the prunings applied as mulch to the plots. The control plots were cropped without hedgerows. Partial shading of the crops by the hedgerows was still observed despite periodic pruning of the shrubs. Incident radiation measured at the height of the leaves subtending the ear in maize, and just above the cowpea canopy, decreased exponentially as a function of an index defined by the ratio of the relative height of the shrubs above the respective height of measurement in the crops (H8-Hc) to the distance (D) between the hedgerow and the adjacent crop row. A higher degree of shading associated with the faster growing species (*Leucaena, Gliricidia*) and/or closer interhedgerow spacing resulted in corresponding decreases in crop yield. Larger amounts of hedgerow biomass production (5 t/ha dry weight) were found to be associated with significant decreases in crop yields owing to increased hedgerow shading particularly with

Leucaena. Hedgerows and the organic residue mulch from the prunings improved the overall soil moisture retention.

Competition; Crop Production

260
DE
Maclean, R.H., J.A. Litsinger, K. Moody, and A.K. Watson. 1992.
The impact of alley cropping *Gliricidia sepium* and *Cassia spectabilis* on upland rice and maize production. Agroforestry Systems 20: 213–228.

Hedgerows of *Gliricidia sepium* and *Cassia spectabilis* were established on slopes ranging from 18 to 31% in an effort to reduce soil erosion and improve upland rice and maize production. Upland rice and maize responded more to soil incorporated *G. sepium* biomass than to mulched, *C. spectabilis*. Incorporating hedgerow biomass equivalent to over 40 kg N/ha, however, did not increase upland rice productivity. Maize planted during the second season responded more to mulching than did rice. Crop performance improved along the slope gradient. Hedgerow-crop competition was observed at the upper and lower interfaces. Terracing increased hedgerow-crop competition at the upper interface by reducing the crop's effective rooting depth. Under prevailing climatic and soil conditions, mixed hedgerows of *C. spectabilis* and *G. sepium* initially produced approximately 7 tonnes of fresh biomass per hectare every 3 months. However, at 4 years after hedgerow establishment, *C. spectabilis* biomass was chlorotic and considerable mortality was observed, suggesting that *C. spectabilis* may be depleting soil N reserves.

Modelling

261
DE
Nygren, P. and J.M. Jimenez. 1993.
Radiation regime and nitrogen supply in modeled alley cropping systems of *Erythina poeppigiana* with sequential maize-bean cultivation. Agroforestry Systems 21: 271–285.

The effect of the spatial arrangement of trees on the photon exposure above an associated crop (PE) was simulated for an alley cropping system using *Erythina poeppigiana* with sequential maize-bean cultivation. These results were combined with estimates of the nitrogen supplied by prunings from different tree densities. A significant difference was found in the PE between the east-west and north-south oriented alleys. The latter exhibited more areas of moderate shade, while the former has unshaded centers and heavily shaded parts next to the tree row. When the simulated PE data was combined with the N supply from tree residues, the wider between-row tree spacings (6 or 8 m, with 1 or 2 m within-row spacing) seemed to be best. Alley cropping tree arrangements of high between-row and low within-row spacings has greater potential to minimize shading and maximize organic matter and N supply from prunings. The east-west seems to be better than north-south orientation.

Alfisol; Crop Production; Competition

262
DE
Rao, M.R., C.K. Ong, P. Pathak, and M.M. Sharma. 1991.
Productivity of annual cropping and agroforestry systems on a shallow Alfisol in semiarid India. Agroforestry Systems 15: 51–63.

An investigation was undertaken at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Center, Patancheru, India from June 1984 to April 1988 on a shallow Alfisol to examine the potential of improving the productivity of annual crop systems by adding perennial species such as *Leucaena leucocephala* managed as hedgerows. Results indicated that crop yields were suppressed by *Leucaena* due to competition for moisture except in the first year. A high degree of competition

was observed in years of low rainfall and on long-duration crops such as castor and pigeon pea. Based on total biomass, sole *Leucaena* was most productive; even when based on land productivity requiring both *Leucaena* fodder and annual crops, alley cropping had little or no advantage over block planting of both components. Application of hedge prunings as green manure or mulch in addition to fertilizer top dressing of 60 kg N and 30 kg P2O5 ha to annual crops did not show any benefit during the experimental period mainly due to below average rainfall. There were indications that (i) alley cropping was beneficial in terms of soil and water conservation with less runoff and soil loss with 3-m alleys than with 5.4-m alleys, and (ii) root pruning or deep ploughing might be effective in reducing moisture competition between hedgerows and crops.

263
DE
Rao, M.R., M.M. Sharma, and C.K. Ong. 1990.
A study of the potential of hedgerow intercropping in semiarid India using a two-way systematic design. Agroforestry Systems 11: 243–258.

Investigations were conducted to explore the potential of hedgerow intercropping with *Leucaena luecocephala* on Vertic Inceptisols over 4 years at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Center, Pantacheru, India. A systematic layout involving different alley widths ranging from 1.35 to 4.95 m and with varying distances between hedge and crops was used. The alleys were cropped with alternate rows of sorghum and pigeon pea. Hedges comprised double *Leucaena* hedgerows 60 cm apart and were periodically harvested for fodder. Soil crops of all components and a sorghum/pigeon pea intercrop were included in all four replications of the study. Starting in the second year, *Leucaena* was progressively more competitive with annual crops, causing substantial yield reduction. Severe competition (primarily for moisture) was observed in narrow alleys and was greatest on pigeon pea. The growth of *Leucaena* was not sufficient to compensate for reduced crop yields. Land equivalent ratios (LERs) calculated on the basis of grain yield of crops and *Leucaena* fodder yields showed that hedgerow intercropping (HI) was advantageous over sole crops only during the first 2 years using wide alleys, but not in the last 2 years. LERs calculated on the basis of total dry matter indicated only a small advantage for HI (13–17%) over sole crops in wider (4 m) alleys. Average returns per year from HI exceeded those of the most productive annual crop system (sorghum/pigeon pea intercropping) by 8% in 4.05 m alleys, and by 16% in 4.95 m alleys. Fodder production during the dry season was 40% of the annual total in these alley widths. Thus hedgerow intercropping at 4–5 m alley width is not very attractive for farmers in semiarid India, which has 600–700 mm of annual rainfall. There is a need to examine the potential of HI in wider alleys. The advantages and limitations of the systematic design are discussed.

264
DE
Rao, M.R., M.M. Sharma, and C.K. Ong. 1991.
A tree-crop interface design and its use for evaluating the potential of hedgerow intercropping. Agroforestry Systems 13:143–158.

A tree-crop interface (TCI) experiment was conducted for 4 years (1984–1987) to investigate the effects of row orientation using *Leucaena leucocephala* Lam. Each TCI plot consisted of a regularly pruned *Leucaena* hedge in the middle and 12 crop rows on either side. Eight such plots were arranged at 45° around a sole *Leucaena* plot with rows oriented viz: north-south, east-west, northeast-southwest, and northwest-southeast. Results showed no significant effect of row orientation, and similarly, no effect was seen on crop rows due to their location on the windward or leeward side of the hedge. The TCI effect was positive on the first crop row in the first year because

Leucaena grew slowly, but depressed the yield of the first 4 to 6 crop rows (1.8 to 2.7 m from hedge) in subsequent years. The adverse effect of *Leucaena* was more severe on sunflower in a relatively dry year than on sorghum in other years. The yield of five hedgerow intercropping (HI) systems with varying alley widths (2.7 to 9.9 m) were compared. Compared to sole stands of *Leucaena* and crops, HI was more productive particularly at close alley widths. For example, hedges spaced at 2.7 m and 3.6 m averaged 37% and 25% higher productivity than the respective sole stands. However, the real potential may have been overestimated. The use and limitations of TCI experiments for studying agroforestry systems are discussed with regard to the design employed in this paper.

Crop Production; Weeds

265
DE
Siaw, D.E.K.A., B.T. Kang, and D.U.U. Okali. 1991.
Alley cropping with *Leucaena leucocephala* (Lam.) De Wit and *Acioa barteri* (Hook. f.) Engl. Agroforestry Systems 14: 219–231.

Seven combinations of *acioa* and *Leucaena* hedgerows and a control (no hedgerow) treatment were sequentially alley cropped with maize and cowpea in 1985 and 1986. The trial was carried out on an Alfisol in the humid zone of southwestern Nigeria. Hedgerows were established in 1983, at 4 m interhedgerow spacing and pruned to a height of 25 cm during cropping. Highest dry matter, wood, and nutrient yields of prunings of *acioa* and *Leucaena* hedgerows were obtained when sole planted. Growing *Leucaena* and *Acioa* in the same hedgerow suppressed dry-matter production and nutrient yield of *Acioa* more than of *Leucaena* due to the faster growth of *Leucaena*. Total pruning dry matter yield was reduced as the proportion of *Acioa* increased in the combination. *Leucaena* prunings had higher nutrient yield than *Acioa*. Under 22-month old uncut hedgerows, weed biomass declined in the presence of *Leucaena*, either alone or in combination with *Acioa*. Weed weight was by about 3 times lower under sole *Leucaena* hedgerows compared with that in the control plot. Alley cropping did not significantly affect weed biomass, although alley cropping with *acioa* and *Leucaena* hedgerows resulted in the dominance of broadleaf weeds while the control had a mixture of broadleaves and grasses. Alley cropping with various combinations of *acioa* and *Leucaena* hedgerows increased maize and cowpea yields more than in the control. Nitrogen application in both years increased maize grain yield. Mean yield increase due to N application in both years was highest in the control (47.2%) followed by the sole *acioa* hedgerow (25.2%) and least in hedgerows with *Leucaena*. There was no obvious advantage for the tested *Leucaena* and *acioa* combinations on maize and cowpea crops as compared to the sole hedgerows over the 2 years.

Crop Production; Root Competition

266
DE
Smucker, A.J.M., B.G. Ellis, and B.T. Kang. 1993.
Root, nutrient, and water dynamics in alley cropping of an Alfisol in a forest savanna transition zone. Agronomy Abstracts (1993): 61.

A 3-year field study comparing root competition between alley crops of maize or cowpea with *Leucaena* hedgerows was conducted at the International Institute for Tropical Agriculture in Ibadan, Nigeria. Above- and below-ground growth, root depth, and soil, water, and nutrient contents were monitored by the minirhizotron, time domain reflectometry, and destructive sampling. Yields of maize increased with distance from the hedgerows. Root numbers were lowest directly below the hedgerows and increased at 50, 150, and 350 cm from the tree hedgerows. New root growth approached 950 $m^{-2}d^{-1}$ during the first 58 days after planting of the maize. Root death rates approached 470 $m^{-2}d^{-1}$. Accumulations of water and possibly some essential nutrients, at 60 cm soil depths, contributed to root growth in this region. First approximations of more than 175 kg of N/ha and more than 2.5 t of C/ha were generated by the death and decomposition of maize and *Leucaena* roots each year.

Competition; Crop Production; Hedgerow Species; Soil Fertility; Weeds

267
DEFG
Salazar, A.A., L.T. Szott, and C.A. Palm. 1993.
Crop-tree interactions in alley cropping systems on alluvial soils of the Upper Amazon Basin. Agroforestry Systems 22: 67–82.

Three leguminous species *Inga edulis*, *Leucaena leucocephala*, and *Erythina* sp. were tested for their potential use for alley cropping on alluvial soils in the upper Amazon Basin, using a crop hedgerow interface design. Prunings were applied as mulch at three rates, 0, 3, and 6.7 mg dry matter/ha/crop. Crop yields, nutrient budgets, and weed control were monitored for three consecutive crops of alley cropped upland rice. Crop yield reductions up to 1.5 m from each of the hedgerow species were more pronounced with *Leucaena* hedgerows. Additional mulching was able to compensate for these reduced yields close to the hedges in *Leucaena* and *erythina* but not in *Inga* systems. In general, rice yields were higher with *Leucaena leucocephala* and *erythina* mulch than with *Inga* mulch; this was attributed to the higher levels of available N provided by the *Leucaena* and *Erythina* as compared to *Inga*. The slowly decomposing *Inga* mulch suppressed weed growth more than *Leucaena* and *erythina* mulches. There was a net export of P from the system which was exhibited by declining soil P levels and decreasing crop yields in all the three tree-crop systems.

Crop Production; Fertilization

268
DF
Adedire, M.O. and S.O. Bada. 1994.
Alley cropping maize and okra with *Leucaena*. Nitrogen Fixing Tree Research Reports 12: 80–82.

Despite the popularity of alley cropping in parts of Nigeria, the peasant farmers in Ogun State, southwest Nigeria became aware of this low input technology only recently. This study was carried out in Igbogila area of Ogun State (7°0'N, 2°9'E) in the forest savanna zone of southwestern Nigeria. The soil was an Alfisol belonging to the Alagba series. Two-meter alleys of *Leucaena leucocephala* established in 1988 were cropped to maize/cassava for 15 years and left to fallow and recropped in 1991 and 1992 for this study. The experimental design was a randomized block with four treatments and three replications. Treatments were alley cropping with *Leucaena* hedgerows, with and without fertilizer applications and the control (no hedgerows), with and without fertilizer application. The plot size was 5 x 5 m, and fertilizer rate was 30 N-13 P-24 K applied in 2 doses at 3 and 6 weeks after planting maize, and okra at 50% flowering. *Leucaena* hedgerows were pruned 3 times and spread in alleys as mulch. Yield of okra was determined from multiple harvests and maize yield determined at 12% moisture. Data were analyzed using the minitab statistical package. Results indicated higher yield under alley cropping for both crops. However, treatments that received only organic fertilizer gave higher yields than plots with *Leucaena* alone. The general performance was: alley cropped + fertilizer > control + fertilizer > alley cropped - fertilizer > control - fertilizer. The study showed that *Leucaena* prunings can increase crop yield even in the absence of inorganic fertilizer.

Crop Production; Soil Fertility; Oxisol

269
DF
Agus, F., D.K. Cassel, D.F. Garrity, and J.O. Rawlings. 1993.
Crop and soil variability under a contour hedgerow system in the Philippines. Agronomy Abstracts (1993): 54.

Alternative farming system packages are needed to promote sustained soil productivity on marginal sloping lands. This research, performed on two Oxisols, evaluated the effects of several farming systems on soil properties and crop production. Hedgerows of *Gliricidia sepium* (G); *G. sepium* and *Paspalum notatum* (GP); *G. sepium*

and *Penisetum purpureum* (napier grass) (GN); and napier grass (Nap) were planted at approximately 5-m intervals on the sloping lands; the control (C) had no hedgerows. Subplot treatments were 0 and 60 kg N/ha. Crop grain yields were higher on treatment G when no N was applied, but declined on treatment Nap regardless of N rates 3 years after hedgerow establishment. The yield decline under treatment Nap may be related with the removal of high K-containing napier biomass. In one sloping alley, soil organic C, pH, exchangeable Ca, and Bray-2 P increased while exchangeable Al decreased with a decline in soil elevation. This gradient caused better crop performance in the lower part of the alley. Yield was suppressed in the first few rows adjacent to each hedgerow. Contour hedgerows with G look promising as a practice to improve soil productivity and reduce soil erosion.

Crop Production: Fallowing: Soil Fertility

270
DF
Atta-Krah, A.N. 1990.
Alley farming with *Leucaena*: effect of short-grazed fallows on soil fertility and crop yields. Experimental Agriculture 26: 1–10.

In a long-term trial comparing the sustainability of *Leucaena*-based alley farming with the conventional cropping system without trees and with continuous cultivation of maize, the integration of short grazed fallows in rotation within *Leucaena* alleys and their effect on soil fertility and crop yields were assessed. The various treatments had no effect on soil pH during the 4-year trial period. The organic carbon and total nitrogen contents of the soils under conventional cropping were lower by the end of the fourth year than those under alley cropping and alley grazing treatments, whereas soil phosphorus levels were lower in the alley cropping and grazing plots. Foliage dry matter production of *Leucaena* under alley cropping management ranged from 6.0 to 6.7 t/ha/yr under continuous cropping and reached 8 t/ha when alley cropping was preceded by a grazed fallow. Crop yields were consistently higher with alley cropping than with conventional cropping. Alley cropping alternated with 2-year grazed fallows gave better crop yields during cropping years than those under continuous cultivation.

Crop Production: Soil Fertility

271
DF
Bashir, J. 1988.
A study of alley cropping maize and green gram with *Leucaena leucocephala* (Lam.) de Wit at Mtwapa, Coast Province, Kenya. MSc thesis, University of Nairobi, Kenya. 135 pp.

Green leaf manure (GLM) from *Leucaena leucocephala* hedgerows established in a split-plot systematic design with 5 replications were incorporated to boost soil fertility by cutting them down to 0.5 m from the ground level 2 weeks before maize crop planting. Two additional cuttings were made during the cropping season for additional GLM and to minimize *Leucaena* shading on the crop. Assessment of crop yields and monitoring of soil fertility trends were carried out over a period of 4 years (1982–1985). It was observed that the usual trend of soil fertility decline that normally results with continuous cropping was reversed with the use of *Leucaena* alley farming. The system was even able to increase maize yield by 38% after four continuous cropping years, except for the period of tree establishment and pruning during which crops were significantly reduced due to excessive shade effect. Soil tests also showed a gradual increase in soil organic carbon, phosphorus, potassium, calcium, magnesium, and pH over the control plots. This was due to the high organic N-additions, up to 283 kg N/ha from *Leucaena* GLM, nutrients released from tree root death and decomposition, and, finally, nutrients savings from uptake by weeds.

Crop Production; Mulching

272
DF
Budelman, A. 1989.
Effect of the application of the leaf mulch of *Gliricidia sepium* on early development, leaf nutrient contents, and tuber yields of water yam (*Dioscorea alata*). Agroforestry Systems 8: 243–256.

Investigations were undertaken to determine the effects of the leaf mulch of *Gliricidia sepium* on the development and yield of water yam (*Dioscorea alata*). The sprouting time of the yam setts can be reduced by 20% due to mulching. Organic mulches contain considerable quantities of plant nutrients. Increasing amounts of mulch improved the leaf nutrient contents of the yam crop and consequently, resulted in higher tuber yields. Each additional tonne of *Gliricidia sepium* mulch applied resulted in a yield increment of about 2 tonnes of yam tubers per ha. A nutrient supply from mulch-nutrient export in harvested tubers was discussed in the paper. Mulching is considered a useful and affordable tool in low external input cropping systems.

Alfisol; Soil Fertility; Vegetable Production

273
DF
Chen, Y.S., Kang, B.T., and F.E. Caveness. 1989.
Alley cropping vegetable crops with *Leucaena* in southern Nigeria. Hortscience 24: 839–840.

An alley cropping trial was carried out on an Oxic Paleustalf soil in southern Nigeria. With application of N, P, and K fertilizer there were no yield differences between crops grown with alley cropping compared to the control plots. With no fertilizer application, alley cropped paitsai (*Brassica chinensis* L.) enhanced yield and plant mineral concentration. Higher plant stand of direct-seeded paitsai was obtained with alley cropping rather than in the control, and this was attributed to reduced soil erosion.

Crop Production; Soil Fertility

274
DF
Danso, A.A. and P. Morgan. 1993.
Alley cropping maize (*Zea mays* var. *Jeka*) with *Cassia (Cassia siamea)* in the Gambia: crop production and soil fertility. Agroforestry Systems 21: 133–146.

The effect of *Cassia* prunings and inorganic fertilizer on growth and yield of maize, maize grain quality (weight of 3 largest size fractions) and soil pH, N, P, K, and organic matter contents were investigated at a semiarid site in The Gambia. There were treatments including: control (no prunings or fertilizer applied), only prunings applied, prunings plus half the recommended rate of fertilizer; and the full recommended fertilizer rate plus prunings. Treatments were replicated in a Latin square design. A fertilizer rate of 125 kg/ha of NPK (8:24:24) plus 43.5 kg/ha urea was broadcast at the time of sowing followed by 100 kg/ha of urea applied as a side dressing 2 weeks after crop germination. Soil N, P, K, and organic matter and pH were not significantly different at a depth of 0–15 cm before and after crop harvest. Crop yield was significantly different among treatments. The application of prunings plus full recommended fertilizer produced the highest yields. The weights of the three largest grain size fractions, grades A, B, and C, differed significantly between treatments. Yield of grade A grain increased by 202% over the control with the application of prunings plus the full rate of fertilizer and declined by 31% relative to the control with the application of only prunings. A better grade of maize grain was produced with the application of the full rate of fertilizer plus prunings than in the control treatments. However, application of half fertilizer rate combined with *Cassia* prunings gave a higher proportion of grade A grain.

Crop Production; Soil Fertility

275
DF
Danso, A.A. and P. Morgan. 1993.
Alley cropping rice (*Oryza sativa* var. *Barafita*) with *Cassia* (*Cassia siamea*): soil fertility and crop production. Agroforestry Systems 21: 147–158.

Investigations were carried out to determine the effect of alley cropping with *Cassia siamea* on rice grain weight and quality (weight of larger size fractions). Soil pH, and N, P, K, and organic matter content were studied where rice was alley cropped with *Cassia* on a semiarid site in The Gambia. The four treatments: control (no *Cassia* prunings or inorganic fertilizer added), only prunings added, prunings plus half the recommended fertilizer rate, and prunings plus the full recommended rate of fertilizer, were applied in a Latin square design with 10 × 8 m plots, each subdivided into two 4-m wide alleys. Fertilizer rates were 93.7 kg/ha NPK (8:24:24) plus 32.4 kg/ha urea followed 2 weeks later by 100 kg/ha urea applied as a side dressing. Soil samples before and after cropping at 0–10 cm and 10–15 cm depths and *Cassia* pruning samples were analyzed for pH, N, P, K, and organic matter contents. *Cassia* prunings applied as mulch did not affect rice grain weight or quality in alley cropping. The addition of inorganic fertilizer and *Cassia* prunings did not significantly increase rice grain and straw weights compared to the control and prunings only treatments. In all treatments, rice rows, grown within 80 cm of hedgerows, produced less grain and straw than center rows. Neither the larger grade A nor the smaller grade B grain weights were different between treatments. Weight of grain, straw, and larger grade A and smaller grade B quality grain were not significantly different regardless of row positions.

Hedgerow Husbandry; Soil Fertility; Ultisol

276
DF
Fernandes, E.C M. 1990.
Alley cropping on acid soils. PhD thesis. North Carolina State University, USA. 168 pp.

Two greenhouse studies were undertaken to evaluate (1) the effects of rock phosphate additions and vesicular arbuscular (VA) mycorrhizae on growth and nodulation of *Inga edulis*, *Erythina* sp., and *Centrosema macrocarpum*, and (2) shoot pruning effects on root dynamics, VA mycorrhizal infections, and P and N accumulation in *Inga* and *Centrosema* on an Ultisol. Non-mycorrhizal plants required additions of between 30 to 40 kg P/ha to attain the same shoot weight as mycorrhizal plants without added P. Plants with mycorrhizae and rhizobia had significantly more nodules than plants with rhizobia alone. Shoot pruning reduced fine root biomass. The greater the intensity of shoot pruning, the greater the decline in root biomass, VA mycorrhizal infection, and nodule activity. On acid soils with low P availability, additions of 20 kg P/ha coupled with plant management to encourage VA mycorrhizae could significantly improve the productivity of leguminous tree and pasture species. Two field experiments were performed on an Ultisol (pH 4.3–44) to (1) evaluate competition between *Inga* hedgerows and crops in alley cropping, and (2) identify provenances of *Gliricidia sepium* with potential for alley cropping on acid soils. Root competition between *Inga* hedgerows and crops became significant at 11 months after hedgerow establishment and resulted in lower grain yields from alley plots relative to non-alley cropped controls. Fertilizer application and root pruning of hedgerows significantly improved yields across the whole alley. Root competition between hedgerows and crops, and asynchrony of nutrient release from *Inga* prunings and nutrient demand by crops were probably the main causes of low crop yields. *Gliricidia* provenance OFI 14/84 showed good tolerance to acid soil conditions and produced 60% more total biomass than the second ranked provenance. Selection of 14/84 for hedgerows in alley cropping, however, will result in excessive competition with crops. The use of less vigorous provenances may improve crop yields in alley cropping.

Alfisol: Crop Production: Soil Fertility

277
DF
Gichuru, M.P. and B.T. Kang. 1989.
***Calliandra calothyrsus* (Meissn.) in an alley cropping system with sequentially cropped maize and cowpea in southwestern Nigeria. Agroforestry Systems 9: 191–203.**

Despite the increasing acceptance of alley cropping as an appropriate technology with the potential to provide stable and sustainable food production in the tropics, only a few of the potential trees/shrubs have been tested. The performance of *Calliandra calothyrsus* (Meissn.) as a hedgerow species was evaluated on an Oxic Paleustalf. The treatments were: prunings removal, prunings application, and three N levels, 0, 45, and 90 kg N/ha, in a factorial arrangement. The cropping sequence was maize (main season) followed by cowpea (minor season). Nitrogen fertilizer treatments were applied to the maize crop only. Four annual prunings of *Calliandra* hedgerows produced a total of 6 t/ha of dry matter prunings containing about 200 kg/ha of N. Application of prunings increased maize yields but no benefits were obtained by supplementing the prunings with inorganic N. An average maize grain yield of 3.1 t/ha per year was maintained without any chemical fertilizer input. However, maize yields were substantially increased by the application of inorganic N without any prunings. Cowpea yield was not affected by application of prunings but plants grown adjacent to the hedgerows had reduced yield probably due to shading. Six rows (0.57 m interrow spacing) between *Calliandra* hedgerows spaced at 4 m are optimum for this cowpea variety. *Calliandra* was shown to be equally as effective as *Leucaena* which has been found suitable for alley cropping systems in the region.

Crop Production: Soil Fertility

278
DF
Gunasena, H.P.M. and H.M.G.S.B. Hitinayake. 1981.
Nutrient recycling in alley cropping systems. Pages 66–72 *in* Proceedings on Nitrogen Fixation and Soil Fertility, edited by H.P.M. Gunasena. Faculty of Agriculture, University of Peradenija, Peradenija, Sri Lanka.

A long-term experiment was initiated in 1985 at the University Experimental Station, Dodangolla in the intermediate agroecological zone to study the effect of integration of tree legumes in cropping systems, their effect on crop yields, and changes in soil fertility. Single rows of *Leucaena leucocephala* and *Gliricidia maculata* spaced at 3.6 m formed the alleys while corn (var. Thai composite), winged bean (var. SLS 40), and *Dioscorea* (*D. alata* var. *Rasawalli*) either as sole or intercrops formed the cropping systems. The loppings of the alley crops and the residues of the annual crops were incorporated in the same plots at the end of each cropping season. Among sole crops, *Dioscorea* recorded the highest yield (3.6 t/ha) followed by corn (3.5 t/ha). Corn/*Dioscorea* and winged bean/*Dioscorea* performed better than the corn/winged bean intercrop. The latter was incompatible due to heavy mutual shading by both crops. The crop residues added by corn was the highest (6.6 t/ha) when compared to the other crops, which ranged from 0.62 to1.7 t/ha. The tree legumes added considerable amounts of biomass during and at the end of the growing season. The total green manure produced by *Gliricidia* and *Leucaena* were 7.4 t/ha and 4.8 t/ha, respectively. *Gliricidia* showed better growth than *Leucaena* particularly during prolonged periods of drought. *Gliricidia* also produced more fuelwood (7.1 t/ha) compared with *Leucaena* (4.3 t/ha). The soil fertility increased due to the addition of crop residues and loppings of leguminous trees as indicated by changes in soil N and organic matter contents. The results show the multiple advantages in the use of tree legumes and the potential of their extensive use in the intermediate zone of Sri Lanka.

Alfisol; Crop Production; Soil Fertility

279
DF
Hauser, S. and B.T. Kang. 1993.
Nutrient dynamics, maize yield, and soil organic matter in alley cropping with *Leucaena leucocephala*. Pages 215–222 *in* Soil organic matter dynamics and sustainability of tropical agriculture, edited by K. Mulongoy and R. Merckx. J. Wiley, Chichester, UK.

This study presents the results of a *Leucaena leucocephala* alley cropping trial conducted on an Alfisol at Ibadan in southwestern Nigeria. Maize grain yield was generally higher in the alley cropped plots than in the control plots where there were no hedgerows. The average yield advantage in 5 years of alley cropping compared to the control was 967 kg/ha (25.8%). No significant correlation was found between the total amount of nitrogen and potassium applied with the prunings and the maize grain and dry-matter yields. The amounts of N and K applied with the first pruning were significantly correlated with grain and dry-matter yields as well as with N and K content in maize grain and K content in the dry matter. Over 90% of the K applied with the first pruning was released by the time of the second pruning; N release was slower. The higher maize yield obtained in the alley cropped plots was partly attributable to nutrients being readily available from the first pruning. After 6 years of continuous cropping, surface (0–15 cm) soil organic matter declined. A higher surface soil organic carbon level (0.94%) was maintained in the alley cropped plots than in the control plots (0.59%). High organic C levels were maintained under the hedgerows (1.23%). More earthworm casting was observed under the hedgerows than in the space between the hedgerows or in the control, causing greater nutrient and C recycling and retention under the hedgerows.

Crop Production; Tillage

280
DF
Hulugalle, N.R. and J.N. Ndi. 1993.
Effects of no-tillage and alley cropping on soil properties and crop yields in a Typic Kandiudult of southern Cameroon. Agroforestry Systems 22: 207–220.

The paper examines the effects of no-tillage and alley cropping with *Cassia spectabilis* hedgerows on soil properties and crop yields in a Typic Kandiudult of the humid forest zone in southern Cameroon from 1990 to 1992. The experimental treatments were no-tillage and hand tillage, both of which were either alley cropped with *C. spectabilis* hedgerows at an interhedgerow spacing of 6 m or not alley cropped (control). A maize + cassava intercrop was planted in all plots at the beginning of each growing season. No-tillage did not affect soil physical properties except decrease in soil temperature. In comparison to hand tillage, no-tillage increased soil organic C and total N in both years and pH in 1991. Mean organic C (1.77%) and total N (0.174%) with no-tillage were superior to hand tillage estimated at 1.35% and 0.145%, respectively. No-tillage also resulted in a greater proportion of *C. spectabilis* roots in the topsoil. Alley cropping reduced dry season soil temperature, surface seal formation and cassava root growth, and increases in exchangeable Ca, effective cation exchange capacity (CEC), and water infiltration compared with non-alley cropped controls. Infiltration rates 2 h after commencing measurements were greater by 75% with cropping. No-tillage alone gave higher maize cob and cassava tuber yield than the combined practice of alley cropping and no-tillage.

Crop Yields; Soil Fertility; Ultisol

281
DF
Hulugalle, N.R. and J.N. Ndi. 1994.
Changes in soil properties of a newly cleared Ultisol due to establishment of hedgerow species in alley cropping systems. Journal of Agricultural Science 122: 435–443.

The short-term (3 years) ability of some selected acid-soil adapted hedgerow species when planted in alley cropping systems to improve soil properties in a newly cleared Ultisol of southern Cameroon, was evaluated from 1990 to 1992. The hedgerow species selected were *Senna spectabilis, Flemingia congesta*, and *Dactyladenia barteri*. A non-alley cropped control was also included in the trial. *Senna* and *Flemingia* produced the highest amount of prunings. Exchangeable Ca, effective cation exchange capacity (ECEC), and water infiltration were greatly increased in the alleys of plots where either *Flemingia* or *Senna* had been planted within 2.5 years of hedgerow establishment. Root growth of *Senna* in the subsoil was more than that of either *Dactyladenia* or *Flemingia*, however the roots of cassava were reduced by alley cropping with all three hedgerow species. Compared to the control or alley cropping with *Dactyladenia*, maize and cassava yields were greater when alley cropped with either *Flemingia* or *Senna* hedgerows.

Crop Production; Soil Fertility

282
DF
Jama, B. 1988.
A study of alley cropping maize and green gram with *Leucaena leucocephala* (Lam.) de Wit at Mtwapa, Coast Province, Kenya. MSc thesis, University of Nairobi, Kenya.

Crop yields in the Kenyan coastal lowlands are low because of poor soil fertility and high weed infestation. The sandy soils (92% sand), deficient in all major nutrients N, P, K, are highly leachable and fertilizer application is necessary for good crop yields. Green leaf manure (GLM) from *Leucaena leucocephala* hedgerows (alleys) established in a split-plot systematic design with 5-replications were incorporated to boost soil fertility by cutting them down to 0.5 m from ground level 2 weeks before maize crop planting. Two additional cuttings were made during the cropping season for additional GLM and to minimize *Leucaena* shading on the crop. Assessment of crop yields and monitoring of soil fertility trends were carried out over a period of 4 years (1982–1985). It was observed that the usual trend of soil fertility decline that normally results with continuous cropping was reserved with the use of *Leucaena* alley farming. The system was even able to increase maize yield by 38% after 4 continuous cropping years, except for the period of tree establishment and pruning during which crops were significantly reduced due to excessive shade. Soil tests also showed a gradual increase in soil organic carbon, phosphorus, potassium, calcium, magnesium, and pH in the control plots. This was due to the high organic N-additions, up to 283 kg N/ha, from *Leucaena* GLM nutrients savings from uptake by weeds. In general, the higher the tree density/ha, the higher the concentration of soil nutrients including an increase in soil pH. Significant weed control of up to 90% was achieved due to the fallow effect of the preceding alley cropping. Besides, most of the difficult to control grass weeds were reduced in favor of the easier to control, broad-leaved, non-grass weeds. The financial returns and savings from the sale and use of *Leucaena* fuelwood and GLM to the system were also remarkably high. *Leucaena* cuttings during one cropping season yielded 28.3 t/ha of fresh GLM.

Crop Production: Soil Fertility

283
DF
Kang, B.T. and A.U. Dikko. 1991.
Effect of alley cropping and nitrogen application on plant and soil micronutrient status. Agronomy Abstracts (1991): 62.

The effects on plant and soil micronutrient status of long-term alley cropping with four woody species—*Acioa barteri* (Ac), *Alchornea cordifolia* (Alc), *Gliricidia sepium* (Gl), and *Leucaena leucocephala* (Lc)—and N application were studied on an Alfisol in southern Nigeria. In 8 cropping years, the hedgerow biomass yield was Lc>Gl>Alc>Ac. With no N applied, maize yield was significantly higher with Gl and Lc than other hedgerow and control (no tree) treatments. With 45 kg N/ha, maize yields with Alc, Gl, and Lc were higher than in Ac and control treatments. Prunings showed higher Cu and Fe yields with Alc and Lc, and higher Mn yield with Alc. The lowest micronutrient yield was observed with Ac. Compared to the control, soil Cu level was higher under Alc and Lc, Fe and Mn were higher under all woody species, and Zn was higher under Gl and Lc. No relationship was observed between micronutrients added with prunings and crop and soil micronutrients added with prunings and crop and soil micronutrient status.

Crop Production: Erosion

284
DF
Kang, B.T. and B.S. Ghuman. 1991.
Alley cropping as a sustainable system. Pages 172–182 *in* Development of conservation farming on hillslopes, edited by W.C. Moldenhauer, N.W. Hudson, T.C. Shang, and S.W.J. Lee. Soil and Water Conservation Society, Ankeny, Iowa, USA.

Results obtained during the 1988 cropping season are presented and discussed from a long-term trial established in 1982 near Ibadan, Nigeria, to evaluate the effect of alley cropping and tillage on soil properties, runoff, soil loss, and crop performance. Plot size was 10-m wide and 70-m long. Th experimental treatments were hedgerows of *Leucaena leucocephala* or *Gliricidia sepium* established across the slope (which was about 7%) at interhedgerow spacings of 2 or 4 m, with the space tilled (by hand hoeing) before planting maize. The 2 control (no hedgerow) treatments were either tilled or not tilled. Hedgerows were allowed to grow freely in the 1987–88 dry season and were pruned in March 1988; the resulting twigs and leaves were spread as mulch between the (tilled) alleys, and the stems were placed against the upslope of the hedgerows. During first season, all plots were sprayed with paraquat and primextra 1 wk after pruning and compound fertilizer (42:20:36 [N:P:K] kg/ha) applied. Maize was planted at 25 × 100 cm spacing in control plots and 25 × 80 cm in alley cropping plots (to give a uniform density of 40,000 plants/ha). Weeding was done 4 wk after planting and 30 kg N/ha applied as a side dressing at 5 wk. During cropping, hedgerows were pruned twice (in May and July) to 0.75 m height to prevent shading. Cowpeas were planted in the second season (after harvesting the maize in August) at 25 × 80 cm spacing in the control plots and 25 × 75 cm in the alley cropping plots (giving 50,000 plants/ha). Paraquat was applied and hedgerows pruned before planting cowpeas, and weeding was done after 4 wk. Analysis of soil properties showed that soil pH was slightly lower (5.1–5.2) in alley cropped plots than in control plots (5.3–5.4). The lowest organic carbon content (0.5%) was in the tilled control, with values in the other plots ranging from 0.8 to1.1%; the tilled control plot also had the lowest exchangeable K, Ca, and Mg. Biomass and wood yield from prunings were highest in the 2-m spaced alleys for both species. Maize, grain, and stover yields were significantly higher in the alley cropped plots than in both controls. Cowpea yields (plant biomass and seed yield) and nodulation were lowest in the tilled-control plot; the alley cropping plots (mostly) showed higher plant biomass and seed yield than the no-tillage control, but values were depressed in the 2-m *L. leucocephala* plot, mainly due to shading. Runoff, soil loss, and nutrient loss were all highest in the tilled-control plot, with values in the no-tillage control and the 2-m alley plots the lowest.

Crop Production; Soil Fertility

285
DF
Kang, B.T. and K. Mulongoy. 1987.
***Gliricidia sepium* as a source of green manure in an alley cropping system. Pages 44–49 *in Gliricidia sepium* (Jacq.) Walp. management and improvement, edited by D. Withington, N. Glover, and J.L. Brewbaker. Nitrogen Fixing Tree Association (NFTA) Spec. Publ. 87-01, Waimanalo, Hawaii, USA.**

Trees and shrubs, particularly leguminous species, play an important role in traditional farming systems. *Gliricidia sepium* performs best in lowland humid tropics on nonacid soils. Loppings of *Gliricidia* produce up to 15 t/DM/ha/yr. Biomass yield is affected by germplasm, soil conditions, and management practices. Loppings containing high nutrients and a low C:N ratio decompose readily and are used as green manure for perennial and annual crops. Best results are obtained with fresh loppings and incorporation in the soil. *Gliricidia* can be successfully alley cropped with food crops in less acid soils in the humid and subhumid tropics. Nitrogen contribution to associated food crops is estimated to be about 40 kg/N/ha.

Crop Production; Soil Management

286
DF
Kang, B.T., A.C.B.M. Van Der Kruijs, and D.C. Couper. 1986.
Alley cropping for food crop production in the humid and subhumid tropics. Pages 16–26 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. International Development Research Centre (IDRC), Ottawa, Canada.

Upland arable farming on fragile, tropical soils requires viable, sustainable, and environmental 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* 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 *Acioa barteri* 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.

Crop Production; Soil Fertility

287
DF
Kang, B.T., G.F. Wilson, and L. Sipkens. 1981.
Alley cropping maize (*Zea mays* L.) and *Leucaena* (*Leucaena leucocephala* Lam.) in southern Nigerian. Plant and Soil 63: 165–179.

A maize *Leucaena* alley cropping system was studied on a N-deficient sandy Apomu soil series (Psammentic Usthorthent) at Ibadan in the forest zone of southern Nigeria from 1976 to 1980. In this system, maize was grown in 4-m wide alleys between *Leucaena* hedgerows. Five to six annual prunings of the *Leucaena* hedgerows yielded between 5 to 8 tonnes of dry biomass/ha/yr with N-yield of between 180 to 250 kg N/ha/yr. Though efficiency of N utilization from *Leucaena* prunings was low, the maize *Leucaena* alley cropping system can be utilized as a low N-input system. The addition of *Leucaena* prunings from the full grown hedgerows was able to sustain maize grain yield at about 3.8 tonnes/ha/yr for 2 consecutive years with no N addition, while with no addition of prunings, yield declined. Higher maize grain yields were obtained with supplementation with low N rates of 20 to 80 kg N/ha depending on variety and

season. The maize/*Leucaena* alley cropping system also has the potential for being developed as a stable alternative for the traditional bush fallow system. *Leucaena* plants which have unique properties suitable for growing in alley cropping, still retain important functions of a traditional bush fallow: for nutrient recycling, as a source of green manure, and for firewood and staking material. The addition of *Leucaena* prunings increased total soil N and organic C level.

Crop Production; Soil Fertility

288
DF
Kass, D.C.L., J. Sanchez, and G. Sanchez. 1988.
Results of five conservative years of production of maize and beans under alley cropping on a Typic Humitropept, fine halloysitic, isohyperthermic in Turrialba, Costa Rica. Agronomy Abstracts, American Society of Agronomy 80th Annual Meeting: 57.

In 5 years of alley cropping maize (*Zea mays* L.) and beans (*Phaseolus vulgaris* L.), maize yields averaged 2011, 2164, 2687, and 3038 kg/ha/yr for the non alley cropped control without N fertilizer, alley cropping under *Erythina poeppigiana* (Walp.) O.F. Cook spaced 6 m x 3 m and pruned twice annually without N fertilizer, non alley cropped control with N fertilizer, and non alley cropped plots with *erythina* mulch without mineral N, respectively. Corresponding yields were 800,1137,1088, and 1146 kg/ha/yr for beans. The greater success of alley cropping with beans rather than with maize, apparently due to shading from trees, was also observed with *Gliricidia sepium* (Jacq.) Walp. spaced at 3 m x 0.5 m. Alley cropping and mulch applications had no significant effect on soil organic matter or total N but appear to have increased exchangeable cations.

Crop Production; Fertilization

289
DF
Mapa, R.B. 1993.
Effect of alley cropping on improvement of soil fertility. Pages 22–25 *in* Proceedings of International Foundation of Science Workshop on Improvement of Soil Fertility, 18–24 Apr 1993, Nanjing, China.

Soil fertility reflects the soil's ability to supply the nutrients essential for plant growth in suitable proportions. Young listed soil depth to limiting horizon, texture, structure, consistence, moisture conditions, cation exchange capacity, plant nutrient content, presence or absence of weatherable minerals, soil reaction, salinity, and organic matter content as general conditions affecting soil fertility. Despite the popularity of alley cropping in parts of Nigeria, the peasant farmers in Ogun State, southwest Nigeria were aware of this low input technology only recently. This study was carried out in the Igbogila area of Ogun State in the forest savanna zone of southwestern Nigeria. The soil was an Alfisol belonging to the Alagba series. Tw- meter alleys of *Leucaena leucocephala* established in 1988 were cropped to maize/cassava for 1.5 years and left to fallow and recropped in 1991 and 1992 for this study. The experimental design was a randomized block with four treatments and three replications. Treatments were alley cropping with *Leucaena* hedgerows, with and without fertilizer applications, and the control (no hedgerows), with and without fertilizer applications. The plot size was 5 x 5 m, and the fertilizer rate was 30 N:13 P:24 K applied in 2 doses at 3 and 5 weeks after planting maize and okra at 50% flowering. *Leucaena* hedgerows were pruned 3 times and spread in alleys as mulch. Yield of okra was determined from multiple harvests and maize yield determined at 12% moisture. Data were analyzed using the mintab statistical package. Results indicated higher yields under alley cropping for both crops. However, treatments that received only inorganic fertilizer gave higher yields than plots with *Leucaena* alone. The general performance was: alley cropped + fertilizer > control + fertilizer > alley cropped – fertilizer > control – fertilizer. The study showed that *Leucaena* prunings can increase crop yield even in the absence of inorganic fertilizer.

Crop Production; Soil Management

290
DF
Marchand, D. 1987.
Ipil-Ipil. Mountain marvel. IDRC Reports 16(1): 8–9.

The Mindanao Centre for Rural Life in the southern part of the Philippine archipelago is keenly aware of the difficulties of these poor people. Since 1978 it has been carrying on an agroforestry program designed to increase the agricultural output of cultivated slopes and, at the same time, reduce the catastrophic effects of soil erosion. The cropping system developed, called Sloping Agricultural Land Technology (SALT), has been highly successful and is now the most advanced agroforestry program in the Philippine archipelago. Its linking of reforestation with farming is essentially based on the use of *Leucaena*, commonly known as ipil-ipil in the Philippines. The technique developed makes it possible to reforest the bare mountainsides and leave enough clear space for subsistence crops. Ipil-ipil is particularly suited to such crops because it improves the yield and fertility of the soil. Its roots, which penetrate deep into the earth, draw nutritional elements to the surface and its leaves, because they decompose rapidly, supply abundant and cheap organic fertilizer. The SALT method is to plant trees close together to form double hedges along the contours of the hillsides at intervals of roughly 7 to 10 m from the bottom to the top of the slope. These rows of *Leucaena* mark out the areas which can be cultivated and also constitute barriers to erosion which eventually become genuine retaining walls. In effect, natural terraces are formed.

Crop Production; Soil Fertility

291
DF
Mulongoy, K., E.B. Ibewiro, O. Oseni, N. Kilumba, A.O. Opara-Nadi, and O. Osinubi. 1993.
Effect of management practices on alley cropped maize utilization of nitrogen derived from prunings on a degraded Alfisol in southwestern Nigeria. Pages 223–230 *in* Soil organic matter dynamics and sustainability of tropical agriculture, edited by K. Mulongoy and R. Merckx. J. Wiley, Chichester, UK.

In earlier studies on a degraded Alfisol in southwestern Nigeria, maize recovery of nitrogen released from prunings of various hedgerow trees was found to be low. In the study reported here, the authors compared prunings of different biochemical composition, prunings applied at different times or in different quantities, and two methods of pruning placement in order to identify management practices that would increase maize uptake of N in alley cropping. Prunings of *Senna (Cassia) siamea*, *Gliricidia sepium*, and *Leucaena leucocephala* contributed the largest amount of N when applied close to maize planting time, with an effect equivalent to fertilization with 70 kg urea N/ha. The effect of surface application of these prunings and prunings of *Flemingia macrophylla* on maize N uptake was similar to that of their incorporation into the soil. Maize N uptake increased in response to different amounts of prunings of *S. siamea* following a cubic function. The rate constant of decomposing of prunings of *L. leucocephala* C/N (11) or lignin/N (4) was reduced by 60% when the prunings were mixed with the relatively high C/N (15) or lignin/N (11) leaves of *S. siamea*. A reduced rate of decomposition is expected to prolong N contribution of the prunings to food crops. Thus it was concluded that an application of prunings close to maize planting time and a mixture of high N prunings with low N prunings could enhance N recovery from prunings in alley cropped maize.

Crop Production; Nitrogen Contribution

292
DF
Mulongoy, K. and M.K. Van der Meersch. 1988.
Nitrogen contribution by *Leucaena (Leucaena leucocephala)* prunings to maize in an alley cropping system. Biology and Fertility of Soils 6: 282–285.

The uptake of N by alley cropped maize was assessed on an Alfisol in southwestern Nigeria. Although the application of prunings increased the maize N content in both sole and alley cropped maize, the N contributed to the maize by the prunings was low, ranging between 4.4 and 23.8 kg/ha. This was equivalent to 3.2%–9.4% of the N released during decomposition of the prunings. Application of the prunings increased the grain yields of the sole maize by 38% and the maize yield in the alley cropped plots by 104%, compared with yields in plots where prunings were not applied. The results suggest that part of the N from the prunings was retained in the soil organic-N pool. Maize, N, and grain yields were lowest in the alley cropped plots where prunings were removed and were attributed to competition between the maize and the hedgerow trees.

Crop Production; Soil Erosion

293
DF
O'Sullivan, T.E. 1994.
Farming systems and soil management: the Philippines/Australian Development Assistance Program experience. Pages 77–81 *in* Soil erosion management, edited by E.T. Craswell, J.V. Romeny, and L.G. Nallana. Proceedings of The Philippines Council for Agricultural and Resources Research and Developments, Los Banos, The Philippines.

The agroforestry project of the BFD and the Hillside Farming Project of MAF promote the production of corn, mungbeans, and peanuts in contour bays between double-row hedges of ipil-ipil. The crops are mulched with cuttings from the hedges and the process is called alley cropping. A long-term experiment was started in 1981 to determine the effect of alley cropping corn with ipil-ipil. There were no significant differences among the treatments until the fourth phase which was the second cropping of 1982. From that time, corn yields were consistently higher in treated plots than in control plots. This could be attributed to the mulching effect of ipil-ipil. The last two cropping phases, phases 6 and 7, showed that trimming ipil-ipil hedges twice during a corn crop and using these trimmings as mulch resulted in a three-fold increase in yield over the control. Results showed that under the alley cropping system with mulching, soil erosion is reduced by 60.2%. Of this, 48% can be attributed to the land covered by ipil-ipil, the depositional area introduced into the system, and the mulching effect. The remaining 12.2% is attributed to the changed profile caused by deposition (7.75%) and contour working (4.43%).

Crop Production; Erosion

294
DF
Pacardo, E. 1984.
Soil erosion and ecological stability. Pages 83–85 *in* Soil erosion management, edited by E.T. Craswell, J.V. Remenyi, and L.G. Nallana. Australian Centre for International Agricultural Research (ACIAR), Canberra, Australia.

The paper discusses cases of cropping systems in the Philippines where a unified concept of agriculture and the environment is being practised. This includes (1) the Bontoc paddy rice system which includes the construction of stone-walled terraces on the hill or mountain side to conserve soil and water with rice grown on terraces with compost, and (2) the corn/*Leucaena* systems where the presence of *Leucaena* hedgerows and hedgerow prunings reduce runoff and soil erosion and increase maize yield and result in the formation of natural terraces.

Crop Production; Soil Fertility

295
DF
Palada, M.C., M.P. Gichuru, and B.T. Kang. 1988.
Alley cropping maize + cassava and maize + cowpea with *Leucaena* and *Gliricidia* in southern Nigeria. Agronomy Abstracts Nov/Dec 1988: 60.

A field trial was established in 1986 in southern Nigeria on an Apomu soil (Psammentic Usthortent) which had been under *Imperata* fallow, to determine the effect of alley cropping on yields of maize and cassava intercropping and yields of maize and cowpea in sequential cropping. During the establishment year, maize and cassava yields were not affected by either hedgerows, but cowpea yield was significantly reduced due to shading by hedgerows. Yield reduction on cowpea was 40 to 60%. When prunings were applied in the second year, a positive effect of alley cropping, particularly with *Gliricidia*, was observed in maize and cowpea yields. Mean yields of maize and cowpea in *Gliricidia* alley plots without fertilizer were almost similar with those in no alley plots. Both hedgerows reduced cassava yield by 15 to 35%. *Leucaena* had more yield reducing effect on cassava than *Gliricidia*. Soil chemical properties of trial plots are being monitored and data will be used to explain relationships between crop yields and changes in soil fertility at the end of 5 years.

Crop Production; Soil Fertility

296
DF
Palm, C.A. 1988.
Mulch quality and nitrogen dynamics in an alley cropping system in the Peruvian Amazon. PhD thesis, North Carolina State University, USA. 120 pp.

Alley cropping has the potential to sustain crop production in the tropics because of N supplied to crops from prunings of N-fixing legumes. Results from some alley cropping experiments are promising but the efficiency of N utilization is low. A reason given for the low efficiency is possible asynchrony between supply and demand of N. Efficiency could perhaps be improved if release of N was synchronized to crop demand, either by timing of application or by using mulches with differing N release patterns. A study to address these questions was conducted over a 2-year period in the Peruvian Amazon. There were three main objectives: (1) To determine whether leaves of leguminous plants differed in their N release patterns, and if so what factors are controlling N release; (2) to determine the effect of leguminous mulches of differing quality on soil C and N dynamics; and (3) to determine the effect of mulches of differing quality on crop yields and N utilization efficiencies. Results of a laboratory experiment in which N release patterns were determined for ten tropical legumes showed that legumes do differ in quality. Nitrogen release patterns were negatively correlated to polyphenolics in the leaves but were not correlated to N or lignin. Polyphenolics may form stable complexes with amine or nitrite N, making N unavailable to microbes. A field experiment addressed the second and third objectives. Prunings from three leguminous trees, *Inga edulis*, *Cajanus cajan*, and *Erythina* sp. were applied as mulch at rates of 0, 3.3, and 6.7 t of dry matter ha to four consecutive crops of upland rice. Soil and light fraction C and N did not differ among treatments at 22 months. Mineralization patterns and microbial N did differ. *Erythina*, the mulch of highest quality, generally had higher values. Yields of rice did not differ among the mulches despite differences in mulch quality, N mineralization, and soil microbial N. Yields did increase with mulch rates. Nitrogen utilization efficiencies were in general quite low (15). The N losses could be due to volatilization or leaching resulting from asynchrony of N supply and demand.

Hedgerow Species; Erosion

297
DF
Paningbatan, E.P. 1986.
Alley cropping in the Philippines. Pages 385–395 *in* Soil management under humid conditions in Asia (Asia land), edited by M. Latham. International Board for Soil Research and Management (IBSRAM), Bangkok, Thailand.

Comparative tests of alley cropping vs. the traditional shifting cultivation system in the Philippines have recently been carried out successfully. The main plants to be tested were *Leucaena leucocephala, Gliricidia sepium*, and *Alnus japonicum*, and food crops were normally used between the hedgerows. An account is given of the establishment and management of the alley crops, and their beneficial effects on erosion and nutrient inputs. Alley cropping has proved attractive to farmers, providing increased yields and an alternative source of income from the sale of dried leaves. However, the investment involved is a problem. Research is needed to assess the long-term sustainability of specific alley cropping practices, to determine the effect of alley width and alternative alley managements on soil erosion, to screen acid-tolerant shrub legumes, and to make a socioeconomic evaluation.

Crop Production; Soil Erosion; On-Farm

298
DF
Rosseau, F.N., A.G. Hunter, and A.L. Somers. 1993.
Hillside agroforestry in Haiti: assessment of hedgerow farming. Agronomy Abstracts (1993): 60.

Hillside farmers in Haiti, generally practising mixed cropping, have successfully been introduced to hedgerows. A reliable on-farm methodology for assessing hedgerow technology and food crop production in mixed crop situations has been developed and tested. Stratified samples were taken in farmers' fields which were selected in major land resource areas of the North West, Central Plateau, and South provinces. The effectiveness of hedgerows in controlling soil erosion on steep hillsides was also evaluated in a simple and innovative way. Hedgerows were shown to control the decline of the soil resource base. Crop yields increased significantly in a band immediately uphill from the hedgerow. The data presented illustrate that Haitian farmers can achieve a sustainable output using agroforestry as a vehicle to stabilize agricultural production, while preserving soil and preventing degradation of the environment.

Crop Production; Mulching

299
DF
Sangakkara, U.R. 1989.
The role of leguminous alley crops in the nitrogen nutrition of annual crops in smallholder farming systems of Sri Lanka. Pages 271–278 *in* Nutrient management for food crop production in tropical farming systems, edited by J. Van der Heide. Institute of Soil Fertility, The Netherlands.

A study evaluated the effects of the addition of *Leucaena* and *Gliricidia* leaves to selected crops in an alley cropping system. The loppings were either placed on the soil surface or incorporated into the soil soon after crop establishment in the wet season. In addition, three levels of inorganic nitrogen fertilizer were applied to the selected crops. Plant yields indicated that the addition of leaves of alley crops had a greater effect in the dry season. Among the two methods of addition, incorporation of leaves into the soil had a significantly better effect. In terms of nitrogen nutrition, the added leaves did not act as a total substitute for inorganic nitrogen. However, the mulch enhanced yields obtained under all levels of fertilizer nitrogen. The value of the study for the smallholder in terms of increasing production by the use of loppings to enrich the nitrogen nutrition of selected crops is presented.

Acid Soils; Crop Production; Soil Fertility

300
DF
Szott, L.T., C.A. Palm, and P.A. Sanchez. 1990.
Agroforestry in acid soils of the humid tropics. Advances in Agronomy 40: 275–301.

Three agroforestry options including alley cropping, managed fallows, and tree-crop production systems were investigated as alternatives to or improvements of shifting cultivation in Yurimaguas, Peru. Several acid-tolerant, fast-growing, and coppicing hedgerow species have been identified: *Inga edulis, Erythina* sp., *Cassia reticulata*, and *Gliricidia sepium*. Nutrient release patterns from prunings depend on their lignin and total soluble polyphenolic contents. Asynchrony between nutrient release from hedgerow prunings and crop nutrient uptake has been a major limitation to the use of prunings as a nutrient source. Phosphorus appears to be the most limiting nutrient. Crops are severely affected by root competition from hedgerow species. Consequently, the suitability of alley cropping on humid tropical acid soils has not been conclusively demonstrated, except for the obvious soil erosion control in steep slopes. The length of the fallow period for shifting cultivation may be reduced by managed leguminous fallows. Several stoloniferous species were found to be more effective in suppressing weeds than the natural secondary forest fallow during a 4-year period. Nitrogen and phosphorus stocks in the abandoned *Inga*, *Desmodium*, and secondary bush fallow increased consistently during the 4-year period while calcium and magnesium stocks decreased drastically during the first 2 years and leveled off. The processes involved need to be investigated. Fruit crop production systems established with a low-input upland rice-cowpea rotation and followed by a legume cover crop, seem highly promising for the region and as a way to move from shifting cultivation to settled farming. Despite the great potential for fruit crop production, further research is needed on germplasm selection and improvement, and the development of management techniques to optimize positive interactions among the plant components of multispecies systems.

Crop Production; Soil Fertility

301
DF
Van der Meersch, M.K., R. Merckx, and K. Mulongoy. 1993.
Evolution of plant biomass and nutrient content in relation to soil fertility changes in two alley cropping systems. Pages 143–154 in Soil organic matter dynamics and sustainability of tropical agriculture, edited by K. Mulongoy and R. Merckx. J. Wiley, Chichester, UK.

The amount of prunings produced and nitrogen contributed to the soil and to maize by *Leucaena leucocephala* and *Senna (Cassia) siamea* was studied over a 5-year period at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Biomass production of *L. leucocephala* was highest (19 t/DW/ha/yr). The prunings of these two hedgerow tree species had different decomposition rates. The *L. leucocephala* prunings, which had a high N content (3.7), decomposed faster (half-life of 27 days) than those of *S. siamea* (1.8 N; half-life of 75 days). At the different pruning dates, when materials of different ages were applied, the half-life values recorded were fastest for the youngest materials. Synchronization between N release and N uptake appeared to be highest during the period between 50 and 90 days after planting, indicating that improvements are possible if dates of the second pruning operation are changed. There was a contribution of 20% and 32% of the N released from the *L. leucocephala* and *S. siamea* prunings, respectively. Chemical soil properties increased significantly in the bush regrowth after 5 years. The level of plant nutrient content declined in the cultivated systems, but less so in the alley cropping systems than in the continuous monocropping systems. Changes in soil microbial biomass, used as an early indicator of changes in soil fertility, indicated that soil fertility was improving in the alley cropping systems. Also, maize yields were maintained in the alley cropping systems, with the highest yields in the fertilized *S. siamea* system (3.7 t/ha). An adjacent bush regrowth cropped after 4 years of fallow produced a yield of 3 t/ha.

Crop Production: Soil Fertility

302
DF
Xu, Z.H., P.G. Saffigna, R.J.K Myers, and A.L. Chapman. 1993.
Nitrogen cycling in *Leucaena* (*Leucaena leucocephala*) alley cropping in semiarid tropics: I. Mineralization of nitrogen from *Leucaena* residues. Plant and Soil 148: 63–72.

Two experiments on decomposition of *Leucaena* leaf, stem, and petiole and mineralization of N from *Leucaena* residues were conducted in field microplots which received application of either 15N-labelled *Leucaena* materials or ammonium sulphate fertilizer. The microplots were installed in alleys formed by *Leucaena* hedgerows spaced 4.5 m apart and cropped with maize. The decomposition of *Leucaena* leaves, stems, and petioles was estimated by several methods. The decomposition ranged from 50 to 58% with leaves, 25–67% with stems, and 38–51% with petioles 20 days after addition. More than 55% of the N was released in 52 days during decomposition of *Leucaena* residues. By 20 days after application of 15N-labelled *Leucaena* 3.3–9.4% of the added 15N was found in the maize plants, 32.7–49.0% was in the *Leucaena* residues, 36.0–48.0 in the soil, and 0.3–21.9% lost (deficit). By 52 days 4.8% of the 15N applied in *Leucaena* prunings was taken up by maize, 45.1% was detected in the residues, 24.9% in the soil, and 25.2% lost. However, when N fertilizer was applied, 50.2% of the fertilizer N was recovered by maize, 35.5% was retained in the soil, and 14.3% apparently lost. Pruning application markedly improved maize dry matter and N uptake in the microplots. Most of the labelled 15N remaining in the soil profile was found in the top 25 cm soil depth with less than 2 cm below this depth.

Crop Production: Soil Fertility: Semi-Arid

303
DF
Xu, Z.H., R.J.K. Myers, P.G. Saffigna, and A.L. Chapman. 1993.
Nitrogen cycling in *Leucaena* (*Leucaena leucocephala*) alley cropping in semiarid tropics: II. Response of maize growth to addition of nitrogen fertilizer and plant residues. Plant and Soil 148: 73–82.

Three field trials with alley cropped maize were conducted in a semiarid environment in northern Australia to determine: (1) the effect of N fertilizer and *Leucaena* prunings on maize growth; (2) the effect of incorporation of *Leucaena* and maize residues on maize yield and the fate of 15N in plant residue under the alley cropping; and (3) the 15N recovery by maize from 15N-labelled *Leucaena*, maize residues, and ammonium sulphate fertilizer. Maize crop yield and N uptake were increased by *Leucaena* residues although pruning N did not completely meet the N requirement of the maize crop. The addition of N fertilizer further increased the maize yield and N uptake in the presence of *Leucaena* residues. Placement (incorporation or surface application) of *Leucaena* residues had little effect on the availability of N to maize plants over a 2-month period. After 2 months, similar proportions of the residue 15N were recovered by maize from mulched *Leucaena* (6.3%), incorporated *Leucaena* (6.1%), and incorporated maize (7.6%). By the end of one cropping season (3 months after application), about 9% of the added 15N was taken up by maize from either 15N-labelled *Leucaena* as mulch or 15N-labelled maize residues applied together with unlabelled fresh *Leucaena* prunings as mulch. Much higher 15N (42.7%) was recovered from the 15N-labelled ammonium sulphate fertilizer at 40 kg N/ha in the presence of unlabelled *Leucaena* prunings. Isotope analysis in soil profile indicated that little 15N was recovered beyond 25 cm soil depth. About 27–41% of the *Leucaena* 15N seems to have been lost through denitrification from the soil and plant system in one cropping season. This compared with 35% of the fertilizer 15N lost when the N fertilizer was applied in the presence of prunings.

Crop Yield; Fertilization; Hedgerow Species; Ultisol

304
DFC
Salazar, A.A. and C.A. Palm. 1990.
Effects of P fertilization on upland rice and cowpea yields alley cropped with leguminous trees. Agronomy Abstracts (1990): 62.

Low soil phosphorus is limiting to cropping systems on many acid tropical soils. The effect of phosphorus fertilization on crop yields and tree biomass production was studied in an alley cropping system on an Ultisol in the Peruvian Amazon. Cowpea/cowpea upland rice were planted in rotation between hedgerows of *Inga edulis, Cassia reticulata*, and *Gliricidia sepium*. Twenty-five kg/ha or no P_2O_5 was added to each rice crop as a split-plot treatment. Phosphorus additions increase tree biomass production. In general, crop yield was not affected.

Crop Production; Inceptisol; Soil Fertility; Soil Physical Properties; Weeds

305
DFG
Rosecrance, R.C., S. Rogers, and M. Tofinga. 1992.
Effects of alley cropped *Calliandra calothyrsus* and *Gliricidia sepium* hedges on weed growth, soil properties, and taro yields in Western Samoa. Agroforestry Systems 19: 57–66.

The effects of alley cropping on soil characteristics, weed populations, and taro yield were studied on a tropical Inceptisol at Apia, Western Samoa. Taro yields were compared in *Calliandra calothyrsus* and *Gliricidia sepium* alleys, spaced at 4 m, 5 m, and 6 m, and a no- tree control. Soil moisture and temperature, weed growth, hedge biomass production, and taro growth and yield were measured. Data was analyzed over 4 consecutive years from 1988 to 1991. During the 4-year period, hedge biomass yields ranged from 5.1 to 16.1 t/ha/yr dry weight with *Calliandra* and *Gliricidia* performing equally well. Biomass yields decreased by about 2 t/ha with increasing alley width from 4 to 6 m alleys. Weed populations were lower in the 4 m alleys than in the 5 m, 6 m, and control plots. Soil from alley plots held significantly more water in the 0.3 to 1 bar range than soils from the controls. Soil water holding capacity and bulk density were improved by mulch application. However, N, P, K, Ca, Mg, and organic carbon contents in the alley plots were not different from the controls. There was no positive yield effect of alley cropping on taro yield. Thus, alley cropping was not superior to traditional shifting cultivation after 4 years of continuous cropping in this trial.

Crop Production; Soil Fertility; Weeds

306
DFG
Van der Meersch, M.K. 1992.
Soil fertility aspects of alley cropping systems in relation to sustainable agriculture. PhD thesis, Katholieke Universiteit, Leuven, Belgium. 179 pp.

An alley cropping experiment was laid out to evaluate the sustainability of various alley cropping systems compared to continuous cropping with or without fertilizers over a 5-year period. Alley cropping systems included *Leucaena leucocephala*, a nitrogen-fixing tree, and *Senna siamea*, a non-nitrogen fixing species. Both *Leucaena* and *Cassia* hedgerows were well developed 4 years after establishment. Biomass production was high over the years and about 20 tonnes dry matter ha/yr were produced by the *Leucaena* trees, and 13 tonnes by the *Senna* trees. Pruning material contained about 360 and 240 kg N ha/yr for *Leucaena* and *Senna* prunings, respectively. The decomposition and N release of the various pruning materials was primarily determined by the resource quality. On average, 23% of the total amount of N applied with the prunings was recovered by the maize. The N-use efficiency declined when prunings were applied in combination with fertilizer, and in the *Leucaena* system, N uptake from the prunings was negligible when combined with fertilizer. Soil

fertility as measured by soil chemical properties declined in both alley cropping systems, although at a slower rate than in the continuously cropped systems. Soil organic matter was maintained in the *Senna* system but a decline in total organic N demonstrated that the N losses exceeded the N inputs into the system. The level of available mineral nutrients such as K and Mg gradually decreased and the application of nutrients through the *Senna* prunings seemed not to be sufficient to replenish the losses. Soil fertility was maintained at a higher level in the *Leucaena* alley cropping system which can be attributed to the extra N input through biological N fixation. However, a gradual increase in soil acidity was observed. Soil microbial biomass values after some years of alley cropping were higher than in a continuously cropped system, indicating a larger labile organic matter fraction and the associated higher nutrient availability. Both alley cropping systems maintained an economically acceptable production over the 5 years. Highest maize yields were obtained in the fertilized *Senna* alley cropping systems, that is, 3 tonnes maize grain per ha but no effects of fertilizers were observed in the *Leucaena* alley cropping system where 2 tonnes per ha were produced. The economic advantage to the Nigerian farmer of the alley cropping systems was lower than that of the fertilized continuous cropping system because of the high labor input required during the first years. In the long term, there are indications that income increases as compared to the costs due to the lower weed infestation in the alley cropping system.

Crop Production; Fuelwood; Soil Fertility

307
DFJ
Torres, F. 1983.
Potential contribution of *Leucaena* hedgerows intercropped with maize to the production of organic nitrogen and fuelwood in the lowland tropics. Agroforestry Systems 1: 323–333.

The impact of intercropping *Leucaena* hedgerows with maize on the physical productivity of grain and fuelwood were hypothesized based on available information. Data indicate that productivity of organic nitrogen (N) by *Leucaena* hedgerows cut approximately every 8 weeks at a height of 15–30 cm and planted at a distance between rows wider than 150 cm is 45 g/m/yr. When soil-N availability is the limiting factor, utilization of *Leucaena*-N by the maize crop seems to be inversely related to baseline maize production. The grain:*Leucaena*-N ratio declines from 20:1 when maize yield is in the order of 500 kg/ha, to 3:1, when the 4000 kg level is achieved. The yield estimates per area of intercropped land under different intercropping arrangements were derived from the proportion of land planted to maize. The impact of hedge intercropping on maize productivity, although substantial, would be limited to systems where existing production levels of maize are lower than 1500 kg/ha. As spacing between *Leucaena* hedgerows increases, production per hectare decreases. For a 1000 kg/ha baseline, hypothetical increments expressed as percentage of baseline production range from 112 to 28% for between-hedgerow spacings of 1.5 and 6 m, respectively. Research required to substantiate the formulated hypotheses is discussed. The potential for *Leucaena* hedgerow intercropping to increase maize productivity was indicative.

Crop Production; Economics; Erosion

308
DFK
Ehui, S.K., B.T. Kang, and D.S.C. Spencer. 1990.
Economic analysis of soil erosion effects in alley cropping no-till and bush-fallow systems in southwestern Nigeria. Agricultural Systems 34: 149–168.

This study uses a capital budgeting approach to determine the profitability of alternative land use systems, taking into account the short- and long-run impact of soil erosion on agricultural productivity in southwestern Nigeria, using a simulation model. The fallow systems include: (1) two continuous cultivation alley cropping systems

with *Leucaena* hedgerows planted at 2-m and 4-m interhedgerow spacings; (2) the continuous cultivation no-till farming system; and (3) two traditional bush-fallow systems with a 3-year cropping period in 6- and 12-year cycles. Under a 10% discount rate, when no yield penalties are imposed (low population density), the 12-year cycle shifting-cultivation system seems to be most profitable, followed by the 4-m alley cropping, the no-till, the 2 m alley cropping, and the 6-year cycle shifting cultivation systems. When penalties are imposed on yields due to land being taken out of production because of fallow vegetation (rising land values), the 4 m alley cropping is most profitable, followed by the no-till, the 2-m alley cropping, and the 12- and 6-year cycle bush fallow systems. Thus where access to new forest land is at no cost, slight yield damage due to erosion will not be sufficient to discourage the practice of traditional bush-fallow systems with longer fallows.

Crop Yield: Weed Control

309
DG
Gutteridge, R.C. 1985.
Alley cropping *Leucaena* with kenaf (*Hisbiscus cannabinus*). *Leucaena* Research Reports 6: 1–2.

Hedgerows of *Leucaena* were established in 1983 at interrow spacings of 3 or 5 m in southeast Queensland. Kenaf was sown in 1984 in the interrow spaces. Fertilizer was applied at 0, 50, and 100 kg N/ha as urea. *Leucaena* was cut at 50 or 25 cm heights, 2 or 4 times, and evenly spread. Growth of *Leucaena* was initially slow but picked up when herbicide was used to control weeds. Cutting height did not significantly affect *Leucaena* yield. *Leucaena* prunings supplied 66 kg N/ha to kenaf planted at 3 m, and 110 kg N/ha at 5 m spacing. Yield of kenaf was highest with 100 kg N/ha at 5 m spacing while 50 kg N/ha was comparable to the alley cropped plot.

Crop Production: Weeds

310
DG
Poku, J.A., G.F. Wilson, and C.F. Yamoah. 1988.
The effect of herbicides on volunteer seedlings of *L. leucocephala* and hybrid maize performance in alley cropping. *Leucaena* Research Reports 9: 74–76.

The paper describes a trial conducted on a degraded Alfisol (Oxic Paleustalf) at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Rainfall during the trial followed the normal bimodal pattern. *Leucaena* was direct seeded in 1978 in hedgerows 2 m apart. The plot was managed by the alternate year fallow method. One year of *Leucaena* fallow was followed by a year of maize cropping. The trial was carried out in the first (April–July) and second (August–November) seasons of 1984. In the first season, two maize cultivars, a hybrid (EN 10), and a composite (TZSRW) were combined with herbicides in a split-plot design in which maize cultivars were the main plots, weed control the subplots, and an unweeded plot the control. There were four replications. In the second season, one early maturing maize composite was combined with the weed control treatments in a randomized complete block design that had eight replications. Plot size was one alley width (2 m by 11 m). Maize yield in the herbicide-treated plots did not differ significantly from the control treatment in any of the two cropping seasons. The difference in maize yield between cultivars was significant with the hybrid being superior to the composite. Yield of TZSR in the second season appears low in comparison to yields of the other cultivars in the first season but is a reasonable yield for this cultivar during the second season.

Crop Production; Fodder Production

311
DH
Atta-Krah, A.N. and J.E. Sumberg. 1987.
Studies with *Gliricidia sepium* for crop/livestock production systems in West Africa. Pages 31–43 *in Gliricidia sepium* (Jacq.) Walp.: management and improvement, edited by D. Withington, N. Glover and J.L. Brewbaker. Nitrogen Fixing Tree Association (NFTA) Special Publication 87-01, Waimanalo, Hawaii, USA.

This paper reports on 4 years of research on *Gliricidia sepium* (Jacq) Walp. conducted by the Humid Zone Programme (HZP) of the International Livestock Centre for Africa (ILCA) at Ibadan in southwest Nigeria from 1982 to 1986. It examines the biological characteristics with respect to growth and analyzes its potential to improve crop production (through soil fertility maintenance) and livestock production (through production of improved fodder). Integration of *Gliricidia* into cropping systems is necessary for optimum realization of its crop improvement quality. The alley farming system presented in the paper is one means of achieving sustained crop production through the integration of trees, such as *Gliricidia*. Intensive feed gardens for production of leguminous fodder is also described as an alternative production system. Experiences with local farmers in on-farm research and development for the integration of *Gliricidia* and *Leucaena* (*Leucaena leucocephala* (Lam. de Wit) into local farming systems are reported. More research, targeted specifically at improvement of the species and its utilization, is suggested.

Crop Production; Fodder Production

312
DH
Lulandala, L.L.L. and J.B. Hall. 1989.
Fodder production from *Leucaena leucocephala* intercropped with maize and beans in Tanzania. Pages 131–136 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. International Development Research Centre (IDRC), Ottawa, Canada.

From 1980 to 1988, a study was carried out at Mafiga, Morogoro in the subhumid area of Tanzania to determine the effect of intercropping *Leucaena leucocephala* with maize and beans on food crops and fodder production. Crop yields were assessed for four cropping seasons. The implications of the results to meeting livestock fodder needs and the effects on long-term soil productivity are discussed.

Crop Production; Forage Production

313
DH
Singh, R.P., K. Vijayalakshim, and M. Osman. 1987.
Alternate land-use systems for drylands of India. International Centre for Research in Agroforestry (ICRAF) Research Bulletin No. 6. Central Research Institute of Dryland Agriculture, Hyderabad, India. 500–659. 61 pp.

The bulletin presents results and experiences of some of the experiments on alternate land-use systems for arable and marginal rainfed lands at the Central Research Institute for Dryland Agriculture, Hyberabad. The bulletin contains information on alley cropping, by farming, pasture management, tree farming, the silvipastoral management system, and the agrohorticultural system which are more relevant to dryland situations.

Crop Production; Economics; Fodder Production; Livestock Production

314
DHIK
Sumberg, J.E. 1984.
Alley farming in the humid zone: linking crop and livestock production. ILCA Bulletin 18: 2–6.

The paper gives the background to small ruminant production in the humid zone of West Africa and describes the alley farming techniques which are being evaluated by ILCA's team based in Ibadan. The importance of crops in the zone is emphasized, to the extent that any improvement in livestock production should also show a positive effect on crop production. Alley farming employs the fast-growing leguminous trees *Leucaena leucocephala* and *Gliricidia sepium* which can provide both high-quality fodder for small ruminants and nitrogen-rich mulch for crop production. Crops are grown in alleys between rows of these leguminous trees. The cut-and-carry feeding of browse to small ruminants is expected to be one of the major benefits of alley farming. Alley farming also offers the possibility of allowing sheep to graze the fallow and the leguminous trees during periodic fallow years. A partial budget analysis of the two systems shows that short-term fallow grazing is competitive with continuous cropping. During 1984, in a pilot development scheme of the Nigerian Federal Livestock Department, 60 participating farmers will plant 0.33 ha mixed browse alley farms and will start an animal health program recommended by ILCA. ILCA's team will provide the browse seed, administer the health package and train the Ministry personnel in the principles and practices of alley farming.

Crop Production; Firewood; Fodder

315
DHJ
Singh, R.P., R.J. Van Denbeldt, D. Hacking, and G.R. Korwan. 1989.
Alley farming in the semiarid regions of India. Pages 108–122 *in* Alley farming in the humid and subhumid tropics. Proceedings of an international workshop held 10–14 Mar 1986 at The International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, edited by B.T. Kang and L. Reynolds. International Development Research Centre (IDRC), Canada.

Preliminary studies by the All-India Coordinated Research Project for Dryland Agriculture and Agroforestry indicate that alley farming is suitable for the semiarid areas of India. Although crop yields grown in adequately spaced alleys are reduced by 25–35%, the use of *Leucaena* for firewood and fodder makes the gross economic returns in alley farming almost twice those in sole cropping. *Leucaena* is drought tolerant and, therefore, in areas where rainfall is erratic, the risk of total crop failure is reduced.

Crop Production; Livestock Production

316
DI
Okali, C. and K. Cassaday. 1985.
Community response to a pilot farming project in Nigeria. Discussion paper No. 10. Africa-American Issues Center, Boston, Massachusetts, USA. 28 pp.

This paper reports on a preliminary study of farmers' response to alley farming, a technology designed to improve small ruminant (sheep and goats) and arable crop production in the humid zone of West Africa. The study forms part of a long-term evaluation being undertaken to see how the technology, or the way it is introduced, needs modifying. Alley farming is one part of a small ruminant development model which was introduced in southwest Nigeria as a pilot project in 1984. This project, initiated by the Livestock Project Unit of the Federal Government of Nigeria, is based on a small ruminant development model designed by the Small Ruminant Programme of the International Livestock Centre for Africa (ILCA) over 6 years. The model in-

cludes vaccination against the disease Peste des Petits Ruminants (PPR) and a one-third hectare alley farm. ILCA seeks to link small ruminant and crop production through the use of fast-growing leguminous trees, such as *Leucaena leucocephala* and *Gliricidia sepium*. Crops are grown in 4 m wide alleys between rows of these densely planted trees which are pruned 3 to 5 times per growing season. Trees under such management can produce 4 to 8 tonnes of mulch dry matter/hectare/year, and yield over 100 kg of nitrogen for crop production. Such a farm can provide supplementary feed for approximately five adult animals and their followers, with 75 percent of the tree foliage being used as mulch for crops. The model assumes that most of the foliage will be used as mulch during the wet (cropping) season and as feed during the dry season. The development approach is based on the gradual transformation of existing production. ,rather than the immediate substitution of an alternative model of production. Although small ruminant management varies throughout the area, most animals roam freely, receiving only limited management or capital inputs. Owners normally provide no special feed, housing, or veterinary care. While production losses from diseases can therefore be high, potential returns of these production systems are also high. The major investment is the acquisition of new stock which most people acquire through a process of exchange. The main management intervention is supplementary feeding of animals with kitchen waste and crop by-products.

Crop Production; Staking

317
DJ
Budelman, A. 1990.
Woody legumes as live support systems in yam cultivation II. The Yam-*Gliricidia sepium* Association. Agroforestry Systems 10: 61–69.

The effect of *Gliricidia sepium* as a live support system on the development and tuber yield of water yam (*Dioscorea alata*) is described in this paper. *Gliricidia* was planted in 3-m rows apart. The intrarow distance was 1 m. In the alleys 2 rows of yam were planted at 0.5 × 1 m. The objective of this study was to examine the green manuring effect of *Gliricidia* leaves on the tuber yield of yam due to the presence of the *Gliricidia* live stakes. Using *Gliricidia sepium* as live support more than doubles the yield per unit of area of yam: 8.8 t/ha in the sole yam control against 20.7 t/ha in the yam-tree association. Staking accounts for more of the yield increment than the mulch factor. The trees and the mulch created more favorable conditions for development of the yam plant, while the capability of the trees to absorb nutrients from soil layers beyond the reach of the yam roots was demonstrated.

Crop Production; Live Stake

318
DJ
Ngambeki, D.S. and G.F. Wilson. 1980.
Economic and on-farm evaluation of alley cropping with *Leucaena leucocephala*. Consolidated report 1980–83 Farming Systems Program, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 45 pp.

From the results of the agroeconomic experiments at IITA, four conclusions can be drawn: (1) The consistently significant increases in maize yields under *Leucaena* and the small negative interactions between *Leucaena* and nitrogen from three successive seasons, suggest that the maize-*Leucaena* alley cropping system can give high maize yields without nitrogenous fertilizers. The use of nitrogenous fertilizers at the full rate with *Leucaena*, even at subsidized prices, is an economic waste. (2) Although *Leucaena* stands occupy about 20% of the land, cutting and pruning *Leucaena* increases labor costs by about 52%; the economic contributions of *Leucaena* are

greater than those from *Leucaena*-nitrogen or those from herbicide-nitrogen or from herbicide. (3) The highest level of technological input, *Leucaena*-nitrogen-herbicide, gave, on average, the highest increase of 90% on maize yields followed by *Leucaena*-herbicide and *Leucaena* alone with, respectively, 70% and 69% increases on maize yields; its economic contributions are not necessarily better than those of herbicide-nitrogen, or those of *Leucaena*-herbicide. (4) With a crop sequence of maize-maize, *Leucaena* gave the best economic returns followed by herbicide-nitrogen and *Leucaena*-herbicide. But with a crop sequence of maize-cowpea, herbicide-nitrogen gave the best economic returns followed by *Leucaena*-herbicide. However, *Leucaena* was observed to have depressing effects on cowpea yields unlike that of maize. This needs to be investigated even further. In all cases, the *Leucaena* treatment gave better economic contributions than *Leucaena*-nitrogen. Results obtained from the on-farm trials so far, suggest that *Leucaena*-maize-yam alley cropping has definite benefits for small-scale farmers particularly in areas where soil fertility problems and scarcity of staking materials exist. The farmers recognize the benefits of using *Leucaena* in an alley cropping system, but there are a number of questions that require further research. These are: (a) problem of establishing *Leucaena* on farmers' field; (b) farmers management of *Leucaena* live in-situ stakes for yams, (c) the need for better tools (or mechanization) for pruning *Leucaena* bushes to reduce labor requirements at peak periods; and (d) evolving a strategy for the management of the *Leucaena* trees in the alley cropping system that allows continuous cultivation of the land, covers a wide range of crops, and provides sufficient biomass production for mulch (and/or animal fodder) and sufficient wood for stakes and firewood. In spite of some management problems, farmers reacted favorably to alley cropping and are interested in *Leucaena* as an inexpensive source of stakes.

Crop Production; On-Farm Research

319
DK
Kass, D.L. 1987.
Alley cropping with *Gliricidia sepium* (Jacq.) Walp. on farmers' fields in Costa Rica, Pages 50–58 *in Gliricidia sepium* (Jacq.) Walp.: management and improvement, edited by D. Withington, N. Glover, and J.L. Brewbaker. Nitrogen Fixing Tree Association (NFTA) Special Publication 87–01, Waimanalo, Hawaii, USA.

An alley farming experiment with *Gliricidia sepium* (Jacq.) Walp. was set up with interested farmers in the San Carlos Canton of Costa Rica. Field experiments started in October 1984. A Latin square design was used with four treatments in the main plots: (1) No amendment, (2) *G. sepium* mulch at 2 kg/m per planting, (3) alley cropping with *G. sepium* at 6 m × 1 m spacing, and (4) alley cropping with *G. sepium* at 9 m × 1 m spacing. Plots were divided into three nitrogen levels, 0, 100, and 200 kg/ha/yr. A cropping system consisting of phaseolus beans followed by maize (*Zea mays* L.) was used. The maize received 60% of the applied mineral N as NH_4NO_3. Trees were established from cuttings in October 1984 and the first bean crop was planted in December 1984. There were harvests of beans in March 1985 and March 1986. Corn was planted in May 1985 and June 1986. For the June 1986 planting, it was decided to associate cassava (*Manihot esculenta* Crantz) with the maize because yields in the control plots remained high and cassava is known for its high nutrient removal and it is a popular crop often grown with maize and beans. Native fertility at the site, located in the Pital district of the San Carlos Cantaon at 180 m elevation, was somewhat higher than expected from the soil analyses (46.5 mg/g organic matter, 2.9 mg/L Olsen P, 0.45 cmol (+)/1 extractable K, and 0.32 cmol (+)/1 exchangeable acidity). Therefore, yields of beans and corn (740 and 1957 kg/ha, respectively, in 1985, and 1451 and 442 kg/ha, respectively, in 1986) were only slightly lower in the control plots without mineral N than in the plots receiving *G. sepium* mulch (906 and 2271 kg/ha in 1985, and 1689 and 835 kg/ha in 1986); and this difference was never statistically significant. Yields in the alley cropping treatments were always lower than in the control plots, but these plots received only about half of

the biomass applied to the mulch plots. A planting of *G.sepium* from seed in the middle of the 9 m rows to increase tree population in this treatment was only moderately successful due to considerable weed competition.

Crop Production; Economics; Labor Use

320
DK
Ngambeki, D.S. 1985.
Economic evaluation of alley cropping *Leucaena* with maize-maize and maize-cowpea in southern Nigeria. Agricultural Systems 17: 243–258.

Alley cropping is an aspect of agroforestry being developed for small farmers in the tropics. It consists of establishing fast-growing leguminous shrubs or tree species in rows. Shading from the trees during cropping is controlled by pruning the branches which can be used as mulch or green manure to benefit the companion crops planted between the alleys. This paper assesses the economic implications of labor utilization for the management of the *Leucaena* hedgerows, crop yields, and the overall benefits from alley cropping with *Leucaena*. The results show that although the management of *Leucaena* trees increases labor requirements by about 50%, the system can sustain and increase maize yields by over 60%, reduce N-fertilizer requirement, and increase net income and marginal rate of return per unit cost. The system gives a reasonable benefit-cost ratio of 1.23:1.32 and seems promising, especially for maize production in tropical areas.

Crop Production; Economics; Labor

321
DK
Turay, F. 1981.
An optimization model of a *Leucaena*-rice alley cropping system for upland rice region of Sierra Leone. BSc thesis, Faculty of Agriculture, Njala University College, Sierra Leone. 112 pp.

Self-sufficiency in rice production, the staple food, has been and is the aim of the government. In pursuing this goal of self-sufficiency, the recommended production package involves the use of high cost inputs like fertilizer, particularly nitrogen, and high yielding varieties. This study concerns the design of an alternative rice production system in which the nitrogen necessary for rice consumption is produced within the system itself. This system is based on the biological recycling of plant nutrients (N) by legume trees such as *Leucaena leucocephala*. The system described here is based on an economic optimization model of *Leucaena*-rice alley cropping. It involves rice production in alleys between evenly spaced hedgerows of *Leucaena*. Linear programming is used to design the model. An economic evaluation of the model, in terms of the constraints and variables, and the model's behaviour with variabilities in time, labor constraints, and prices of unsubsidized nitrogen per kilo and labor per man-day is presented. To compare the profitability of this low-cost input system, the economically optimum doses of the latter for nitrogen use from urea and ammonium sulphate (both unsubsidized) are found. The points highlighted in the study include: (1) the model uses 100 kg nitrogen equivalent from *Leucaena* for profit maximization. This profit is greater than that of the high input system, and it is maintained over time. (2) The break-even point between these systems of rice production occurs at a minimum fertilizer subsidy of 97% for urea and about 99% for ammonium sulphate. (3) The economic optimum of nitrogen use from urea is 100 kg, which is constant with time. That of nitrogen from ammonium sulphate was 40 kg N for 1972 and was nonexistent for 1980 and 1990. Labor is a limiting constraint. Hired labor is profitable up to a maximum wage of Lr 2.13.

Competition; Microclimate

322
E
Corlett, J.E., C.R. Black, C.K. Ong, and J.L. Monteith. 1992.
Above- and below-ground interactions in a *Leucaena*-millet alley cropping system. II. Light interception and dry matter production. Agricultural and Forest Meteorology 60: 73–91.

Studies involving alley cropping *Leucaena leucocephala* and pearl millet (*Pennisetum glaucum* (L.) R. Br.) were undertaken in a semiarid area of India. The five treatments included sole millet (SM), sole *Leucaena* (SL) planted in double rows to form hedges with an alley width of 2.8 m, and alley cropping treatments LM5, LM6, and LM6P with alley widths of 2.8, 3.3, and 3.3 m, respectively. Millet rows within the alleys were spaced at 47 cm, giving five rows in LM5 and six rows in both LM6 and LM6P. LM6P differed from LM6 in that a vertical polyethylene barrier separated the root systems of *Leucaena* and millet to a depth of 50 cm. Dry matter production and light interception for millet and *Leucaena* were measured under contrasting hedge management in the rainy seasons of 1986 and 1987. Dry matter yields of *Leucaena* did not differ significantly between treatments in the rainy season, but were much higher in 1987 than in 1986 because of the less severe lopping regime. The higher yields in 1987 resulted from a greater mean fractional light interception by *Leucaena*, which increased shading of alley cropped millet when compared with 1986. The dry matter yields of millet in treatments LM5 and LM6 were reduced relative to their sole crop in both years. In 1986, this reduction appeared to result primarily from shading, while in 1987 the mean fractional light interception and the preanthesis conversion coefficient were both lower in LM5 than in SM. There was interaction between above- and below-ground competition, with reduced root competition LM6P. In 1986 the millet grew taller and comparable to *Leucaena* in height, thereby reducing hedgerow shading and yield reduction experienced in treatments LM5 and LM6. Shading seems to have an overriding effect on crop growth in 1987 thereby obscuring the effect of the root barrier.

Microclimate

323
E
Corlett, J.E., C.K. Ong, and C.R. Black. 1989.
Microclimatic modification in intercropping and alley cropping systems. Pages 419–430 *in* Meteorology and Agroforestry, edited by W.S. Reifsnyder and T.O. Danhofer. ICRAF/WMO/UNEP/GTZ, Nairobi, Kenya.

Modification of microclimate is one facet of agroforestry where potential exists for favorable interspecific interaction, but where few data are available. Studies of the possible beneficial microclimate modifications in agroforestry systems may usefully draw upon the detailed data already amassed for soil crops and some multiple-cropping systems. Data are presented from rainfed experiments carried out at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (Hyderabad, India) during the 1985 and 1986 rainy seasons. In both years millet (BK 560) and groundnut (R33-1) were grown as sole crops and as an intercrop with a row ratio of 1:3 (millet:groundnut) and row spacing of 30 cm. Instrumentation was installed in sole and intercrop plots. In 1986 millet (BK560) was grown as an alley crop between one-year- old *Leucaena leucocephala* hedges. The hedges were spaced at 3.4 m intervals in sole *Leucaena* and alley-crop plots while millet row spacing within the alleys and in sole plots was 47 cm. Instrumentation was installed in sole and alley-crop plots. In each experiment light interception, wind speed, saturation deficit, and soil and leaf temperatures were routinely monitored. The microclimatic characteristics and their effects on yield in the two systems are compared. Additional data are presented from the agroforestry trial indicating how competitive interactions below ground may negate any beneficial changes in microclimate.

Competition: Microclimate

324
E
Corlett, J.E., C.K. Ong, C.R. Black, and J.L. Monteith. 1992.
Above- and below-ground interactions in a *Leucaena*-millet alley cropping system. I. Experimental design, instrumentation, and diurnal trends. Agricultural and Forest Meteorology 60: 53–72.

Leucaena hedgerows were alley cropped with pearl millet (*Pennisetum glaucum* (L.) R. Br.) in a semiarid area of India. The five treatments included sole millet (SM), sole *Leucaena* (SL) planted in double rows to form hedges with an alley width of 2.8 m, and alley cropping treatments LM5, LM6, and LM6P with alley widths of 2.8, 3.3, and 3.3 m, respectively. Millet rows within the alleys were spaced at 47 cm, giving five rows in LM5 and six rows in both LM6 and LM6P. LM6P differed from LM6 in that a vertical polyethylene barrier separated the root systems of *Leucaena* and millet to a depth of 50 cm. Light interception, wind speed, saturation deficit and air, soil, and leaf temperatures were monitored during the 1986 and 1987 rainy seasons in treatments SM, SL, and LM5. This paper illustrates the nature of the microclimatic changes associated with alley cropping. Results indicated that hedgerows affected the microclimate of alley cropped millet and the extent varies with proximity to the hedge, hedge shape, and the relative size of the two components. The larger *Leucaena* canopy in 1987 than in 1986 resulted in more substantial reductions in wind speed and incident light in the alleys of LM5 compared with SM. Leaf and soil temperatures within the alleys tended to be warmer during the night and cooler during the day than in SM and temperature differences between rows within LM5 were related to the degree of shading by *Leucaena*. Analysis of integrated data predicted little effect of the observed changes in saturation deficit on the productivity of millet, while thermal time analysis for 1987 suggested a 2–3 day delay in flowering for millet adjacent to the hedge as compared with sole millet.

Competition

325
E
Field, S.P. and S.S. Oematan. 1990.
The effect of cutting height and pruning frequency of *Leucaena leucocephala* hedgerows on maize production. *Leucaena* Research Reports 11: 68–69.

Alley cropping has been recommended as an appropriate cropping practice for eastern Indonesia. One concern highlighted by farmers adopting the technology is that the *Leucaena leucocephala* intercrop would compete against the main food crop, maize. Farmers have stipulated that they will only adopt technologies that do not reduce maize yields, even if the alternative cropping systems provide greater monetary returns. Management systems that reduce the competitiveness of the tree legume and ensure that maize yields are not reduced need to be identified. Also, it is necessary to ensure that productivity of the tree legume is optimized under these conditions to provide benefits to the farmer, e.g., cattle fodder, firewood, and an alternative source of nitrogen for the crop. This report examines the effect of cutting height and pruning frequency of maize and *L. leucocephala* yields.

Tree-Crop Interface

326
E
Huxley, P.A. 1985.
The tree/crop interface—or simplifying the biological/environmental study of mixed cropping agroforestry systems. Agroforestry Systems 3: 251–266.

The tree/crop interface provides the key to understanding the biological potentials and restraints of agroforestry systems, and the environmental responses of plant components within them. All agroforestry systems can be studied by separating the growth and yield characteristics of the three basic sets of variables: (1) the sole

agricultural crop, (2) the effects of the tree/crop interface on the crop and tree, and (3) the growth of the tree as a whole crop. The interface can be studied wherever it occurs in natural situations, or conventional or systematic experimental layouts, but simple form (geometric) layouts seem to be very space efficient.

Soil Moisture

327
E
Lal, R. 1989.
Agroforestry systems and soil surface management of a tropical Alfisol. V. Water infiltrability, transmissivity, and soil water sorptivity. Agroforestry Systems 8: 217–238.

In a long-term agroforestry experiment established on an Alfisol in western Nigeria the soil infiltrability was evaluated once a year for five consecutive years. There were 6 treatments including plow-till, no-till, and contour hedges of *Leucaena leucocephala* and *Gliricidia sepium* established at 4- and 2-m intervals. Continuous cultivation based on 2 crops per year caused drastic reductions in infiltrability in all treatments. The rate of decline was, however, the most severe in the no-till treatment. Following 5 years of continuous cultivation, the equilibrium infiltration rate was 8, 19, 21, and 24 cm/h for no-till, *Gliricidia*-based, plow-till, and *Leucaena*-based treatments, respectively. The cumulative infiltration at 2 h was 24, 59, 70, and 76 cm for no-till, *Gliricidia*-based, *Leucaena*-based, and plow-till treatments. The soil/water sorptivity (S) also differed among treatments, respectively. Philip's and Kostiakov's infiltration models were used to express the infiltration data.

Competition; Microclimate

328
E
Monteith, J.L., C.K. Ong, and J.E. Corlett. 1991.
Microclimatic interactions in agroforestry systems. 1. Forest Ecology and Management 45: 31–44.

The interaction of agroforestry systems with elements of microclimate is presented in terms of the interception by foliage of radiant energy and of rainfall; and of the temperature, humidity, and windspeed of air surrounding the foliage. Measurements were taken in a trial in which pearl millet was grown at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, between hedges of *Leucaena leucocephala* Lam. The alley system has the advantage of the ability to intercept more light throughout the year and therefore to produce more biomass. Temperature and humidity within the alleys were not significantly different from values in the open but windspeed was considerably reduced. Competition below ground rather than above ground was probably a major limitation of the system in terms of pearl millet production.

Light Competition

329
E
Neumann, I.F. and P. Pietrowicz. 1989.
Light and water availability in fields with and without trees: an example from Nyabisindu in Rwanda. Pages 401–406 *in* Proceedings of an international workshop on the Application of Metereology to Agroforestry Systems Planning and Management, 9–13 Feb 1987, Nairobi, Kenya, edited by W.S. Reifsnyder and T.O. Darnhofer.

The effects of tree spacing, spatial arrangement, and pruning on light interception, water availability, and crop yields were evaluated in demonstration fields with *Grevillea robusta* of about 8-years-old. The results indicated that shading can be minimized if trees are planted in an east-west direction. Trees planted at 250–350 trees/ha re-

duced light transmission by over 50% of the total radiation in sole plots. The maize/bean combination was found to tolerate shading. Potential evapotranspiration at the middle of the field was reduced by 36%. Plants in the open field (control) showed severe wilting in the hot afternoons. The drought season was observed to accentuate the moisture competition on crops grown close to trees. Five season yields were improved in the alley cropped potato while soybean and weed yields were reduced.

Competition

330
E
Ong, C.K., J.E. Corlett, R.P. Singh, and C.R. Black. 1991.
Above- and below-ground interactions in agroforestry systems. Forest Ecology and Management 45: 45–57.

The above- and below-ground utilizations of physical resources between trees and crops are examined. Above-ground interactions of the changes in light, temperature, and humidity on understorey crops are examined. Results shows that atmospheric interactions in alley cropping in the semiarid tropics are positively less important than below-ground interactions. Partitioning the below-ground interactions with a shallow polyethylene barrier (0.5 m depth) indicated that competition for soil moisture is responsible for the negative interactions reported in the semiarid tropics (SAT). Root observation indicated that roots of *Leucaena leucocephala* trees are abundant in the top 30 cm of the soil and the presence of a root barrier was effective in restricting lateral movement of the roots. This evidence is contrary to the assumption that trees have deep rooting systems which do not compete with crops. The importance of root studies and the ways in which positive interactions could be achieved are discussed.

Water Use

331
E
Ong, C.K., J.C.W. Odongo, M. Frona, and C.R. Black. 1991.
Water use by trees and crops: five hypotheses. Agroforestry Today 3(2): 7–10.

Experiments in India's semiarid zone demonstrated that the inclusion of trees in the cropping system can enhance the utilization of rainfall, leading to increased overall productivity. However, the trees tended to compete with crops for moisture, which depressed crop production. The standard hedgerow intercropping system demonstrated the most severe form of moisture competition. There is still an urgent need to identify woody species of appropriate phenology and rooting habits to minimize competition with crops. An understanding of water use is an essential step towards the much more formidable objective of developing models to help us predict the sustainability of agroforestry systems in the semiarid tropics. So far, we have not been able to demonstrate that microclimatic improvements due to agroforestry improve the water-use efficiency of understorey crops. One final limitation is that, in many parts of India and much of the semiarid and arid tropics, virtually all crop residues and organic matter consumed by livestock-tree prunings are simply too valuable as a source of fodder to be returned to the soil. Under such conditions, the major benefit from tree-crop interactions in agroforestry systems will have to be obtained from a greater utilization of physical resources.

Competition

332
E
Ong, C.K., M.R. Rao, and M. Mathuva. 1992.
Crops and trees: Competition for resources above and below the ground. Agroforestry Today 4(2): 4–5.

When trees and crops are grown close together, they inevitably compete. This competition is more acute when prunings from the trees are removed for use as fodder and fuelwood, rather than applied to the crops as mulch. One of the most important challenges of agroforestry research is to develop systems that enhance the positive interactions of trees and crops and keep competition to a minimum. Studies on tree-crop competition are in progress at the International Centre for Research in Agroforestry (ICRAF's) research station in Machakos, Kenya. At an altitude of 1600 m, the climate is transitional between dry subhumid and semiarid, with bimodal rainfall averaging 760 mm a year. Soils are variable, but predominately Haplic Lixisols, and most of the land is sloping. Current evidence indicates that in the seasonally dry tropics, competition between *Leucaena* and maize for below-ground growth resources extends well beyond the tree canopy.

Water Use

333
E
Palada, M.C., S.M.A. Crossman, C.D. Collingwood, and S.A. Kowalski. 1993.
Water use and yield of Bell peppers in hedgerow intercropping with drip irrigation. Agronomy Abstracts (1993): 59.

An alley cropping experiment was conducted for two seasons to determine the effects of pigeon pea (*Cajanus cajan* L.) hedgerows on soil water, yield, and water use of intercropped pepper (*Capsicum annuum* L.) under drip irrigation. Peppers were planted at 1-m row spacing in 4-m alleys between hedgerows. Plots were drip-irrigated at soil water tensions of 20, 40, and 60 k Pa. In the first season, soil water in hedgerow plots was 5–20% higher than in the control (no hedgerows) and was attributed to low evapotranspiration (ET), reduced wind speed, and green manure mulch. In spite of low ET, total water use in hedgerow plots was 18% higher than in the control. Low pepper population and partial shading by hedgerows resulted in significant ($P < 0.01$) yield reduction (48–58%) in alley cropping. In the second season, pepper yield in alley cropping was lower than in the control even under equal plant population. Low yield was mainly attributed to reduced pepper growth which can be explained by the inhibitory effect of pigeon pea crop residues.

Vegetable Production

334
E
Palada, M.C., B.T. Kang, and S.L. Claassen. 1992.
Effect of alley cropping with *Leucaena leucocephala* and fertilizer application on yield of vegetable crops. Agroforestry Systems 19: 139–147.

Field trials were set up on a sandy loam Oxic Paleustalf in southwestern Nigeria to investigate the effect of alley cropping vegetable crops with *Leucaena leucocephala* (Lam.) de Wit over two seasons. Four vegetable crops (*Amaranthus cruentus* L.; *Celosia argentea* L.; okra, *Hibiscus esculentus* L.; and tomato, *Lycopersicon esculentum* Mill.) were grown in control plots and in 4-m wide alleys between established *Leucaena* hedgerows without and with fertilizer (30 N-13, P-24, K/kg/ha). *Leucaena* prunings yielded large dry biomass and nutrients during both seasons. Yield of four vegetable crops responded more to fertilizer in the control than in alley cropped treatments. Fertilizer application increased mean yields of *Amaranthus*, *Celosia*, okra, and tomato by 325, 164, 47, and 94 in the control plots and by 36, 26, 4, and 20 in the alley cropped plots, respectively. Differences between the alley cropped

plots with and without fertilizer and the control with fertilizer treatments were not significant for both seasons. The lowest yield was obtained in the control plot without fertilizer. Alley cropping with *Leucaena* can reduce fertilizer requirement for vegetable production. Cost/benefit analysis based on the 1988 market showed that alley cropping with vegetable crops can be a profitable venture.

Crop Production

335
E
Yamoah, C.F., V.J. Eylands, and A.J. Rimkus. 1990.
Effect of lime and NPK on crop performance and soil properties in an alley cropping setting. Agronomy Abstracts (1990): 64.

The agronomic value of lime from a local source was evaluated on an acid soil in the highland region of Rwanda. There were four levels of lime (0, 2, 4, and 8 t/ha) combined with NPK fertilizer at 0 and 60 kg/ha. Wheat and beans used as test crops were planted within *Leucaena* hedgerows spaced 5 m apart. Wheat yield increased linearly and significantly with lime. Wheat yield was inversely related to exch. Al (-0.63**). At the high rates of lime (4 t/ha), wheat floret length and root weight were increased by 24% and 118%, respectively, compared to the control. Bean yields from residual lime were: 823, 1132, 1312, and 1389 kg/ha, respectively. Soil pH was: 4.4, 4.6, 5.2, and 5.6 and exch. Al: 4.2, 3.3, 1.5, and 0.75 meq/100 g for the respective lime treatments. There were significant differences between low (0–2) and high (4–8 t/ha) lime rates for bean yield, pH and exch. Al.

Competition: Rooting Patterns

336
EB
Huxley, P.A., A.Y. Pinney, E. Akunda, and P. Muraya. 1994.
A tree/crop interface orientation experiment with a *Grevillea robusta* hedgerow and maize. Agroforestry Systems 26: 23–45.

In an alley cropping trial with *Grevillea robusta* hedgerows and maize, pruned triple-row hedges of *Grevillea robusta* with 11 rows of maize planted parallel on either side were grown in 12.5 × 16.0 m plots on a flat, freely exposed site. There were two replicates of four orientation treatments and crop yield data were collected on a row-wise basis for 9 seasons. There were marked differences in maize yields between sides especially in the first rainy season. The maize on the downside of prevailing winds consistently performed better than the nonsheltered maize, by 50% over the whole subplot and up to 80% in the tree/crop interface zone. These differences varied between positions, seasons, and zones. Since meteorological data were not collected at the plot level it was difficult to attribute results to the shelter effect. The shading effect was not considered important over the whole subplot. At the end of the experiment, the distribution of fine roots of both species was examined by means of root trenching. The *G. robusta* root system extended almost symmetrically to the edges of the plot in the uncropped part, but only to some 4 m from either side of the hedge in the cropped area. Part of the upper profile to 1.3 m was shared with the maize roots, but *Grevillea* rooted further down to at least 2 m. The possible implications of such niche differentiation for below-ground resource sharing are indicated.

Competition: Nitrogen

337
EF
Akinnifesi, F.K., B.T. Kang, N. Sanginga, and H. Tijani-Eniola. 1994.
Nitrogen competition between *Leucaena* hedgerows and maize in alley cropping. Agronomy Abstracts (1994): 69.

A field trial was undertaken for 2 years on an Alfisol in the humid zone of southwest Nigeria using 15N to assess N competition between *Leucaena leucocephala* hedge-

rows and maize grown in alley cropping. Treatments included were with and without alley cropping, applications of hedgerow prunings, and root barriers. The application of prunings increased maize yield. Efficiency of N-utilization from prunings was low and was attributed to leaching and volatilization losses due to asynchrony of N-release and N-demand. Presence of root barriers adjacent to hedgerows did not affect yield and N-use by maize, implying no significant competition between hedgerows and maize for applied fertilizer N.

Soil/Tree-Soil Fertility

338
EF
Jimenez, M., D.C.L. Kass, J. Sanchez, and G. Sanchez. 1988.
Results of five consecutive years of production of maize and beans under alley cropping on a Typic Humitropept, fine halloysitic isohyperthermic in Turrialba, Costa Rica. Agronomy Abstracts (1988): 57.

In 5 years of alley cropping maize (*Zea mays*) and beans (*Phaseolus vulgaris*), maize yields averaged 2011, 2164, 2687, and 3038 kg/ha/yr for the non alley cropped control without N fertilizer; alley cropping under *Erythina poeppigiana* (Walp) O.F. Cook spaced 6 m × 3 m and pruned twice annually without N fertilizer; non alley cropped control with N fertilizer; and non alley cropped plots with *erythina* mulch without mineral N, respectively. Corresponding yields were 800, 1137, 1088, and 1145 kg/ha/yr for beans. Alley cropping with beans rather than with maize was also observed to be more successful, apparently due to shading from trees.

Competition; Model

339
EO
Haggar, J.P. 1994.
Trees in alley cropping: competitors or soil improvers? Outlook on Agriculture 23(1): 27–37.

The high potential of agroforestry to sustain agricultural production in the humid tropics is well known. The alley cropping system has received much attention as a means of producing staple food crops within an agroforestry system. It is evident that alley cropping maintains soil fertility above levels found in pure annual cropping systems. However, competition between the trees and crops may reduce yield of the associated alley crop. A model on how the balance between the improved soil fertility in alley cropping and competition from the trees determines the final crop performance is presented. Better design and management of the alley cropping system will improve crop production under this system.

EFFECTS ON SOIL PROPERTIES

Leaf; Decomposition; Microarthropods

340
F
Adejuyigbe, C.O. 1994.
Soil microarthropods and litter decomposition under different cropping systems and fallow management in the humid tropics. MSc thesis, University of Ibadan, Ibadan, Nigeria. 87 pp.

An investigation was carried out in 1993 at Ibadan to quantify the effects of bush fallow with *Pueraria phaseoloides* relay cropping, alley cropping with *Leucaena*, and the traditional cropping system on soil microarthropods and their roles in litter decomposition. Microarthropod population increased during the peak of rainfall, but decreased by cropping compared to secondary forest. The highest population was recorded under alley cropping. Fallowing for 1 year restored the microarthropod population close to the level under forest. Leaf decomposition was higher under secondary

forest than cropped plots. The highest decomposition rate of litter was found under alley cropping. The effect of fallow on litter decomposition was in the following order: 3-yr fallow; 15-yr secondary forest; 2-yr bush fallow; 1-yr bush fallow; *Leucaena* alley cropping; *Pueraria* relay cropping; and traditional cropping. The decomposition rate constant did not respond to fallowing length after 1 year fallow. Results imply that improved cropping systems could restore microarthropod activities and litter decomposition.

Nutrient Leaching; Ultisol

341
F
Agus, F., D.K. Cassel, and D.P. Garrity. 1993.
Solute transport under the contour hedgerow farming system in The Philippines. Agronomy Abstracts (1993): 54.

Optimum use of fertilizers in the sloping, low fertility lands of the tropics requires an understanding of solute transport processes. Bromide ion transport was studied in soils, tentatively classified as clayey, halloysitic, and clayey, kaolinitic, isohyperthermic, Typic Kandiudox, on 20 to 30% slope without hedgerows (Control (C) and on plots with contour hedgerows of *Gliricidia sepium* plus *Paspalum notatum* (GP). Bromide concentration was determined on soil and soil solution samples taken with suction lysimeters. Samples from soil solutions usually gave lower Br concentrations than Br in the soil, probably reflecting that the percolating water usually bypassed the Br in the soil aggregates. Treatment GP reduced the amount of runoff and soil erosion. Slightly greater lateral movement and lower vertical movement was found for treatment C. After the plots received about 200 mm of rainfall, 50% of the Br had leached below the 20-cm-thick plow layer. Solutes below this depth are unlikely to be available to plants in this highly acid subsoil.

Ultisol; Erosion; Runoff

342
F
Alegre, J.C. 1991.
Runoff and erosion losses under low-input forest and alley cropping on slopes in the humid tropics of Peru. Agronomy Abstracts (1991): 58.

The use of imported mulch or in situ residues has been demonstrated to be very efficient in soil and water conservation. Furthermore, vegetation such as trees grown in situ and used as a source of mulch, can provide a physical barrier to soil erosion, especially on slopes. A long-term experiment comparing three management options (low-input continuous cropping, alley cropping, and secondary forest) under slopy areas is being conducted in a Typic Paleudult of the humid tropics of Peru. Ten crops in contour rows (rice-cowpea) were planted during the first 3 years of study. There were no significant differences in yields for low input cropping and alley cropping. In the low-input cropping system, there were approximately 28 times the erosion and 7 times the runoff measured in the hedge system. Runoff losses from the secondary forest were very low. Bulk density at 0.5 cm depth increased from 1.1 Mg/m^3 to 1.29 and 1.33 Mg/m^3 for alley cropping, and low-input cropping, respectively.

Soil Conservation; Soil Fertility

343
F
Anecksamphant, C., S. Boonchee, and A. Sajjapongse. 1990.
Management of sloping lands for sustainable agriculture in northern Thailand. Pages 198–203 *in* Transactions of the 14th International Congress on Soil Science, Kyoto, Japan. Volume VI.

The paper reports results of a first-year study on management of sloping lands for sustainable agriculture at Doi Tung in Chang Rai province and Chiang Dow in Chiang

Mai province in northern Thailand. Results showed the effectiveness of soil conservation measures in reducing soil loss and runoff, especially at Chiang Rai with slope ranging from 20 to 50%. Alley cropping, grass strip cropping, and hillside ditches reduced soil loss and erosion by more than 50% when compared to the farmers' practice. The yields of corn and upland rice observed in this study were rather low, and can hardly encourage farmers to invest money in any soil conservation measures. To be more attractive to the farmers, the yield must be increased. This can be done in two ways; i.e., planting fruit trees or coffee on the bank of the ditches or on the strips to give extra income to the farmers, and/or improving the soil fertility, especially by the input of N and P fertilizers, which may increase the cereal yield significantly. The introduction of a legume into the cropping system may also help to enhance the N supply and decrease the weed pressure which was a major constraint during this cropping season.

Decomposition

344
F
Budelman, A. 1987.
***Gliricidia sepium* (Jacq.) Walp. in the southern Ivory Coast: production, composition and decomposition of the leaf biomass. Pages 74–81 *in Gliricidia sepium* (Jacq.) Walp.: management and improvement, edited by D. Withington, N. Glover, and J.L. Brewbaker. Nitrogen Fixing Tree Association (NFTA) Special Publication 87-01, Waimanalo, Hawaii, USA.**

Data are provided on the dry matter production, nutrient content, and decomposition rate of *Gliricidia sepium* leaves used as a mulch. The production is generally lower than that of *Leucaena leucocephala*. Analysis shows that *Gliricidia sepium* does not meet its ecological optimum in the southern Ivory Coast. The nutrient contents of *Gliricidia* leaves more or less follow the pattern found in *Leucaena leucocephala* leaves. The dry matter content is about 5% lower compared to *Leucaena*. *Gliricidia* leaves decompose rapidly. Half of the dry weight leaf material is lost after just 3 weeks. Phosphorus and nitrogen are released within a similar period of time. The loss rate of potassium is about twice as fast as the rate for carbon, nitrogen, and phosphorus.

Soil Management

345
F
Celestine, A.F. 1984.
Farming systems approach to soil erosion control and management. Pages 64–69 *in* Soil erosion management, edited by E.T. Craswell, J.V. Remenyi, and L.G. Nallana. Proceedings of the Philippines Council for Agriculture and Resources Research and Development, Los Banos, The Philippines.

Reviews potential farming systems and subsystems used for soil and water conservation. Systems discussed include: (1) corn *Leucaena* farming system using double hedgerows of *Leucaena* planted along contour lines, (2) agroforestry systems, (3) legume based pasture livestock system, and (4) zero tillage. Stresses the need for development of location-specific farming systems.

Erosion

346
F
Celestino, A. 1984.
Farming systems approach to soil erosion control and management. Pages 65–70 *in* Soil erosion and management, edited E.T. Craswell, J.V. Remenyi, and L.G. Nallana. Australian Centre for International Agricultural Research (ACIAR), Canberra, Australia.

Discusses various potential farming systems and subsystems used for soil and water conservation including maize/*Leucaena* intercropping, agroforestry, a legume-based pasture-livestock system, and no-tillage.

Soil Moisture Depletion

347
F
Chirwa, P.W., P.K.R. Nair, and P. Nkedi-Kizz. 1994.
Pattern of soil moisture depletion in alley cropping under semiarid conditions in Zambia. Agroforestry Systems 26: 89–99.

An alley cropping experiment with *Leucaena leucocephala* and *Flemingia macrophylla,* and maize established at the SADC/ICRAF Agroforestry Research Station in a semiarid region near Lusaka, Zambia was studied (28° 29' 56" East and 15° 21' 32" South). The pattern of soil moisture changes was studied and soil moisture potential was monitored at regular intervals using tensiometers installed at 15, 30, and 45 cm depths in fertilized and unfertilized alleys within the double hedgerow, and the first, second, and third rows of maize in the alleys. Results indicated that soil moisture moved mostly towards the top horizon during very dry conditions. Alleys that had received a combination of fertilizer and hedgerow prunings depleted more moisture than those that had only hedgerow prunings. Differences in moisture utilization patterns between *Leucaena* and flemingia hedgerows were not significant. The hedgerows depleted the same amount of moisture as the maize plants. However, during dry conditions, there was a higher soil moisture content under the hedgerows than in maize rows, implying there was no significant competition for moisture between the hedgerows and the associated maize plants.

Manure

348
F
Cobbina, J., A.N. Atta-Krah, and B.T. Kang. 1989.
Leguminous browse supplementation effect on the agronomic value of sheep and goat manure. Biological Agriculture and Horticulture 6: 115–121.

The trend of N buildup in wood shavings used as bedding for sheep/goats fed on leguminous fodder supplementation in the diet on manurial value of the litter was monitored. Basal diet consisting of ad libitum guinea grass (*Panicum maximum*) was supplemented with leguminous fodder at four levels: 200, 400, 800, 1200 g dry matter/head/day. Samples of wood shavings mixed with faeces, urine, and spilled feed were taken at 2-week intervals and analyzed for N content after penning the animals for a period of 7 weeks. Manure from the four feed types was compared at three rates of application (4, 8, 12 g/kg soil) in a pot trial. Another trial was set up to test the effects of increasing levels of wood shaving on immobilization of applied and native N. Results showed that accumulation of N in litter increased with time. Increasing leguminous fodder supplementation in the diet improved manurial value of bedding. Wood shavings used as bedding seemed to reduce the agronomic value of manure.

Erosion, Runoff and Soil Porosity

349
F
Comia, R.A., E.P. Paningbatan, and I. Hakansson. 1994.
Erosion and crop yield response to soil conditions under alley cropping systems in The Philippines. Soil and Tillage Research 31: 249–261.

Trials were conducted to compare the conventional tillage (T1) and alley cropping treatments whether tilled-unmulched (T2), tilled-mulched (T3), or untilled-mulched (T4) in terms of their effects on erosion, crop yield, and selected properties of a clay soil on a 17% slope. The alley cropping systems consisted of 1-m wide contour hedges (three rows of *Desmanthus virgatus* planted at 10 cm spacing with 40 cm between rows) between 5-m wide alleys where maize (*Zea mays* L.) and mungbean (*Phaseolus aureus*) were grown sequentially. The hedgerows were pruned every 45–60 days to 50 cm height and used as green manure for the alley crops. The saturated hydraulic conductivity and air permeability during the pod development stage of the mungbean crop in T4 were twice that in T1 in both the 0–5 and 7–12 cm soil depths after a 3-year trial. In the 0–5 cm layer, soil bulk density was lower, and total porosity and the volume of pores with equivalent diameter 30 m were significantly greater in T4 than in T1. The trend however reversed for the pore volume within the 10–30 m and 0.2 m diameter ranges. The effect of T2 was superior to that of T1 but inferior to T3 or T4 in terms of erosion control, although comparable with the latter treatments with respect to mean crop yields. The lowest annual soil and nutrient losses were in the mulched alley cropping systems (T3 and T4) which gave similar maize yields, but smaller mungbean yields, compared with the other treatments.

Decomposition-Soil Fertility

350
F
Constantinides, M. and J.H. Fownes. 1993.
Nitrogen mineralization patterns of leaf-twig mixtures from tropical leguminous trees. Agroforestry Systems 24: 223–231.

The impact of twigs on net N mineralization or immobilization from hedgerow cuttings were assessed by separating cuttings from *Calliandra calothyrsus* and *Gliricidia sepium* into leaf-only, twig-only, and mixed (leaf + twig) fractions, and incubating them with moist soil in the laboratory. Results indicated that soil extractable inorganic N did not differ among treatments after 2 weeks, but after 4 and 8 weeks was greatest in the leaf-only, and least in the twig-only treatments. After 2 weeks, extractable N from the leaf-only treatment rose steadily, while that from the twig-only and mixed treatments was variable due to periods of net mineralization and net immobilization. The pattern of variation in mixed treatments was similar to the twig-only, suggesting that net immobilization in the mixture was largely caused by the presence of twigs. Extractable N from the mixture was somewhat lower than that predicted from the sum of leaf-only and twig-only treatments. It was demonstrated that twigs in green manure reduce short-term availability of N to associated crops in agroforestry systems.

Soil Fertility-Soil Physical Properties

351
F
Dalland, A., P.I. Vaje, R.B. Matthews, and B.R. Singh. 1993.
The potential of alley cropping in improvement of cultivation systems in the high rainfall areas of Zambia. III. Effects on soil chemical and physical properties. Agroforestry Systems 21: 117–132.

This study described the soil chemical and physical properties in a 7-year-old alley cropping trial containing *Leucaena leucocephala* and *Flemingia congesta* in Northern Zambia. A strong correlation exists between the maize yield and the total amount of nitrogen applied, both from prunings and fertilizer, suggesting that an improvement in nitrogen supply was a major benefit of the alley cropping system especially with

Leucaena. *Leucaena* produced higher biomass, and had higher concentrations of nitrogen, phosphorus, and potassium and lower C/N and C/P ratios than did *Flemingia*. There was also evidence that the trees had a beneficial effect on other soil chemical properties; under the hedgerows, particularly those of *Leucaena*, there were higher levels of organic carbon, Mg, K, and effective cation exchange capacity (ECEC) and pH values were also highest. Alley cropping plots showed lower bulk density, lower penetration resistance, and a higher infiltration rate and pore volume fraction but no significant effect on soil water release parameters. Constant applications of nitrogen fertilizer (urea) decreased Mg, K, and pH and increased Al, soil acidity, and penetrometer resistance. Further research on biological means of maintaining soil fertility is urgently needed.

Soil Fertility

352
F
Escobar-Munera, M.L., C. Ramirez, and D. Kass. 1994.
Nitrogen in alley cropping using *Erythina poeppigiana* and *Gliricidia sepium* with common beans, *Phaseolus vulgaris*. Pages 133–147 *in* Tapado-slash/mulch: How farmers use it and what researchers know about it, edited by H.D. Thurston. CIFAD, Cornell University, Ithaca, N.Y., USA.

The paper presents work carried out in Costa Rica with the objective of exploring the potential of *Erythina* and *Gliricidia* alley cropping systems in terms of N mineralization during the phaseolus cropping cycle and on bean yields.

Soil Fertility; Soil Erosion

353
F
Eylands, V.J. and C.F. Yamoah. 1990.
Sustaining soil fertility with alley cropping systems in the highlands of Rwanda. Journal of Farming Systems Research and Extension 1: 31–36.

At current rates, the Rwandan population will double every 19 years. This situation is critical from an agricultural standpoint as the thin topsoil that supports this population is rapidly disappearing through erosion. Soil fertility is declining as the topsoil is removed and the acidic subsoils are exposed. The mountain farming system is characterized by an open-ended nutrient cycle, loss of essential plant nutrients is faster than gains. An alley cropping system involving the planting of leguminous shrubs on terraces has been proposed as being able to close the nutrient loop by reducing slopes and thus erosion and recycling leached cations through a deep rooting system; in addition, the system provides poles for bean production. When lime and a green manure/cover crop such as vetch are added to the system, acceptable crop yields can be attained while soil fertility is maintained. A large degree of farmer involvement and a high acceptability index for the technologies has been produced using the farming system approach in this study. The system which relies on locally purchased goods will work for the Rwandan farmers. The continued success of the program after the current Farming Systems Research Program (FSRP) project ends is ensured by training extension agents, farmers, and nursery managers in the raising and distribution of tree seedlings as well as management practices.

Soil Fertility

354
F
Greenland, D.J. 1985.
Nitrogen and food production in the tropics: contributions from fertilizer nitrogen and biological nitrogen fixation. Pages 9–38 *in* Nitrogen management in farming systems in humid and subhumid tropics, edited by B.T. Kang and J. Van der Heide. IITA/Institute of Soil Fertility, The Netherlands.

In farming systems of the semiarid tropics responses to nitrogen fertilizers are frequently limited by water deficiencies. Where rains are concentrated over a short period, fertilizer may be successfully and economically used. Grain legumes may contribute their own nitrogen. Cereal crops may receive some nitrogen accumulated in a previous fallow phase. Legume-based pastures may contribute larger amounts of nitrogen to a succeeding arable crop, but for most of the semiarid tropics, satisfactory pasture legumes have still to be identified. In the humid tropics, nitrogen fertilizers normally produce significant yield increase, but other nutrients may also be needed and soil acidity may need to be controlled. Grain legumes and green manures can also be successfully grown and contribute fixed nitrogen to the system. Nitrogen is also accumulated by biological nitrogen fixation (BNF) under forest fallows, and released to crops grown when the forest is cleared. Alley farming systems may be more productive and combine the advantages of the forest fallow system with much greater rates of BNF, and more intensive land use. Live and other mulches can also lead to increased BNF. Grass pastures may lead to the accumulation of nitrogen, but the rates of associated nitrogen fixation are significantly less than under legumes. In the wetlands, rice cultivation is normally accompanied by substantial nitrogen fixation. Although use of nitrogen fertilizers normally leads to greater yields of rice, BNF is sufficient to maintain stable yields at a moderate level over many years. Nitrogen can also be supplied to the crop from BNF associated with Azolla, BGA inoculation, and green manures or grain legumes grown in succession to rice. Methods of integrated nitrogen management need to be developed whereby nitrogen fertilizers can be used to supplement and not reduce BNF contributions to the crops grown. Proper nitrogen management allowing maximum advantages to be taken of BNF can substantially reduce the need for mineral nitrogen fertilizers.

Soil Fertility

355
F
Gutteridge, R.C. 1992.
Evaluation of the leaves of a range of tree legumes as a source of nitrogen for crop growth. Experimental Agriculture 28: 195–202.

The leaf mulches from selected tree legumes including *Acacia cunninghamii*, *A. fimbriata*, *Calliandra calothyrsus*, *Gliricidia sepium*, *Leucaena leucocephala*, and *Sesbania sesban* were explored as nitrogen sources for maize growth in pot experiments. The mulch of *Sesbania sesban* resulted in the largest yields of maize stover but yields were less than those that resulted from the application of equivalent rates of fertilizer nitrogen. *Gliricidia* and *Leucaena* mulch also increased maize yield more than those of *Calliandra* and the two *Acacia* species which were ineffective as N sources in the short term. Maize yield obtained from 5 t/ha dry matter (DM) of *Sesbania* mulch was similar to that obtained with 75 kg N/ha. The poor maize response to *Calliandra* and *Acacia* mulches may be linked to the high polyphenol and/or lignin content of the leaves of these species.

Soil Fertility

356
F
Haggar, J.P., G.P. Warren, J.W. Beer, and D. Kass. 1991.
Phosphorus availability under alley cropping and mulched and unmulched sole-cropping systems in Costa Rica. Plant and Soil 137: 275–283.

Availability of phosphorus was measured in soils under five cropping systems including: alley cropping with *Erythina poeppigiana*, alley cropping with *Gliricidia sepium*, sole cropping with *Erythina poeppigiana* mulch applied, sole cropping with *Gliricidia sepium* mulch applied, and sole cropping with no mulch. The following parameters were measured: (1) plant-available soil P assessed by P uptake of maize and bean bioassay plants; (2) phosphate desorbable by anion exchange resin; and (3) adsorption of added P into isotopically exchangeable and nonexchangeable pools. Results from the bioassay suggest trees had not incorporated a significant quantity of P into the system after 7 years and, probably, there was a decrease in available soil P due to the sequestration of P in the tree biomass. Potentially resin-desorbable P was higher in alley cropped and mulched sole-cropped soils than in unmulched sole-cropped soils. Alley cropping had no effect on the adsorption and desorption of added P into and from exchangeable and non-exchangeable pools in the soil. Higher crop yield and crop N, P, and K uptake were obtained in the alley crops than in the unmulched sole crop. The supply of P to the crop under alley cropping seems to be dependent on P cycled and released from the mulch. The P cycle in alley cropping and moderate P fertilizer input seem to be self-sustaining.

Soil Fertility : Weeds

357
F
Handawela, J., P.T. Bandara, and W.R.A. Perera. 1987.
Biological N-fixation through trees for upland annual cropping. Pages 73–77 *in* Proceedings in nitrogen fixation and soil fertility, edited by H.P.M. Gunasena. Faculty of Agriculture, University of Peradenija, Peradenija, Sri Lanka.

Upland annual crop cultivation in the dry zone of Sri Lanka is limited by moisture availability, poor structural stability of the soil, graminaceous weed proliferation, and low nutrient status particularly, nitrogen and phosphorus. Using a leguminous tree stand whose canopy is regularly pruned to make way for annual crop growth underneath and to add loppings to the field could help to solve some of these problems. A long-term field experiment conducted using *Gliricidia maculata* shows that the tree component provides nitrogen, improves tilth and moisture status of soil, and smothers graminaceous weeds. Yield decline observed after some years of continuous cropping without the application of phosphorus could be due to phosphorus deficiency. This has to be investigated and ameliorative measures taken.

Nitrogen Leaching

358
F
Hartemink, A.E., R.J. Buresh, B. Jama, and B.H. Janssen. 1994.
Inorganic nitrogen dynamics as affected by *Sesbania sesban*, weeds, and maize in Kenya. Agronomy Abstracts (1994): 74.

A study was conducted on a Kandiudalfic Eutrudox in the subhumid highlands of Kenya to determine the ability of a fast-growing, woody perennial to take up subsoil N. Changes in nitrate, ammonium, and water to 2-m soil depth were measured for one rainy season in four land-use systems (LUS): (1) an improved fallow with *Sesbania sesban*, (2) a weed fallow, (3) maize, and (4) a bare fallow. The N budgets based on plant uptake and changes in soil inorganic N, suggest loss of soil N during the season. At the end of the season, soil water content at 1.0 to 2.0 m was lower for *Sesbania* than other LUS, and soil nitrate at 0.5 to 2.0 m was lower for *Sesbania* than maize but similar for *Sesbania* and weed fallow. Sorption of nitrate increased with

depth; about 60% of the nitrate at 1.5 to 2.0 m water sorbed. In conclusion, results suggest downward movement of nitrate and slight ability of *Sesbania* to reduce subsoil water and nitrate.

Nutrient Recycling; Earthworm Activity

359
F
Hauser, S. 1994.
Contribution of earthworms to nutrient recycling in alley cropping. IITA Research 8: 1–4.

Processes involving organic matter and plant nutrients near the soil surface are important in addressing the declining soil fertility faced by African farmers. Alley cropping—the growing of food crops within alleys formed by fast-growing trees as hedgerows—is being studied for its potential benefits. The paper discusses one of the benefits observed: earthworm activity was increased by permanent shading in the vicinity of hedgerows. Casting by earthworms was seen to improve the soil's organic matter and nutrient status by recycling available nutrients (especially N, P, K, Ca, and Mg.)

Alfisol; Soil Physical Properties

360
F
Hulugalle, N.R. and B.T. Kang. 1990.
Effect of hedgerow species in alley cropping systems on surface soil physical properties of an Oxic Paleustaff in southwestern Nigeria. Journal of Agricultural Science, Cambridge 114: 301–307.

In an ongoing alley cropping trial established in 1981 on an Oxic Paleustaff in southwestern Nigeria, the effects of hedgerow species on surface soil physical properties were studied. The experimental treatments were *Leucaena leucocephala*, *Gliricidia sepium*, *Alchornea cordifolia*, and *Acioa barteri* hedgerows planted at 4-m interhedgrow spacings, and a control (no hedgerows). Plots were sequentially cropped with maize (*Zea mays*) and cowpea (*Vigna unguiculata*). Soil physical properties, (particle size distribution, bulk density, apparent pore size distribution, and water infiltration) were monitored during the dry season in January and the main growing season in June 1989. Soil temperature was monitored at monthly intervals from February to June 1989. Soil physical properties of alley cropped plots were superior to those of the control. Soil compaction was highest in the control and lowest with *L. leucocephala* and *A. barteri*. The quantity and quality of prunings produced by the hedgerow species and pruning frequency have positive effects on soil physical properties.

Alfisol; Soil Physical Properties

361
F
Hulugalle, N.R. and B.T. Kang. 1990.
Effect of land management systems on surface soil physical properties of an Alfisol. Pages 390–401 *in* Proceedings of the International Symposium on Water Erosion, Sedimentation, and Resource Conservation. Central Soil and Water Conservation Research and Training Institute, Dehraaun, Uttar Pradesh, India.

The effect of six land-management systems: 4 alley cropping systems, *Leucaena leucocephala*, and *Gliricidia sepium* hedgerows at interhedgerow spacings (alleys) of 4 m and 2 m, no-tillage, and tillage, on surface soil physical properties of an Alfisol was studied in a trial established in 1982. Least soil physical degradation as indicated by measurements of bulk density, soil water retention, infiltration rate, penetrometer resistance, and apparent pore size distribution occurred when *L. leucocephala* was planted at interhedgerow spacings of 2 m. Conversely, the great-

est soil physical degradation occurred with tillage and was attributable to both accelerated soil erosion and soil compaction. Soil physical properties were similar either with no-tillage or in alley cropping systems with 4-m interhedgerow spacings.

Soil Fertility

362
F
Juo, A.S.R. and B.T. Kang. 1989.
Nutrients' effects of modification of shifting cultivation in West Africa. Pages 289–300 *in* Mineral nutrients in tropical forest and savanna ecosystems. Blackwell Scientific Publications, Oxford, UK.

Recycling of plant residues, fertilizer use, and the inclusion of trees and perennials in crop fields are key components in systems for improved food crop production on infertile soils in the forest regions of West Africa. On Alfisols of pH 5.5 or higher in the forest and forest-savanna transitional zones, systems including food crop-cover crop rotation, minimum tillage, and the judicial use of fertilizer can sustain yields on small farms for 10 years or more without reverting land to bush fallow. Interplanting leguminous trees such as *Leucaena leucocephala* with annual crops is shown to improve food crop yields. The leguminous trees fix atmospheric nitrogen, recycle mineral nutrient from the subsoil, and prevent soil erosion and runoff water on sloping land. On strongly leached acid soils (i.e., Ultisols and Oxisols) in high-rainfall regions, nutrient cycling and green manuring are less effective because of subsoil infertility. Intensive food-crop production on such soils requires costly inputs of fertilizer and lime. However, experiments have shown that periodic application of small dosages of lime can sustain a moderate crop yield. Gradual saturation of subsoil horizons with calcium is a prerequisite for effective recycling of nutrients in agricultural systems in the high-rainfall region.

Soil Fertility

363
F
Juo, A.S.R. and R.E. Meyer. 1988.
Woody legumes and soil quality maintenance with special reference to alley cropping. Paper presented at the International Conference on Dryland Farming, 15–19 Aug 1988, Bushland, Texas, USA.

Multipurpose woody legumes such as *Leucaena leucocephala*, *Acacia* spp., and *Prosopis* spp. (mesquite) maintain favorable soil physical and chemical properties through improving organic C and N in the surface soil, recycling subsoil nutrients, and controlling water and wind erosion. In the *Leucaena*/maize alley cropping system, *Leucaena* planted in 4 m-alleys can produce 7 t/ha (dry weight) of green manure in 2 to 3 prunings which contain 250 kg of N, 20 kg of P, 185 kg of K, and 100 kg of Ca. Alley cropping fields established on nonacid soils at Ibadan, Nigeria have maintained soil productivity and crop yield over 10 years. In drier regions, although the use of *Acacia albida* and mesquite as multipurpose trees in traditional farming is well known, the use of these woody legumes in more intensive mixed food crop or pasture production systems requires better understanding of the plant-soil water relationships within a watershed or a land unit.

N Contribution

364
F
Kang, B.T. 1988.
Nitrogen cycling in multiple-cropping systems. Pages 333–348 *in* Advances in nitrogen cycling in agricultural ecosystems, edited by J.R. Wilson. Proceedings of the Symposium on Advances in Nitrogen Cycling in Agricultural Ecosystems, 11–15 May 198,7 Brisbane, Australia. CAB International, Wallingford, Oxford, UK.

Nitrogen is the key nutrient for sustaining or increasing food production in the tropics. Multiple-cropping systems, particularly intercropping, sequential cropping, and rotations, have benefited from the inclusion of legumes in the production sequence. Multiple-cropping systems are more efficient in using native N, biologically fixed N, and fertilizer N. The N benefit to non-legumes in multiple cropping with legumes is mostly derived from N left in crop residues. The amount of N transferred from grain legumes is usually low because most of the N is removed in the grain harvest. There are some indications that in intercropping systems, N excretions from the legumes to the associated crop may take place. The N contribution is higher from sole than from intercropped grain legumes. Sole-cropped grain legumes can contribute between 40 to 70 kg N/ha to the succeeding crop. Inclusion of woody legumes in an alley cropping system can help maintain soil productivity with less N input.

Soil Fertility

365
F
Kang, B.T. and K. Mulongoy. 1992.
Nitrogen contribution of woody legumes in alley cropping systems. Pages 161–169 *in* Biological nitrogen fixation and sustainability of tropical agriculture, edited by K. Mulongoy, M. Gueye, and D.S.C. Spencer. John Wiley, Chichester, UK.

Despite the potential for obtaining high and sustainable crop yields under rainfed upland conditions in the tropics with high fertilizer input, this technology is not widely used in Africa. Alley cropping is an alternative, sustainable, and low-input production system. The inclusion of nitrogen-fixing woody legumes in alley cropping contributes significant amounts of nitrogen to associated crops, while the system itself contributes much-needed organic matter to the soil. This paper reviews recent progress in quantifying some of the components of the nitrogen-cycling mechanism in alley cropping and highlights those issues which still require research attention in order to enhance nitrogen utilization by associated crops. Particular attention needs to be given to areas characterized by acid soils.

Soil Fertility

366
F
Kwapata, M.B., O.T. Edje, and S.S. Chiyenda. 1985.
Soil fertility maintenance under the alley cropping system. Paper presented at a meeting of cooperators in the project on improvement to shifting cultivation held 25–29 Mar 1985 at IITA, Ibadan, Nigeria.

Soil fertility maintenance under an alley cropping system was initiated at Bunda College of Agriculture, Lilongwe, Malawi during the 1983/84 crop season. The treatments consisted of three nitrogen levels (0, 50, and 100 kg/ha N) as the main plot, three tree species (*Cajanus cajan*, *Cassia siamea*, and *Leucaena leucocephala*) as subplots, and alley widths of 2.7, 5.4, and 10.3 m as the sub-subplots in a split-split-plot experimental set up. The crop between the alleys was maize. All tree seeds were directly sown and this affected the rate of establishment and subsequent growth

of the tree species except *Cajanus cajan* which grew normally. As a result of the poor growth in *Cassia siamea* and *Leucaena leucocephala* only *Cajanus cajan* was cut back at the end of the first season and the litter was spread in the alleys of the maize plots. Since the *Cajanus cajan* litter was ridged over at the end of the first season, the maize yield during the first season was essentially a response of the crop to the nitrogen levels. This response resulted in average maize seed yields of 422, 302, and 4646 kg/ha corresponding to 0, 50, and 100 kg/ha of N, in that order.

Erosion+Runoff

367
F
Lal, R. 1989.
Agroforestry systems and soil surface management of a tropical Alfisol. II. Water runoff, soil erosion, and nutrient loss. Agroforestry Systems 8: 97–111.

Agroforestry experiments were undertaken on a tropical Alfisol in southwestern Nigeria to monitor water runoff, soil erosion, and nutrient loss in water runoff. Field runoff plots 70 × 10 m each were established. The nonagroforestry control treatment (A) was established at two levels: plow-till and no-till systems of seedbed preparation. There were two agroforestry systems based on contour hedgerows of (B) *Leucaena leucocephala*, and (C) *Gliricidia sepium* established at 4-m and 2-m spacings. Field plots were established in 1982 and hydrological measurements were made for uniform maize-cowpea rotation for 12 consecutive growing seasons from 1982 through 1987. Well-established hedgerows of *Leucaena* at 2-m spacing were effective in reducing water runoff and controlling erosion. Runoff, erosion, and nutrient losses were generally more from maize grown in the first season than from cowpea grown in the second. Mean seasonal erosion from maize was 4.3, 0.10, 0.57, 0.10, 0.64, and 0.60 t/ha for plow-till, no-till, *Leucaena*-4 m, *Leucaena*-2 m, *Gliricidia*-4 m, and *Gliricidia*-2 m treatments, respectively. Mean runoff in the first season from treatments listed in the order above was 17.0, 1.3, 4.9, 3.3, 4.3, and 2.4 % of the rainfall received. There were high losses of Ca and K through water runoff from the plow-till treatment. The high concentration of bases in runoff was attributed to nutrient recycling by the deep-rooted perennials.

Soil Chemical Properties

368
F
Lal, R. 1989.
Agroforestry systems and soil surface management of a tropical Alfisol. III. Changes in soil chemical properties. Agroforestry Systems 8: 113–132.

Effects of three agroforestry systems on soil chemical properties were evaluated over a period of 12 consecutive crops of maize-cowpea rotation grown on a tropical Alfisol in southwestern Nigeria. Measurements of soil chemical properties for 0–5 cm depths were made over a period of 5 consecutive years from 1982 through 1986. Six treatments studied were plow-till, no-till, *Leucaena* hedgerows established on the contour at 4-m and 2-m spacing, and *Gliricidia* hedgerows established at 4-m and 2-m spacings. Soil organic matter, total N, pH, and exchangeable bases declined significantly in all treatments. In contrast, total acidity and exchangeable A1+3 increased. The relative magnitude of changes in these properties, however, were different among treatments. Depletion of soil fertility was the most severe in plow-till and the least severe in *Leucaena*-based systems. There were increases in soil pH and exchangeable bases in the soil during the third and fourth years of hedgerow establishment.

Soil Physical Properties

369
F
Lal, R. 1989.
Agroforestry systems and soil surface management of a tropical Alfisol. IV. Effects on soil physical and mechanical properties. Agroforestry Systems 8: 197–215.

Changes in soil physical properties (over a period of 6 years) were measured on field runoff plots established on a tropical Alfisol for six systems including plow-till, no-till, contour hedgerows of *Leucaena leucocephala* established 2- and 4-m apart, and contour hedgerows of *Gliricidia sepium* established 2- and 4-m apart. Soil physical properties were measured once every year during the dry season following the harvest of second season crops. Over the 6-year period, there were no significant differences in relative contents of textural separates of sand, silt, and clay for the surface 0–5 and 5–10 cm layers. The gravel concentration of the surface 0–5 and 5–10 cm layers, however, increased significantly due to plowing and mixing of the surface and subsoil layers. Soil bulk density of 0–5 and 5–10 cm layers, respectively, increased in all treatments from initial values of 1.02 and 1.16 g/cm^{-3} in 1982 to 1.43 and 1.65 g/cm^{-3} at the end of the cropping cycle in 1986. The maximum increase in soil bulk density was observed for the no-till treatment. There was an increase in penetration resistance of the surface 0–5 cm layer from an average value of 25.1K Pa in 1982 to 211K Pa in 1986. The highest penetration resistance (353K Pa) of 5–10 cm layer was recorded for the no-till treatment. The total porosity, the gravimetric soil moisture retention at zero suction was higher in the *Gliricidia*-based system than in the no-till system. Both *Leucaena* and *Gliricidia*-based systems improved available water capacity (AWC) of the soil. In comparison with the no-till system, increase in AWC by *Leucaena*- and *Gliricidia*-based systems, respectively, was 42% and 56% by weight for 0–5 cm depth and 12% and 58% by weight for 5–10 cm depth. Alterations in PF curves by agroforestry-based systems were attributed to improvements in soil structure and structural porosity.

Runoff, Soil Erosion

370
F
Logan, T.J. and R. Lal. 1990.
Some experimental results of soil erosion and its control in Africa and Latin America. Transactions of the 14th International Congress Soil Science, Kyoto, Japan. Volume VII: 274–279.

Presents selected results of studies in Africa and Latin America on erosion control measures, including structural measures such as terraces and hillside ditches, and management approaches such as conservation tillage and alley cropping. Alley cropping has the beneficial effect of reducing both runoff and soil erosion.

Decomposition

371
F
Maclean, R.H. 1991.
The decomposition rate of *Gliricidia sepium* and *Cassia spectabilis* mulch and its influence on biomass management in an alley cropping system in the southern Philippines. Nitrogen Fixing Tree Research Reports 9: 43–46.

Reported results of decomposition studies of *Gliricidia sepium* and *Cassia spectabilis* biomass applied as mulch on an acid soil in Claveria in southern Philippines. When *Gliricidia* and *Cassia* are intercropped as hedgerows for green manure and mulch production, *Gliricidia* should be incorporated and *Cassia* applied as mulch. Because *Gliricidia* decomposes almost twice as fast as *Cassia* it would not be as effective at reducing weed abundance during the critical establishment period for upland rice and it could not be expected to reduce the incidence of drought. The simple grid method

is a useful system in evaluating biomass decomposition and helping farmers and development workers to select hedgerow species appropriate to farmers' needs.

Decomposition; Nitrogen Dynamics

372
F
Matta-Machado R.P., C.L. Neely, and M.L. Cabrera. 1994.
Plant residue decomposition and nitrogen dynamics in an alley cropping and an annual legume-based cropping system. Communications in Soil Science and Plant Analyses 25: 3365–3378.

Trials were conducted to assess plant residue decomposition and nitrogen (N) dynamics in an alley cropping system (AC) and an annual legume-based cropping system (NA) in the Piedmont region of Georgia, USA, using hedgerows of *Albizia julibrissin (Albizia)* established in January 1990. Hedges were spaced at 4 m between rows and 0.5 m spacing within rows. A rotation beginning with *Mucuna deeringiana* (velvet bean) followed by a winter annual crop of *Trifolium incarnatum* L. (crimson clover), a summer crop of *Sorghum bicolor* (L.) Moench (grain sorghum), and a winter crop of *Triticum aestivum* L. (wheat) was established in the alley cropping system and in control treatments. All crops were grown using no-tillage systems. Plant residue decomposition and N dynamics in crimson clover, *Albizia*, and grain sorghum were measured using litterbag. Total N, soil, and plant in decay rate constants (K) for dry matter, soil potentially mineralizable N, and nitrification rates were determined. Decay rate constants for N were best correlated with the lignin content of the plant residues. No residue quality parameter was significantly correlated with decay rate for dry matter. There was no significant difference between AC and NA systems in terms of soil organic N and potentially mineralizable N; however, nitrification rates were greater in the alley cropping system.

Soil Fertility

373
F
Mulongoy, K. 1986.
Nitrogen cycling in alley cropping systems. IITA Research Briefs 7(4): 3–5.

This paper discusses the potentials of leguminous trees which are preferred in alley farming hedgerows because they can fix atmospheric N into the system and reduce dependence on expensive chemical N fertilizers as well as providing protein-rich fodder. The need for some validation of N-fixation studies in farmers' fields and extension of biological nitrogen fixation to other hedgerow trees, besides *Leucaena* was indicated. Factors affecting symbiosm in nitrogen-fixing trees and the release of nutrients to companion crops were discussed. Areas where there is a dearth of information in N cycling in alley farming were highlighted.

Soil Fertility

374
F
Mulongoy, K., K.N. Kunda, and C.N.K. Chiang. 1993.
Effect of alley cropping and fallowing on some soil fertility parameters in southern Nigeria. Pages 47–55 *in* Soil organic matter dynamics and sustainability of tropical agriculture, edited by K. Mulongoy and R. Merckx. J. Wiley, Chichester, UK.

Under tropical conditions, the rapid decline of soil fertility when land is cleared and cultivated has emphasized the key role played by soil organic matter in sustaining soil productivity. The study described here was conducted to assess the efficiency of planted or selected fallows and alley cropping in maintaining soil organic matter at five sites in southern Nigeria. Collected soil samples were analyzed for organic carbon and humic acid content, pH, extractable phosphorus, total nitrogen, and effective

cation exchange capacity (ECEC). In general, soil organic C content was at least 46% less in fields under maize or cassava alone than in planted fallow plots and adjacent natural bush fields. Fallow length tended to increase both the organic C and humic acid content of the soils. Established trees maintained soil organic C at levels found in natural bush fallow plots. The performance of leguminous hedgerow trees was similar to that of non-legumes in terms of maintaining soil organic C except at Onne, where organic C and humic acid content were highest under *Dactyladenia barteri*. Organic C was significantly correlated ($P < 0.05$) with soil N and ECEC but not humic acid.

Nutrient Recycling; Soil Erosion

375
F
Nair, P.K.R., B.T. Kang, and D.C.L. Kass. 1993.
Nutrient cycling and erosion control in agroforestry systems. Agronomy Abstracts (1993): 58.

The scientific foundation of agroforestry is the multipurpose trees and shrubs (MPTs) that provide multiple products of economic value and improve soil productivity. Enhanced nutrient cycling, efficient sharing of nutrient and moisture resources, and better soil conservation are the principal ways in which the MPTs contribute to ecological sustainability. These principles are now being used for the development of sustainable and productive agroforestry systems under different agroecological conditions, especially in developing countries. The efforts include improvement of existing practices (e.g., improved fallow management) and development of new technologies that integrate MPTs with crop and animal components (e.g., alley farming). The paper reviews the current state of knowledge on these aspects.

Erosion; Runoff

376
F
Omoro, L.M.A. and P.K.R. Nair. 1993.
Effects of mulching with multipurpose-tree prunings on soil and water runoff under semiarid conditions in Kenya. Agroforestry Systems 22: 225–239.

The effect on the rate of soil and water runoff from a crop field of adding leaf mulches of *Grevillea robusta*, *Cassia siamea*, and *Gliricidia sepium* were studied during two cropping seasons in an Alfisol under semiarid conditions at Machakos, Kenya. The trial was set up in a randomized complete block design with three replications: two rates of mulch of each species (2.24 t and 4.48 t. on a dry matter basis per ha) and a no-mulch control constituted the seven treatments. Soil and water runoff losses after each major fall of rain and the changes in ground and crop cover were measured. Rainfall erosivity and changes in soil bulk density and infiltration rates were also measured. Significantly lower soil losses were estimated in plots mulched with *Cassia siamea*, *Gliricidia sepium*, and *Grevillea robusta* than those from the control ($P < 0.10$). The cumulative soil losses from plots mulched with *Cassia, Gliricidia,* and *Grevillea* were 11, 57, and 81%, respectively, lower than that of the control plot over the two seasons. Similarly, water runoff losses from *Cassia*, *Gliricidia* and grevillea mulch plots were 28, 48, and 58%, respectively, lower than those of the control plot. Thus, *Cassia* was more efficient than *Gliricidia* and *Grevillea* in reducing both soil and water runoff losses. Soil bulk density did not change while the infiltration rate at the end of the experiment was significantly more than in the beginning. However, these soil physical properties were not significantly different among the treatments.

Soil Fertility

377
F
Onim, J.F.M., M. Mathuva, K. Otieno, and H.A. Fitzhugh. 1990.
Soil fertility changes and response of maize and beans to green manures of *Leucaena*, *Sesbania*, and pigeon pea. Agroforestry Systems 12: 197–215.

Prunings from *Leucaena* (*Leucaena leucocephala*), *Sesbania* (*Sesbania sesban* var. *nubica*), and pigeon pea (*Cajanus cajan*) were cut at 60 cm above the ground every 2 months, and resulting plant biomass was incorporated into the soil as green manure. For comparison, maize (*Zea mays*) stover was also incorporated into some plots, while some other plots were left fallow. Varying quantities of plant biomass were incorporated into the soil. Major soil plant nutrients were improved in soil fertility over a period of 12 months. Test crops of maize and beans (*Phaseolus vulgaris*) were grown on the test plots after six biomass incorporations of 4.8, 13.6, 16.7 and 7.8 t/ha/yr for pigeon pea, *Sesbania*, *Leucaena*, and maize, respectively. Crops' response indicated that *Sesbania* and *Leucaena* green manures improved maize stover and grain yields; and bean grain yields by 77.6% when compared to fallow plots. Residual effects of green manures still resulted in significant ($P < 0.05$) yield differences in the test crop in the third season. The economic importance of green manures in increasing food crop yields for small-scale farmers is discussed.

Alley Erosion

378
F
Paningbatan, E.P. 1990.
Alley cropping for managing soil erosion in sloping lands. Transactions of the 14th International Congress of Soil Science, Kyoto, Japan. VII: 376–377.

Reported results of the effect of alley cropping on erosion and runoff on a Typic Tropudalf with slopes of 14 to 19%. Alley cropping with *Desmanthus virgatus* and soil conservation practices reduced runoff and erosion. With rainfall of 1424 mm, and under farmer's practice, soil loss was 127 t/ha. With desmanthus hedgerows, mulching, and no-tillage, soil loss was reduced to 0.2 t/ha.

Decomposition Nitrogen Contribution

379
F
Read, M.D. 1982.
Management alternatives for maize-bean and *Leucaena*-based cropping systems. PhD thesis, Colorado State University, Colorado, USA. 166 pp.

Intercropping and the use of organic soil amendments are two promising possibilities of improving crop yields with the minimum use of expensive fossil-fuel inputs. Experiments were undertaken on intercropping of maize (*Zea mays* L.) and P into bean (*Phaseolus vulgaris*). Field trials were also conducted to evaluate the effect of placement and effectiveness of *Leucaena* leaves alone, or combined with maize stover and/or calcium ammonium nitrate (CAN) as fertilizer sources. Complementary pot experiments were also undertaken. Results showed no definite effect of intercropping maize and cowpea on the land equivalent ratio (LER). Fresh *Leucaena* leaves decomposed in the field more rapidly than dry leaves and field decomposition of *Leucaena* leaves was slower when surface-applied than incorporated. A residual effect of *Leucaena* N was detected on a subsequent maize crop. The potted maize trial showed that surface-applied *Leucaena* was ineffective as N source, while fresh leaves were more effective than dried *Leucaena* leaves. However, results from pot and field experiments disagreed. Field data indicated that management practices such as placement, split-application, and dryness had little effect on the effectiveness of *Leucaena* as a source of fertilizer.

Nitrogen: Soil Fertility

380
F
Rhoades, C.C., T. Nissent, and J. Kettler. 1994.
Soil nitrogen dynamics under alley cropping on the Georgia Piedmont. Agronomy Abstracts (1994): 361.

The primary objectives of alley cropping are to maintain or improve the availability of soil nutrients. The majority of alley cropping research has been in the tropics, so little information exists on the effects of alley cropping on soil nutrient availability in subtropical or temperate areas. On a Hapludult soil in the Georgia Piedmont, cereals have been alley cropped with leaf mulch from *Albizia julibrissin* for 4 years. The objective of this study was to compare nitrogen dynamics in alley cropped and adjacent non-alley cropped plots. We measured inorganic soil nitrogen levels and in situ nitrogen mineralization during a 4-month cropping cycle. Averaged over the entire cropping period, soil NO_3-N and NH_4-N were 2.8 and 1.3 times higher in alley cropped areas compared to controls. Net nitrogen mineralization rates were 1.35 times higher in the alley cropped plots. Although soil carbon and total soil nitrogen pools were not significantly higher in the alley cropped plots, the increase in available nitrogen indicates higher soil productivity in the alley cropping system.

Soil Fertility: Ultisol

381
F
Salazar, A.A. and C.A. Palm. 1991.
Alley cropping on Ultisols: Y-425. Pages 221–222 *in* Tropsoils Technical Report, 1988–89, edited by I.P. McBride. Raleigh, Tropsoils Management Entity, North Carolina State University, USA.

The objectives of this study were: (1) to assess the effects of P fertilization on tree biomass production, crop yields, and the sustainability of the alley cropping system; (2) to assess the effects of alley width on crop yields; and (3) to address problems encountered in previous trials. The design used for the alley cropping experiment was a split-split plot with three replications. Treatments included alley width (4 m versus 8 m) as the split-plot treatment, species of tree for the hedgerows (*Inga edulis*, *Gliricidia sepium*, or *Cassia reticulata*) as the main-plot treatment, and P fertilization (0 vs 25 kg P) for the split-split-plot treatment. A cowpea-cowpea-rice rotation was interplanted with the trees. The phosphorus treatment was applied only to the rice crops. Each hedgerow consisted of two closely planted rows of trees which were planted 0.5 m × 0.25 m within hedgerows. The results showed that hedgerow pruning biomass production was not significantly affected by P fertilization, although there was a tendency for higher *Gliricidia* production with fertilization. Information is not yet available on the P content of the prunings with and without P fertilization. At 30 months, the *C. reticulata* trees began to produce less. The pruning method was modified by pruning dead branches, a process which initiates resprouting from the trunk. This method is now being followed for all the tree species. In general, crop yields are higher on plots with trees than on control plots without them. Crop yields were higher in association with *Inga edulis* hedgerows than with the other two species. Alley width or P treatment had no dramatic effect on crop yields. Yields do not appear to decline with time as they had in previous trials on acid soils. This finding may be related to the higher clay content (25%) of the soils in this trial as compared to the others. The higher clay content could improve cation retention and recycling and also maintain adequate soil moisture levels for longer time intervals. Changes in soil chemical parameters indicate a considerable decrease in exchangeable potassium but little change in other basic or acidic cations. Phosphorus levels increased slightly even in the plots that received no P fertilization. This finding contrasts with previous studies and raises interesting questions considering the large amount of P exported in crops relative to the amount recycled in prunings. This stability could indicate redistributing and recycling of soil P through the trees and into more available forms. Soil P fractions will be compared among the different treatments and controls to see if this recycling has happened.

Nitrogen
Contribution
Soil Fertility

382
F
Sanginga, N., K. Mulongoy, and M.J. Swift. 1989.
Contribution of nitrogen by Leucaena leucocephala and Eucalyptus grandis to soils and a subsequent maize crop. Trees for development in sub-Saharan Africa. Proceedings of a regional symposium held by the International Foundation of Science at Nairobi, Kenya. Pp 253–258.

The contribution of N by *Leucaena leucocephala* and *Eucalyptus grandis* to soils and maize were assessed at 2 Ultisol sites. Soil analyses indicated that *Leucaena* increased soil total N, while *Eucalyptus* increased NO_3-N, P, and organic matter contents in the field. Maize growth in a pot trial was decreased (68%) for the first crop, and increased (29%) for the second crop. The effect of pruning on N contribution was positive but not significant.

Erosion
Stability

383
F
Tacio, H.D. 1993.
Sloping agricultural land technology (SALT): a sustainable agroforestry scheme for the uplands. Agroforestry Systems 22: 145–152.

Deforestation and heavy rains present an extremely serious soil erosion problem in many parts of southeast Asia, particularly in the upland Philippines. To control soil erosion and increase crop yields, the Mindanao Baptist Rural Life Center (MBRLC), a nongovernment organization based in the southern part of the area has developed and spread an agroforestry scheme called Sloping Agricultural Land Technology (SALT). Basically, SALT utilizes nitrogen-fixing trees as a soil binder, fertilizer generator, and livestock feed source. The system also includes growing of annual and perennial food crops in the alley spaces formed between the hedgerows. The SALT model has been tested both in demonstration plots and farmers' fields and has proven to be appropriate for use by typical hilly-land farmers. The system can reduce soil erosion and restore moderately degraded hilly lands to a profitable farming system in these areas.

Erosion

384
F
Wiersum, K.F. 1984.
Surface erosion under various tropical agroforestry systems. Pages 231–239 *in* Symposium on effects of forest land use or erosion and slope stability, edited by C.L. O'Loughlin and A.J. Pearce. Environment Policy Institute, East-West Centre, Honolulu, Hawaii, USA.

The paper evaluates the soil protective value of different agroforestry systems. The effect of trees grown in combination with agricultural crops on rainfall erosivity, soil erodibility, and soil surface protection are examined and quantitative data on surface erosion in various forest and tree crop systems are reviewed. It is concluded that individual trees cannot be expected to exert the same protective effect as undisturbed forest ecosystems. The key to controlling erosion in agroforestry does not lie in the presence of trees themselves, but rather in good management practices, either of trees or by the application of additional soil conservation technologies.

Soil Fertility

385
F
Wilson, G.F., B.T. Kang, and K. Mulongoy. 1986.
Alley cropping: trees as sources of green manure and mulch in the tropics. Pages 165–181 *in* The role of microorganisms in a sustainable agriculture, edited by J.M. Lopez-Real and R.D. Hodges. AB Academic Publishers, Hertfordshire, UK.

Alley cropping brings to the tropics an effective means of using trees and woody shrubs to hasten biological soil fertility restoration. The leaves and twigs through which nutrients are returned to the soil, can be applied as green manure or mulch. There are indications that nitrogen use efficiency is higher with green manuring than with mulching. However, there are situations in which mulching may be preferred to green manuring. Fortunately, alley cropping is compatible with both green manuring and mulching. Compared to herbaceous legumes, which usually die leaving only dry tissues after the long dry period that precedes the major planting season in most tropical regions, the trees in alley cropping remain functional in the dry season providing fresh material for green manure or mulch. They also, to some extent, protect the environment from the fires that commonly destroy the dry residues of dead herbaceous fallows. Besides soil fertility restoration, alley cropping can be managed to prevent soil erosion and other forms of environmental decay and to provide firewood, a renewable and much needed energy source in the tropics.

Soil Fertility

386
F
Yamoah, C.F., A.A. Agboola, G.F. Wilson, and K. Mulongoy. 1986.
Soil properties as affected by the use of leguminous shrubs for alley cropping with maize. Agriculture, Ecosystems and Environment 18: 167–177.

Alley cropping is a crop production system whereby food crops are grown in spaces formed between hedgerows of leguminous shrubs. The leguminous shrubs supply nitrogen and organic materials and recycle leached nutrients. This study was undertaken to evaluate the effects of prunings of three leguminous shrubs on some soil properties in an alley cropping system. Results indicated that soil chemical properties were improved in alley cropped plots. Soils under *Senna* had the highest contents of N, P, K, and organic carbon after the second maize crop. Bulk density, mean aggregate diameters, and water holding capacity were better in the alley cropped plots than the control plot without hedges. Gravimetric moisture content was generally higher in the alley cropped sites and highest under *Senna*. Probably because of its slow rate of decomposition, *Senna* maintained higher soil biomass C than other woody species used. Application of 90 kg N/ha enhanced soil biomass C essentially through increased dry matter production in shrubs and maize.

Soil Fertility; Tree Growth

387
FA
Liya, S.M., K. Mulongoy, C.T.I. Odu, and A.A. Agboola. 1990.
The influence of some parameters of soil fertility on early growth of *Leucaena leucocephala* and *Cassia siamea*, *in* Maximizer la FBA pour la Production Agricole et Forestire en Afrique, edited by M. Gueye, K. Mulongoy, and Y. Dommergues. Proceedings of IIIeme Conférence de l'AABNF, 7–12 Nov 1988, Dakar, Sénégal.

Leucaena leucocephala and *Cassia siamea* were grown in concrete cylinders containing 0.35 t of a sandy, high base status Entisol. The nutrient content of the soils varied from one cylinder to another. Fertilizer was added at the rate of 11 kg N, 88 kg P, and 5 kg Zn per hectare. At 8 months after planting, *Leucaena* was well nodulated and produced on average seven times as much biomass as the non-nodulated *Cas-*

sia. There were significant ($P < 0.05$) correlations with topsoil N. With *Cassia*, positive correlations were observed for plant height (r 0.73) and total stem length (r 0.75). With *Leucaena* there were significant negative correlations for plant height (r 0.85) and estimated total biomass (r 0.90). *Leucaena* plant height was also positively correlated with topsoil K (r 0.81). Ninety-eight percent of the variation in height could be accounted for by the equation Y= 4.88 + 117.37X-14.94X2 where Y plant height and X K/N ratio.

Agro-Soil-Tree-Evaluation-Multipurpose

388
FB
Duguma, B., J. Tonye, J. Kanmegne, T. Manga, and T. Enouch. 1994. Growth of ten multipurpose tree species on acid soils in Sangmelima, Cameroon. Agroforestry Systems 27: 107–19.

A trial was set up with 10 multipurpose tree species planted both in monoculture and intercropped with *Arachis hypogea* (groundnut) in a randomized complete block with three replications. The vigor, biomass, nutrient content, and coppicing percentage of the trees were evaluated. Intercropping with groundnuts during the establishment phase did not affect subsequent growth and development of the species. *Acacia mangium*, *Acacia auriculiformis*, *Senna siamea*, *Calliandra calothyrsus*, and *Paraserianthes falcataria* established well, when compared to *Gliricidia sepium*, *Leucaena leucocephala*, *Dialium guineense*, *Dubocia macrocarpa*, and *Milicia excelsa*, *A. mangium*, *A. auriculiformis*, *C. calothyrsus*, *S. siamea*, and *P. falcataria* produced the highest leaf (4 to 20 t/ha) and wood (12 to 37 t/ha) biomass yield at 1 to 3 years after planting. Coppicing percentages of *A. mangium A. auriculiformis*, and *P. falcataria* were relatively low (35 to 50). *C. calothyrsus* and *S. siamea* showed the highest coppicing percentages (95 to 100) and produced the greatest coppice biomass (9 to 13 t/ha). Total nitrogen and organic matter percentage of soils from under the stands of these two species were also significantly higher than that of the rest. *Calliandra calothyrsus* and *Senna siamea*, may be used in agroforestry for soil improvement on acid soils.

Earthworm-casting-Multipurpose-Trees-Soil-Fertility

389
FB
Kang, B.T., F.K. Akinnifesi, and J.L. Pleysier. 1994. Effect of agroforestry woody species on earthworm activity and physicochemical properties of worm casts. Biology and Fertility of Soils 18: 193–199.

The paper describes the influence of five agroforestry woody species (*Dactyladenia barteri*, *Gliricidia sepium*, *Leucaena leucocephala*, *Senna siamea*, and *Treculia africana*) on the surface casting activity of *Hyperiodrilus africanus* in an Alfisol (Oxic Paleustalf) in southwestern Nigeria. Casting activity under the woody species decreased in the following order: *Dactyladenia*, *Gliricidia*, *Treculia*, *Senna*. These differences in casting activity were partly explained by microclimatic effects. Regardless of woody species, earthworm cast had superior physicochemical properties than corresponding surface soils. The woody species did affect the physicochemical properties and P sorption of the worm casts. The content of water-stable aggregates of worm casts decreased in the following order: *Dactyladenia, Treculia, Senna, Leucaena, Gliricidia*. Large differences in extractable P levels were observed; *Senna* was associated with the highest extractable P level (11.5 mg/kg) and *Treculia* the lowest (4.9 mg/kg). P sorption was highest on worm casts under *Dactyladenia* and lowest on those under *Treculia*. Without fertilizer application, there were no significant differences in the dry weight of maize grown in the different worm casts. With NPK applications, the dry weight of maize grown in worm casts associated with *Treculia* was significantly lower than that of maize grown in the other worm casts, this was related to its low extractable P level. Despite a high organic C and exchangeable K status, maize grown in the worm casts still responded significantly to N and K applications, with lowest N uptake by maize grown in worm casts collected under *Treculia*.

390
FB
Mwiinga, R.D., F.R. Kwesiga, and C.S. Kamara. 1994.
Decomposition of leaves of six multipurpose tree species in Chipata, Zambia. Forest Ecology and Management 64: 209–216.

The objectives of the study were to (1) compare the decomposition rates of foliage in *Leucaena leucocephala, Flemingia congesta, Pericopsis angolensis, Senna siamea, Sesbania sesban,* and *Gliricidia sepium*; (2) compare N concentrations and mineralization among these woody species. Twenty g of each dried leaf material was put into nylon mesh litter bags and placed in the field that was cropped to maize during the previous season at the Msekera Regional Research Station, Zambia. The decomposition and N release rates were determined at 0, 2, 4, 8, and 12 weeks. N mineralization rates were estimated and predictive equations were developed for each species. Significant differences were found in decomposition rates in the following order: *Gliricidia, Leucaena, Sesbania, Senna, Pericopsis, Flemingia.* Differences in N concentration were not significant between species. *Gliricidia* and *Leucaena* showed the greatest potential for use as green methods of green manure.

391
FC
Kang, B.T. and F.K. Akinnifesi. 1990.
Earthworm activity under alley cropping and selected woody species and effect on soil properties. Agronomy Abstracts (1990): 59.

Investigations were carried out on the activity of turret shaped casts producing earthworms on an Alfisol in the forest-savanna transition zone of southern Nigeria, in a well-established (5-year-old) alley cropping trial and under 10-year-old trees and shrubs. In the alley cropping trial, higher casting activity was observed early in the growing season in alley cropped plots than in the control treatment. Under the woody species, there was higher activity under *Acioa barteri* and *Treculia africana* than under *Gliricidia sepium, Leucaena leucocephala,* and *Cassia siamea.* Woody species have differential effects on chemical and physical properties of worm casts. Casts collected from under woody species also have differential effects on growth of maize in pot trials. Applications of N and P on casts showed large increases in maize dry matter yield. With P application, dry matter yield of maize was highest when grown in casts collected from under *Leucaena* and lowest when grown in casts collected from under *Treculia.*

392
FC
Odee, D.W. 1990.
A preliminary study on the compatibility between indigenous rhizobia and some tree legumes in Kenya. Pages 81–91 *in* Maximizer la FBA pour la Production Agricole et Forestire en Afrique, edited by M. Gueye, K. Mulongoy, and Y. Dommergues. Proceedings of IIIeme Confèrence de l'AABNF, 7–12 Nov 1988, Dakar, Sénégal.

Cross-inoculation study with indigenous *Rhizobia* was carried out on seven host species of isolation: *Acacia albida, Acacia mearnsii, Calliandra calothyrsus, Leucaena leucocephala, Prosopis juliflora, Sesbania grandiflora,* and *Sesbania sesban.* The rhizobium strains were highly infective and effectiveness was variable across the host strain combinations. There occurred four cross-inoculation groups within the range of rhizobium strains and host species studied. The two members of the genus *Sesbania* were more specific in their rhizobia partners in terms of beneficial association. Nodule shape and distribution was consistent on the root system of each host species in effective symbiosis.

Decomposition; Species; Nutrient Release; Hedgerow; On-Farm

393
FCM
Kintomo, A. 1992.
The use of shrub legume alleys for soil fertility maintenance in a cassava/maize intercrop. PhD thesis, University of Ibadan, Ibadan, Nigeria. 218 pp.

A study was conducted on an Alfisol at Ayepe and Alabata on-farm research sites in southwestern Nigeria to determine the potential of *Leucaena leucocephala* and *Senna siamea* for crop production in a maize/cassava intercrop. The objectives of the study were (1) to determine the rate of decomposition of prunings and the rate of nutrient release; (2) to determine the nature of root distribution patterns of the legumes; and (3) to determine the effects of the prunings on crop yields and soil fertility maintenance. Results indicated that *Leucaena* prunings decomposed twice as fast as those of *Senna*. The half lives of the prunings were 2.1 and 4.4 weeks for *Leucaena* and *Senna*, respectively. *Leucaena* prunings also released nutrients faster than *Senna*. Using the core sampling, roots of both shrubs were found to be abundant at the top 0–20 cm. About 55% fine roots of *Leucaena* and 75% of *Senna* were located at a 0–40 cm soil depth. Root length density ranged from 0.4–1.4 cm/cm3 at a 60–80 cm depth for *Senna* compared to 0.3–0. 6 cm/cm3 for *Leucaena*. The coppicing ability was greater in *Leucaena* than *Senna*. However, applications of prunings and inorganic fertilizer did not significantly affect soil chemical properties. Maize yields in the alley cropped plots without fertilizer were 48% higher than the control, but 38% lower than NPK fertilizer applied at 45 kg/ha. Cassava fresh root yield in the control plot was higher than for the alley cropped plots with or without fertilizer. Efficiency of utilization of nutrients, especially N released from the prunings of both shrubs, was low. Economic analyses of farming operations showed that maize grain yields accounted for about 75% of total gross field benefits. Labor inputs were, however, very high at about 46% for *Senna* and 72% for *Leucaena* compared to non- alley cropped plots. *Senna* was shown to have greater potential for alley cropping involving a maize/cassava intercrop in the trial.

Soil Conservation; Crop Yield

394
FD
Banda, A.Z., J.A. Maghembe, D.N. Ngugi, and V.A. Chome. 1994.
Effect of intercropping maize and closely spaced *Leucaena* hedgerows on soil conservation and maize yield on a steep slope at Ntheu, Malawi. Agroforestry Systems 27: 17–22.

The soil conservation effect of *Leucaena leucocephala* on performance of maize was tested in a 6-year trial conducted on a steep slope, 44%, with a subhumid climate, using three intraspecific hybrids of *Leucaena leucocephala*. Results showed that soil loss averaged 2.0 t/ha per year on the *Leucaena* plots compared with an initial 80 t/ha per year on the unprotected control plot, falling to 27 t/ha per year after the top soil had been eroded. After 6 years, microterraces of 35 cm high and 81 cm wide seemed to have developed on the intercropped plots, with positive effects on soil properties. Maize yields (unfertilized) were maintained at 1.5–2.0 t/ha on the protected plots, compared to a decline from 0.8 to 0.5 t/ha observed in the sole maize control plot.

Nitrogen Contribution; Vegetable Production

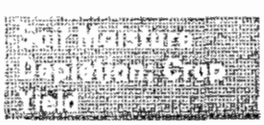
395
FD
Demeterio, J.L. 1988.
Intercropping *Leucaena leucocephala* (Lam.) de Wit with selected vegetables grown on an Alfisol in Guam. Agronomy Abstracts (1988): 54.

Yield response of selected vegetables grown within *Leucaena* hedges were compared with open field cropping. Fifteen-meter long *Leucaena* hedges, 1 and 2 m apart, and open fields of the same plot size were established in a randomized complete

block design. The open field study received nitrogen at 100 and 200 kg/ha. The leaves and green stem of *Leucaena* were used as a source of fertilizer nitrogen and incorporated into the furrow prior to planting and later on side-dressed as a mulch to the vegetable growing within the hedge. Initial planting of head cabbage resulted in significantly lower yields in the alley cropping scheme. This reinforced earlier studies where yield of the intercropped vegetable was depressed during the early stages of *Leucaena* establishment. A second planting of sweet corn showed no significant difference in yield between plants grown within the *Leucaena* hedge and the commercial nitrogen supplied open field. Fertilizer nitrogen contributed by *Leucaena* amounted to 67 and 136 kg/ha. Both studies were done in Guam's dry season (December–May). This longterm study will explore stability of the vegetable intercrop during the rainy season.

396
FD
Jones, R.B. 1994.
Soil improvement using a combination of inorganic fertilizer and tree leaf litter in the subhumid zone of Southern Africa. Agronomy Abstracts (1994): 74.

Soil fertility is the biggest constraint to crop production in the mid-altitude ecology of southern Africa. Inorganic fertilizer is not very profitable for smallholder farmers on soils depleted of organic matter. Research into hedgerow intercropping has shown that *Leucaena leucocephala* (LL) leaf litter alone can improve maize yields but that further yield increases were obtained with supplemental N and P fertilizer. Two trials were conducted to investigate the effect on maize yield of three leaf litter application methods, two leaf litter rates using *Leucaena leucocephala, Senna spectabilis* (SS), and *Gliricidia sepium* (GS) with and without an inorganic N top-dressing. GS gave higher yields than LL. Surface application was superior to burying at the rate of 3 t/ha, but there was no difference at the half rate. SS and LL had comparable effects on maize yield. N increased yield when applied to plots with the half rate of leaf litter. The yield increase was greatest with LL but plots with LL and NN yielded less than those with GS alone.



397
FD
Ssekabembe, C.K. and P.R. Henderlong. 1993.
Effect of hedgerow pruning on corn growth in a black locust-corn alley cropping system. Agronomy Abstracts (1993): 60.

Corn was intercropped between 3-year-old black locust hedgerows. Hedgerows were 5.5 m wide, 1.5 m spacing between 3–3.5-m tall saplings. Four corn rows were planted in the alleys. One hedgerow treatment had 100 cm vertical fiberglass partitions 45 cm from the hedgerow. A hedgerow pruning subplot was imposed when corn attained 50 cm growth. Soil moisture was monitored during the corn grain filling period. Available soil moisture was similar for corn grown within alleys with partitions compared to corn in pure stands. Soil moisture was 40 to 70 g/kg lower when grown in alleys without partitions. Available soil moisture was slightly higher, 10 to 20 g/kg for unpruned vs. the pruned hedgerow system. Corn yield ha^{-1} was reduced by 30% for the pruned hedgerow and 50–60% for the unpruned hedgerow system compared to corn in a pure stand. Meter-row corn yield was not different for the pruned hedgerow system compared to pure corn but reduced by 20 to 40% for the unpruned system. Grain yield difference was attributed to a 20–40% reduction of available irradiance in the unpruned hedgerow system.

398
FE
Lapitan, L.C. and R.V. Dalmacio. 1987.
Productivity and protectiveness of different density combinations of Kakawate (*Gliricidia sepium* Jacq. Steud) and corn (*Zea mays* L.) in an alley cropping scheme under two slope gradients. Sylvatrop 12: 141–157.

Gliricidia sepium hedgerows were established from cutting stock in 2 fields at Cavite, Philippines, in 1988. Planting was in double hedgerows at 30 × 30 cm spacing, and alley widths of 2, 4, and 6 m. The two sites had slopes of 18% at the western and 43% at the eastern exposures. Maize was sown 3 months after planting *Gliricidia*. Hedgerows were pruned to a height of 70 cm and prunings applied as mulch. Maize was harvested at 45 days after sowing; yield and nutrient uptake were estimated. There was a significant effect of alley width and slopes, but interaction was only found in root biomass of maize. Organic matter and N contents of the soil increased as alley width decreased. Narrower alley width (2 m) significantly reduced runoff and sediment yield. Alley width did not affect P and K and soil pH levels. Maize biomass was higher in 4-m alley widths and the 43% slope than in other treatments.

399
FG
Yamoah, C.F, A.A. Agboola, and K. Mulongoy. 1986.
Decomposition, nitrogen release, and weed control by prunings of selected alley cropping shrubs. Agroforestry Systems 4: 239–246.

Decomposition of hedgerow prunings and weed suppression effects were investigated in an alley cropping trial with hedgerows of *Senna siamea, Flemingia congesta,* and *Gliricidia sepium*, at the International Institute of Tropical Agriculture, Ibadan, Nigeria. Decomposition of cutbacks and subsequent prunings ranged from 2.7 to 5.8 dry matter loss per week and the order was: *Gliricidia, Flemingia, Senna* for the cutbacks and *Gliricidia, Senna, Flemingia* for the prunings. *Gliricidia* cutbacks released 71% of the total N required by maize, *Flemingia*, 26%, and *Senna* 77% in 120 days. *Gliricidia* is capable of supplying 29% N deficit from a second pruning at about 66 days after planting of maize. External sources of N would be needed in the case of the other two species (*Senna* and *Flemingia*). *Senna* mulch maintained higher weed control than *Gliricidia* and *Flemingia* during both cropping and fallow periods, while *Gliricidia* suppressed weeds better than *Flemingia*.

EFFECTS ON WEEDS AND PESTS

400
G
Aken'Ova, M.E. and A.N. Atta-Krah. 1986.
Control of spear grass (*Imperata cylindrica* (L.) Beauv.) in an alley cropping fallow. Nitrogen Fixing Tree Research Reports 4: 27–28.

Reports the development of spear grass under a *G. sepium* canopy in an alley cropping fallow. The experimental site was located at Fashola in the derived savanna zone of southwest Nigeria. The result showed a significant relationship (r-0.789, $P < 0.05$) between rhizome yield and light transmission. Above-ground growth of spear grass in the alleys occurred where gaps in the tree rows had been created through the loss of a tree or more. More light was transmitted through such gaps, average number of trees per row was negatively correlated.

Alfisol: Weed

401
G
Anoka, U.A., I.O. Akobundu, and S.N.C. Okonkwo. 1991.
Effects of *Gliricidia sepium* (Jacq.) Steud and *Leucaena leucocephala* (Lam.) de Wit on growth and development of *Imperata cylindrica* (L.) Raeuschel. Agroforestry Systems 16: 1–12.

Investigations were undertaken on an Alfisol in a forest transition zone of Nigeria. Shading by *Gliricidia sepium* and *Leucaena leucocephala* hedgerows reduced density of speargrass (*Imperata cylindrica*) by 67% and 51%, respectively. Shoot biomass of speargrass decreased by 81% and 78% in *Gliricidia* and *Leucaena* hedgerows, respectively. Reduction in speargrass rhizome biomass in *Gliricidia* plots was 96% while rhizome reduction in the *Leucaena* and control plots was about 90%. Rhizome mortality was greater in *Gliricidia* plots than in *Leucaena* and control plots. The bulk of rhizomes was found between 10–20 cm soil depth, and rhizomes were rare beyond 30 cm soil depth in this site. *Gliricidia* hedgerows suppressed speargrass better than *Leucaena*.

Weed Control

402
G
Budelman, A. 1988.
The performance of the leaf mulches of *Leucaena leucocephala, Flemingia macrophylla*, and *Gliricidia sepium* in weed control. Agroforestry Systems 6: 137–145.

The effectiveness of the leaf mulches from *Leucaena leucocephala, Gliricidia sepium*, and *Flemingia macrophylla* on weed control has been tested in two trials. The length of the period during which a mulch layer yields significantly less weed biomass compared to the control plots is called the "effective lifespan" of the mulch. *F. macrophylla* mulch showed greatest promise in weed suppression. In the second trial, *F. macrophylla* leaf mulch was applied at rates of 3, 6 and 9 tonnes dry matter per ha. The effective life span of a mulch layer of 3 tonnes is between 12 and 13 weeks, whereas the treatments 6 and 9 tonnes have effective life spans of over 14 weeks. The effective lifespan is estimated to be about a 100 days for moderate quantities (up to 5 tonnes of dry leaf mulch per ha). The effectiveness of mulch as a weed control measure is limited by the ability of weed species to multiply by seed, or regrow from perennial propagules such as roots or stumps.

Nematodes

403
G
Caveness, F.E. 1986.
Alley cropping observations. Pages 73–77 *in* Root and Tuber Improvement Program Annual Report: Nematology. IITA, Ibadan, Nigeria.

Three common plant-parasitic nematodes—root lesion, root-knot, and spiral—were recovered in all plots and treatments of the hedgerow alley cropping trial. Parasitic nematode numbers were moderate to low in relation to possible crop damage. The rotation of crops and the dry fallow periods appear to be effective in controlling nematode populations.

Nematodes

404
G
Caveness, F.E. 1986.
Nematodes in a *Leucaena*/vegetable alley cropping system: the first year. Pages 11–17 *in* Root and Tuber Improvement Program Annual Report: Nematology. IITA, Ibadan, Nigeria.

Preplant sampling found the spiral, lesion, and false spiral nematodes present in low numbers. Sampling at 6 months and 12 months from the start of the trial added the root-knot and reniform nematodes in very low numbers. Nonparasitic nematode numbers declined by about half under cultivation from the preplanting populations under both the *Leucaena* and control plots. No practical differences developed in parasitic nematode numbers between the *Leucaena* and control plots by the end of the first year.

Nematodes

405
G
Caveness, F.E., S.L. Claassen, S.Y. Chen, and D.C. Couper. 1986.
An antagonistic plant (Asparagus) alley cropping scheme for control of parasitic nematodes in vegetable growing. Pages 18–20 *in* Root and Tuber Improvement Program Annual Report: Nematology. IITA, Ibadan, Nigeria.

Asparagus plants were sampled 18 months after transplanting to the field. The sought after antagonistic effect against plant-parasitic nematodes did not occur. There was an apparent retardation in spiral and root lesion nematode population development on or near (32 cm) the antagonistic plant row but not at 50 or more cm. The root-knot and reniform nematodes increased in the antagonistic plant row. Nonparasitic nematode population levels were not affected by any of the treatments.

Weeds

406
G
Van Noordwijk, M., K. Hairiah, S.M. Sitompul, and M.S. Syekhfani. 1992.
Rotational hedgerow intercropping + *Peltophorum pterocarpu:* new hope for weed-infested soils. Agroforestry Today 4: 4–6.

Paper discusses the possibility of using rotational hedgerow intercropping for control of *Imperata cylindrica* in south Sumatra, Indonesia. *Peltophorum pterocarpum* which has a dense canopy and high biomass production of hedgerow prunings but causes little shade to crops in the first 2–3 months after pruning appears to be a suitable species for the purpose. A field test is in progress.

Weeds; Economics

407
GK
Bohringer, A. 1991.
The potential of alley cropping as a labor efficient management option to control weeds: a hypothetical case. Agriculture in the Tropics and Subtropics 92: 3–12.

Labor represents a major constraint to cropping in most tropical farming systems. Alley cropping requires additional labor use; its acceptance by the local farmers may therefore be labor driven. On the other hand, the application of leaf mulches to the soil surface could help to effectively suppress weeds and reduce the labor demands for weeding. The objective of this paper was to quantify reduction in labor use resulting from the application of different leaf mulches. Data were obtained from literature and transposed to a hypothetical alley cropping system. A traditional maize cropping system, with plant populations of 20,000 plants/ha, yielded 1.05 t/ha grain and 6.25

t/ha weeds and required 300 man-hours for two hand weedings. Realistic yields of leaf mulches at 13,500 trees/ha were estimated to be 3.6 t/ha for *Leucaena*, 3.4 t/ha for *Gliricidia*, and 2.9 t/ha for *Flemingia*. Related to the amount of weed dry matter in the control, the application of leaf mulch at these rates resulted in an increase of weed dry matter of 53.3% for *Leucaena* and a decrease of 64.1% for *Gliricidia*, and 92.3% for *Flemingia*. This change, expressed in man-hours for weeding, was quantified to be 460 man-hours for *Leucaena*, 108 man-hours for *Gliricidia*, and only 23 man-hours for *Flemingia*. The importance of the quality of the different mulches was discussed. In situations of labor scarcity, the effect of leaf mulches to suppress weeds may be a crucial factor in selecting tree species for alley cropping systems.

FODDER AND FORAGE PRODUCTION

Fodder Production

408
H
Akyeampong, E. and K. Muzinga. 1994.
Cutting management of *Calliandra calothyrsus* in the wet season to maximum dry season fodder production in the central highlands of Burundi. Agroforestry Systems 27: 101–105.

The effect of cutting on fodder productions was investigated using *Calliandra calothyrsus* during the rainy season between January and May to determine which period of cutting gives the highest quantity and quality of dry matter in August, the peak of the dry season, when fodder shortage is most acute. The highest quantity of dry-season production was obtained in both 1992 and 1993 from the plots that were harvested in February, 6 months before the driest month. Crude protein content of the dry-season fodder was not affected by harvesting time in the rainy season. The strategies for utilizing dry-season fodder to meet the digestible protein needs of 3.5 goats for a 90-day period in the highlands of Burundi, and the use of biomass harvested in the rainy season for crop production are discussed in the paper.

Decomposition

409
H
Arquello, H., D.L. Kass, and W. Bermudez. 1987.
Nutrient release from prunings of *Gliricidia sepium*. Pages 73–82 *in Gliricidia sepium* (Jacq.) Walp.: management and improvement, edited by D. Withington, N. Glover, and J.L. Brewbaker. Nitrogen Fixing Tree Association (NFTA) Special Publication 87-01, Waimanalo, Hawaii, USA.

Although there was considerable work on this subject done in tea plantations of Sri Lanka in the 1930s, it was thought worthwhile to consider the patterns of nutrient release in terms of annual crop production. Litter bags containing 110 g fresh weight of *Gliricidia sepium* cuttings were left to decompose in a bean field to which *Gliricidia sepium* prunings had been applied. Bags were collected at weekly intervals and analyzed for nutrient content. Over the first 12 weeks, more than half of the nitrogen, phosphorus, potassium, and magnesium had been lost from the bags. More than half of the sulphur and calcium remained in the bags. These results would indicate a nutrient supplying power of 96.8, 2.4, 42.8, 39.5, 4.0, and 4.3 kg/ha of N, P, K, Ca, Mg and S, respectively, in 12 weeks from 9.1 t/ha of *G. sepium* under a fallow of *Panicum maximum* and *Lantana camara*. Total nutrient contents of *Gliricidia sepium* prunings as compared to *Erythina poeppigiana* and *Gmelina arborea* indicate that *Gliricidia sepium* prunings contain more potassium, less magnesium, and a quantity of calcium intermediate between the value of the other two species.

Fodder

410
H
Atta-Krah, A.N. 1989.
Availability and use of fodder shrubs and trees in tropical Africa. Pages 140–162 *in* Shrubs and tree fodders for farm animals, edited by C. Devendra. Proceedings of a workshop held 24–29 Jul 1989, Densapar, Indonesia, International Development Research Centre (IDRC), Ottawa, Canada.

Trees occupy a significant niche in the farming systems and overall way of life in tropical Africa. Fodder shrubs and trees (browse) in this region play a significant role both in farming systems, where they are protected as fallow species and in livestock production. Livestock in this zone depend largely on browse for their dietary protein. Compared with tropical grass, browse is generally richer in protein and minerals. The importance of browse increases with increasing aridity and is generally most essential in the dry seasons when most other feed resources depreciate in quality and quantity. Browse intake increases total dry-matter intake, increases crude protein intake, and improves the digestibility of low-quality forages. The effect of browse feeding on livestock is shown in increased survivability (i.e., lower mortalities, especially over the dry season) and increased productivity. Traditionally, throughout tropical Africa, processing and conservation of tree fodder is uncommon, and cultivation is minimal and insignificant. This paper advocates the need for increased cultivation and integration of fodder trees (especially leguminous ones) into local farming systems through agroforestry. It also stresses the need for increased research support for the efficient cultivation, management, and use of fodder shrubs and trees for improved livestock production.

Soil Fertility

411
H
Hauser, S. 1990.
Water and nutrient dynamics under alley cropping versus monocropping in the humid-subhumid transition zone. Pages 204–209 *in* Transactions of the 14th International Congress on Soil Science, Kyoto, Japan. Volume VI.

Alley cropping can reduce the downward displacement of nutrients. The risk of nutrient losses is higher under the interrow space than close to the hedgerow. Narrowing the interrow space might reduce losses but will decrease productivity due to higher demand for land and labor.

Forage

412
H
Itnal, C.J., L.A. Dixit, and S.V. Patil. 1989.
Forage production as influenced by fodder species and alley widths in an alley cropping system. Karnataka Journal of Agricultural Sciences 2(4): 265–272.

Hedgerows of *Leucaena leucocephala*, *Sesbania grandiflora*, and *Pennisetum massaicum* were grown in paired rows at alley widths of 4, 8, and 12 m. *Leucaena* yielded more green forage then *Sesbania* and *Pennisetum*. Narrow alleys produced higher forage than wider alleys in all the three species.

Fodder Production

413
H
Larbi, A., M.A. Jabbar, E.J. Orok, G.N.B. Idion, and J. Cobbina. 1993. *Alchornea cordifolia*, a promising indigenous browse species adapted to acid soils in southeastern Nigeria for integrated crop-livestock agroforestry production systems. Agroforestry Systems 22: 33–41.

Evaluation was made of the dry-matter (DM) production, crude protein, phosphorus fiber contents, and goat preference for eight indigenous browse species (*Alchornea cordifolia, Dialium guineense, Ficus capensis, Baphia nitida, Manniophytum fulvum, Homalium ylmeri, Glyphae brevis,* and *Rauwolfia vomitoria)* and for two exotics *(Leucaena leucocephala* and *Gliricidia sepium*) in cultivated plots on an acid soil in southeastern Nigeria. Total DM production was higher ($P < 0.05$) for *Alchornea cordifolia* than for the other browse species. *Glyphaea brevis* and *L. leucocephala* were the most preferred species while *A. cordifolia. G. sepium*, and *R. vomitoria* were the least. Mean crude protein content of browse species in this study was higher while P and neutral detergent fiber were lower than reported for other browse species in Nigeria. The complementary use of browse species is argued as the ultimate goal of a crop-livestock agroforestry system such as alley farming.

Fodder Production, Crop Yield

414
H
Larbi, A., M.A. Jabbar, A.N. Atta-Krah, and J. Cobbina. 1993. Effect of taking a fodder crop on maize grain yield and soil chemical properties in *Leucaena* and *Gliricidia* alley farming systems in western Nigeria. Experimental Agriculture 29: 317–321.

The trade-off between the amount of hedgerow foliage used for mulching and the proportion used as fodder were examined on maize grain yield and soil chemical characteristics in *Leucaena leucocephala* and *Gliricidia sepium* alley farming systems under on-station and on-farm conditions in southwestern Nigeria. Yields increased as the proportion of mulch applied increased but the extra increases obtained when more than half the foliage was applied as mulch were relatively small, suggesting that half the foliage may be removed as feed without detrimental effects. The levels of soil organic carbon, nitrogen, and available P increased as the proportion of prunings applied as mulch increased.

Fodder

415
H
Larbi, A., I.I. Osakwe, and J.W. Lambourne. 1993. Variation in relative palatability to sheep among *Gliricidia sepium* provenances. Agroforestry Systems 22: 221–224.

The relative differences in palatibility within 28 provenances of *Gliricidia sepium* collected from West Africa and Central America were determined using the cafeteria technique for 3-year-old West African Dwarf sheep. *Leucaena leucocephala* and *Guazuma ulmifolia* were included as controls. Significant differences in the relative palatability index (RPI) were found among *G. sepium* provenances. Mexican ecotypes had lower relative palatability than those from Costa Rica. Based on their RPI, provenances were grouped into high (RPI 90), medium (RPI 60-90), and low (RPI 60) preference rankings. The importance of the differences in relative palatability is discussed in relation to *Gliricidia*-based alley farming in the humid West African region.

Fodder Production

416
H
Lazier, J., A. Getahun, and M. Velez. 1982.
The integration of livestock production in agroforestry. Pages 84–88 *in* Agroforestry in African humid tropics, edited by L.H. MacDonald. The United Nations University, Tokyo, Japan.

West African dwarf sheep and goats seem to have the potential to satisfy the increasing demand for animal protein in the humid zones of West Africa. Their current management is described and their integration together with that of cattle into agroforestry systems is discussed. The planting of browse species such as *Gliricidia sepium* and *Leucaena leucocephala* may overcome the constraint to animal production caused by the lack of fodder in the dry season. Grazing in forests, plantations, and alley cropping systems is also discussed.

Forage Production

417
H
Remington, T. and K. Eklon-Takpani. 1989.
Alley farming in central Togo. Pages 137–138 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. Proceedings of International workshop held 10–14 Mar 1986, IITA, Ibadan, Nigeria. International Development Research Centre (IDRC), Ottawa, Canada.

The benefits of alley cropping and establishing forage banks on farms that use oxen and keep small ruminants are discussed.

Livestock Production On-Farm Research Fodder Production

418
H
Reynolds, L. and A.N. Atta-Krah. 1989.
Alley farming with livestock. Pages 27–36 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. Proceedings of International workshop held 10–14 Mar 1986, IITA, Ibadan, Nigeria. International Development Research Centre (IDRC), Ottawa, Canada.

Alley farming is an ecologically sound, low-input farming system that links crop and livestock production. *Leucaena leucocephala* and *Gliricidia sepium* have been managed for mulch to sustain and improve crop yields and for fodder in a cut-and-carry system to raise livestock productivity. The competing demands of crops and livestock for tree foliage from alley farms is considered and the inclusion of a grazed fallow in the system is also discussed. A more intensive system of tree production to provide animal feed is described. On-farm trials in southern Nigeria have demonstrated that alley farming is appropriate and acceptable to small farmers.

Fodder Production

419
H
Topark-Ngarm, A. and R.C. Gutteridge. 1990.
Fodder productivity of perennial *Sesbania* species. Pages 79–88 *in* Perennial *Sesbania* species in agroforestry systems, edited by B. Macklin and D.O. Evans. Proceedings of a workshop held 27–31 Mar 1989, International Centre for Research in Agroforestry (ICRAF), Nairobi, Kenya. Nitrogen Fixing Tree Association (NFTA), Waimanalo, USA.

The use of perennial *Sesbania* species as sources of fodder for livestock is discussed. Productivity of these species is moderate with fodder yields of up to 12 t/ha/year recorded from intensively managed hedgerows of *S. sesban*. *Sesbania* forage has a high nutritive value for ruminants and its major role may be in supplementing

low quality basal diets such as rice straw or standing grass. At present these species are used for fodder mainly in India and other south and southeast Asian countries where they are fed predominantly in "cut-and-carry" systems. The cutting method used to harvest forage is an important aspect of the management of these species. *S. grandiflora* is susceptible to severe cutting treatments. The effects of direct grazing have not been widely researched. Perennial *Sesbania* species have the potential for much greater exploitation as fodder species. They will grow in a wide range of edaphic and climatic conditions. They tolerate waterlogging, extremes of pH, periodic flooding, and soil salinity and thus could be used to produce high quality fodder from previously inhospitable, unproductive sites.

420
HB
Gutteridge, R.C. and H.M. Shelton. 1993.
The scope and potential of tree legumes in agroforestry. Agroforestry Systems 23: 177–194.

Due to their multipurpose nature, tree legumes can be used to provide high-quality fodder for livestock, nutrient-rich mulch for crops, fuelwood and timber, microenvironment amelioration, ecosystem stability, and human food. Research and development efforts have concentrated on broadening the resource base by evaluating a wider range of tree legume management strategies and developing appropriate systems with a view to optimizing the advantages of these species. This paper reviews the role of tree legumes in agroforestry, especially for fodder purposes, and highlights the current research focus and some gaps in our knowledge which require further research effort.

421
HB
Nyathi, P. and B. Campbell. 1994.
Leaf quality of *Sesbania sesban*, *Leucaena leucocephala*, and *Brachystegia spiciformis*: potential agroforestry species. Forest Ecology and Management 64: 259–264.

Leaf nutrient content of 75 trees was evaluated in 1990. Fifteen trees were sampled from *Leucaena leucocephala* var. Cuningham and *Sesbania sesban*, and 45 from three age classes of *Brachystegia spiciformis*. The trees were growing at the Makoholi Research Station taken from every three trees sampled, oven-dried ground, and analyzed for dry-matter digestibility and contents of acid detergent fiber, lignin, N, P, K, Ca, and Mg. The highest leaf quality was obtained in *Sesbania*. The lowest quality litter was recorded in *B. spiciformis* which had lower levels of all nutrients in vitro dry-matter digestibility and highest levels of fiber and lignin. There were no differences among the different age classes of *Brachystegia*. One option to improve soil fertility on already cleared land is to introduce *Sesbania* and *Leucaena* litter.

422
HC
Ezenwa, I.V. 1994.
Effect of tree cutting management on fodder and wood yields and persistence of grass in tree-grass pastures. Nitrogen Fixing Trees Research Reports 12: 13–17.

The trial was sited at Fasola (8°7'N, 30°2'E) in the derived savanna zone, Nigeria. Rainfall averages 1110 mm annually. Old stands of *Leucaena* and *Gliricidia* which had not been cut for 6 years were pruned down at 0.5 cm above ground level in 1989. *Panicum maximum* grass was established in the 4-m alleys at 0.5 × 0.8 m spacing. Both tree and grass were cut back to 0.5 m and 0.15 m above ground, respectively, in 1990. The following cutting regimes were imposed: trees cut once (12 months), twice

at 3 and 9 months, at 6 months, and at 3, 6 and 9 months. Results indicated that higher grass dry-matter yields were obtained in the inner than outer grass rows in all plots except in plots cut four times. There was no effect of hedgerow configuration on grass dry-matter yields, survival, fodder, and wood yields. Wood yields increased with increasing intervals between consecutive harvests. About 81% of biomass in plot pruned at 9 and 3 months was wood compared to 51–54% in other treatments. Cutting the trees once after 6 or 9 months produced high fodder and wood yields and decreased grass persistence, while more frequent pruning improved the grass persistence in the alleys. The choice of tree cutting schedule depends on management objectives.

Fodder Production Management Pruning

423
HC
Ezenwa, I.V. 1994.
Cutting management influence on ash contents of *Leucaena* and *Gliricidia* leaves. Nitrogen Fixing Tree Research Reports 12: 10–11.

The trial was carried out at Fasola (8°7'N, 30°2'E) in the derived savanna zone of Nigeria, to determine the best cutting schedule for *Gliricidia sepium* and *Leucaena leucocephala* under the alley farming system. *Leucaena* and *Gliricidia* were established in 1989 at 0.25 × 4 m spacing. Four rows of *Panicum maximum* cv. Ntchisi were established in the alleys, and the trees were cut at 0.5 m above ground level in 1990 using the following cutting schedules: One cutting (12 months), two cuttings at 3 and 9 months, at 6 month intervals, 9 and 3 months, three cuttings at 3, 3, and 6-months and four cuttings every 3 months. Ash contents of *Leucaena* and *Gliricidia* were not significantly different. The ash content in both trees declined with increasing cutting intervals with the lowest obtained in October. The 9- and 3-month cuttings resulted in highest leaf yield in both trees thus resulting into lower ash. A uniform ash concentration in leaves over extended cutting intervals would allow flexibility in adopting cutting regimes for maximum forage yield without adversely affecting the mineral concentration of tree foliages.

Fodder; Livestock Production

424
HI
Reynolds, L. and S.A.O. Adeoye. 1989.
Planted leguminous browse and livestock production. Pages 44–54 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. Proceedings of International workshop held 10–14 Mar 1986, IITA, Ibadan, Nigeria. International Development Research Centre (IDRC), Ottawa, Canada.

Browse is an important component of the diet of small ruminants under traditional management in southern Nigeria. The leguminous trees *Leucaena leucocephala* and *Gliricidia sepium* planted in alley farms or intensive feed gardens can provide a high protein supplement for use in a "cut-and-carry system". The digestibility of browse dry matter increases when a high energy supplement such as cassava peel is also offered. On-station trials have shown that a mixed *Leucaena-Gliricidia* supplement can raise the productivity of West African dwarf sheep on a basal *Panicum maximum* diet by 55%. At the village level, small farmers with established *Leucaena* and *Gliricidia* have fed the foliage to their small ruminants. Strategic feeding to pregnant and lactating females and the use of fallow land within *Leucaena* and *Gliricidia* alleys for grazing and browsing animals are discussed.

Digestibility; Forage Composition

425
HI
Wheeler, R.A., W.R. Chaney, M.J. Cecava, and P.L. Brewbaker. 1994. Forage yield and compositional analysis of *Leucaena* species and hybrids adapted to cool sites. Agroforestry Systems 25: 263–274.

An evaluation of four *Leucaena* species (*L. leucocephala*, *L. diversifolia* 2n and 4n, and *L. pallida*) and three interspecific hybrids KX1 (*L. diversifolia* x *L. pallida*), KX2 (*L. leucocephala* x *L. pallida*), and KX3 (*L. leucocephala* x *L. pallida*) for forage yield was undertaken in an upland site at the Mealani Research Station on the island of Hawaii. Two-month-old seedlings were planted at a density equivalent to 40,000 trees/ha and coppiced (harvested) every 6 months for a 2-year period. Two Holstein steers fitted with cannulae in the rumen and proximal duodenum were used to conduct a replicated trial to examine rumen and postrumen dry matter and crude protein digestibility of leaf material. Nylon bags containing leaf material from K636 (*L. leucocephala*), KX2 (*L. leucocephala* x *L. pallida*), or K376 (*L. pallida*) were suspended in the rumen for periods of 0, 4, 8, 12, 24, 36, and 48 hours. Weight loss and nitrogen content of each sample were determined. Material was placed in nylon bags, inserted into the duodenal cannulae of two steers and collected in the feces for periods of 24 h after insertion. *Leucaena* was shown to be adapted to cool sites and produce good yields of high quality forage. Neither of the ruminal N or intestinal dry matter or crude protein disappearance between K636 and KX2 were significantly different whereas K376 was significantly lower for both values. Nearly 40% of dietary crude protein in the K636 and KX2 leaf material escaped ruminal digestion whereas nearly 70% was nondigested for K376. For K636 and KX2, intestinal availability of that protein which escaped ruminal digestion was nearly 50% whereas only 20% of ruminal escape protein of K376 was available in the intestines. If animal acceptability and rumen retention of dry matter are not problems, plantings on cool sites would favor the use of K636 rather than KX2 in terms of higher forage yields.

Alley Grazing; Forage Production; Livestock Production

426
HI
Wildin, J.H. 1989.
Trees in forage systems. Pages 71–81 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. Proceedings of International workshop held 10-14 Mar 1986, IITA, Ibadan, Nigeria. International Development Research Centre (IDRC), Ottawa, Canada.

Native trees in dense stands can be serious competitors to herbaceous pastures. With appropriate densities and management, however, trees can exploit an expanded biotic environment in forage systems and high economic gains can be achieved. The paper outlines the attributes of useful trees in forage systems and discusses the retention of valuable native trees on grazing lands. Selection of trees of immediate use in forage systems must rely on past experiences in the target region and similar environments throughout the tropics and subtropics. Fast-growing, multiple-use, nitrogen-fixing trees are considered most important in forage systems. *Leucaena leucocephala*, *Gliricidia sepium*, and *Sesbania grandiflora* are quick-growing leguminous trees already used throughout the humid tropics in cropping and forage systems. Selected forage types of *Cajanus cajan* can be undersown with crops. These trees can be put into farm use quickly, especially in alley cropping and alley grazing. *Leucaena* in alley-grazing systems in Australia is discussed. The diversity of agroecological conditions in the tropics can impose severe constraints on crop, forage, and animal production. Research will identify better adapted nitrogen-fixing trees to suit this wide environmental range.

Animal Production; Forage Production; Wood Production

427
HIJ
Liyanage, L.V.K. and A.U.M. Wijeratne. 1987.
***Uses and management of Gliricidia sepium in coconut plantations of Sri Lanka.* Pages 95–101 *in Gliricidia sepium* (Jacq.) Walp.: management and improvement, edited by D. Withington, N. Glover, and J.L. Brewbaker. Nitrogen Fixing Tree Association (NFTA) Special Publication. 87-01, Waimanalo, Hawaii, USA.**

Performance of *Gliricidia sepium* (Jacq.) Walp. was studied over 2½ years in mature coconut plantations in three agroecological zones (wet, dry, and intermediate) in Sri Lanka representing the three soil types, an Ultisol (lateritic) and two Entisols (sandy and sandy loam). Mature *Gliricidia* sticks planted 2.0 m × 0.9 m in double rows in the coconut avenue (1900 plants/ha) achieved 90% establishment at all locations. *Gliricidia* plants cut at 1 m height after 1 year at 3-month intervals produced 8–10 t/ha and more than 10 t/ha of green matter annually at all locations during the first and second years, respectively. Annual fresh firewood production after 1 year was 11–13 t/ha on the Ultisol and Entisol, respectively. Wood production in the second year was 12–13 t/ha on the Entisol and 14–16 t/ha on the Ultisol. Leaf litter production was 2 t/ha on the Entisol (sandy) and 0.5–1.0 t/ha on the other soil. Nodule numbers ranged from 30–100/plant 3 months after staking at all locations. *Gliricidia* incorporated in quarter circle trenches cut 30 cm away from the palm were the most effective trenching, root pruning, and fertilization method attempted. A mixture of 50:50 of *Gliricidia* leaves and the grass, *Brachiaria miliiformis*, fed to crossbred heifers produced average liveweight gains of 700 g/day.

Fodder Production; Livestock Production; On-Farm Research

428
HIM
Reynolds, L., A.N. Atta-Krah, and P.A. Francis. 1988.
A strategy for improving goat productivity under village production systems in the humid tropics. Pages 29–37 *in* Goat production in the tropics, edited by O.B. Smith and H.G. Bosman. Proceedings of a workshop held 20–24 Jul 1987, University of Ife, Ile-Ife, Nigeria. Centre for Agricultural Publishing and Documentation (PUDOC), Wageningen, The Netherlands.

The paper outlines a strategy for the improvement of the productivity of goats under village conditions. Particular emphasis is laid on the need to take production constraints and resource availability at village level into account in the design of improved technologies. The main constraints to increased goat production are discussed. Alley farming and intensive feed gardens with leguminous fodder trees are presented as potential solutions to the existing nutritional constraint. Foliage from the trees is not only protein-rich animal feed but may also be used as a high nitrogen-mulch for the maintenance of soil fertility. The system thus integrates crop and livestock production to their mutual benefit. The alley farming research of the Humid Zone Programme of the International Livestock Centre for Africa (ILCA), which includes agronomic and nutritional trials both on-station and on-farm, is outlined.

Fodder Production; Economic

429
HK
Jabbar, M.A., J. Cobbina, and L. Reynolds. 1992.
Optimum fodder-mulch allocation of tree foliage under alley farming in southwest Nigeria. Agroforestry Systems 20: 187–198.

Whether or not the use of prunings for feeding animals is economic in alley farming depends on crop response to mulching. The results demonstrated that at low crop yields and low crop response to mulching, feeding part of the tree foliage to small ruminants is economically gainful but at high crop yield levels and higher crop re-

sponse to mulching, the use of pruning for feeding animals is uneconomic at current market prices. The trade-off between using pruning as mulch or as a fodder source will be optimized with adequate knowledge of crop response.

Fodder Production: Economics

430
HK
Jabbar, M.A. and J. Cobbina. 1992.
Optimum fodder-mulch allocation of tree foliage under alley farming in southwest Nigeria. Pages 147–152 *in* Financial and economic analyses of agroforestry systems, edited by G.M. Sullivan, S.M. Huke, and J.M. Fox. Proceedings of a workshop held Jul 1991, Honolulu, Hawaii, USA. Nitrogen Fixing Tree Association, Paia, Hawaii.

Previous economic analyses found alley cropping more profitable than conventional farming. One study that also compared alley farming with small ruminants found it less profitable than alley cropping. The present study shows, on the basis of more recent experimental data, that crop response to mulching is the most important determinant of whether or not the use of prunings for feeding animals is economic. At low crop yields and low crop response to mulching, feeding part of the tree foliage to small ruminants is economically gainful, but at high crop yield levels and higher crop response to mulching, the use of pruning for feeding animals is uneconomic.

LIVESTOCK NUTRITION/PRODUCTION

Livestock Production: Nutrition

431
I
Adegbola, A.A., O.B. Smith, and V.O. Asaolu. 1989.
Response of the West African dwarf sheep to diets based on processed cassava peels and *Gliricidia sepium*. Pages 282–289 *in* Overcoming constraints to the efficient utilization of agricultural by-products as animal feed, edited by A.N. Said and B.H. Dzowela. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.

Cassava peel is now readily available in large quantities from rural cassava processing factories. Although many studies have evaluated the nutritive value of cassava peels, none has assessed animal response when used as a main energy source. This study determined the response of the West Africa dwarf sheep to three diets consisting of 100% *Gliricidia sepium*, 80% ensiled cassava peel plus 20% *Gliricidia*, and 80% dried cassava peel plus 20% *Gliricidia*. Animals fed on *Gliricidia* alone consumed 1040 g dry matter (DM) per day and gained 106 g liveweight daily, while those fed on ensiled cassava peels with *Gliricidia* consumed 710 g DM per day and achieved 80 g liveweight daily. Animals fed on dried cassava peel with *Gliricidia* consumed only 640 g DM per day and achieved an average daily weight gain of 59 g per day.

Livestock Production: Nutrition

432
I
Ademosun, A.A., H.G. Bosman, and H.J. Jansen. 1988.
Nutritional studies with West African dwarf goats in the humid tropics. Pages 51–61 *in* Goat production in the tropics, edited by O.B. Smith and G.G. Bosman. Centre for Agricultural Publishing and Documentation (PUDOC), Wageningen, The Netherlands.

At Ile-Ife, Nigeria, a nutrition concept for dwarf goats is being developed as part of a management package for intensive goat rearing, designed to be easily adaptable under village conditions. This means that the nutritional research in the first instance has been focused on the evaluation of locally available feed resources. Grasses like

Panicum maximum and *Cynodon* sp. were among the first feeds to be investigated, followed by the legumes *Gliricidia sepium* and *Leucaena leucocephala*. Concentrate was only used to determine the potential production levels of West African dwarf goats under humid tropical conditions, in order to obtain a guideline for the evaluation of roughage and agro- -by-products. This paper reviews the results of the experiments carried out so far. It is concluded that West African dwarf goats are unable to maintain themselves on poor quality tropical grasses. On the other hand, legumes like *Gliricidia sepium* and *Leucaena leucocephala* can satisfactorily constitute the basic diets of dwarf goats producing weight gains of up to 35–40 g a day. Cassava and brewers' dried grains hold promise as energy of protein-rich supplements, respectively. Further research is required to determine the optimal feeding level and, in the case of cassava, feeding frequency.

Livestock Production

433
I
Carew, B.A.R. 1983.
***Gliricidia sepium* as a sole feed for small ruminants. Tropical Grasslands 17: 181–184.**

In the West Africa subregion farmers are familiar with *Gliricidia sepium*, however, they rarely feed it routinely to their small ruminants. This study was undertaken to determine the usefulness of *Gliricidia* foliage in the feed of sheep and goats on a day-to-day basis. Equal numbers of West African dwarf sheep (18 kg) and goats (14 kg) were fed with a sole diet of *Gliricidia* ad libitum for a continuous period of 21 weeks. Mean daily dry-matter intake was higher for sheep than for goats. Expressed as percentages of the mean liveweights, however, there were no significant differences. Mean daily liveweight gain over the 18 weeks period was 39 g for sheep compared to 14 g for the goats. The daily dry matter did not differ significantly between the two ruminants when expressed as percentages of the mean liveweights.

Livestock Production

434
I
Ifut, O.J. 1989.
Utilization of *Gliricidia sepium* and cassava peels by West African dwarf (WAD) goats in Nigeria. Pages 290–305 *in* Overcoming constraints to the efficient utilization of agricultural by-products as animal feed, edited by A.N. Said and B.H. Dzowela. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.

Bucks of the West African dwarf breed were fed three different diets consisting of 100% *Gliricidia sepium* (T-1), 100% cassava peels (T-2) and 70% *Gliricidia sepium* plus 30% cassava peels (T-3). Goats on diets T-3 consumed the highest dry matter and achieved the greatest average daily liveweight gain, while those on T-2 consumed the least and lost weight daily. Estimated meat yield per treatment was highest for animals on 70% *Gliricidia* plus 30% cassava peels.

Livestock Production

435
I
Okali, C. and J.E. Sumberg. 1985.
Sheep and goats, men and women: household relations and small ruminant development in southwest Nigeria. Agricultural Systems 18: 39–59.

Small ruminant production systems are described for the humid areas of southern Nigeria. Gender differences in ownership patterns are detailed and the unique nature of small ruminants among agricultural resources is emphasized. Development paths that maintain small ruminants in their positions as minor enterprises in existing farm-

ing systems are highlighted, and the implications of these models discussed in terms of intrahousehold processes. Alternative models are reviewed and compared.

Livestock Production

436
I
Reynolds, L. and Adediran, S.O. 1988.
The effects of browse supplementation on the productivity of West African dwarf sheep over two reproductive cycles. Pages 83–91 *in* Goat production in the tropics, edited by O.B. Smith and H.G. Bosman. Proceedings of a workshop held 20–24 Jul 1987, University of Ife, Ile-Ife, Nigeria. Centre for Agricultural Publishing and Documentation (PUDOC), Wageningen, The Netherlands.

Supplementation of a basal diet of *Panicum maximum* and cassava peel with *Leucaena leucocephala* and *Gliricidia sepium* (1:1, w/w) increased lamb growth rates to weaning and to 24 weeks of age, and improved lamb survival rates. Total feed intake of lambs increased with level of supplementation, although intake of the basal diet tended to decrease. Lambs born in the middle of the dry season grew more slowly to weaning than those born at the end of the dry season. Lambs weaned in the middle of the dry season grew more slowly from 12 to 24 weeks than those weaned at the start of the rains.

Livestock Production

437
I
Reynolds, L., C.D. Domenico, A.N. Atta-Krah, and J. Cobbina. 1991.
Alley farming in southwestern Nigeria: the role of farming systems research in technology development. Pages 85–108 *in* Planned change in farming systems: progress in on-farm research, edited by R. Tripp. J. Wiley, Chichester, UK.

In 1978, the International Livestock Centre for Africa (ILCA) set up a research program aimed at improving the living standards of smallholder farmers in the humid zone of West Africa by raising the productivity of their sheep and goats. The initial work, based on the assumption that the whole farming system would have to change, focused on pasture and improved pasture species that could be used for animal fodder. A new approach was adopted 2 years later, when it became clear that farmers were unwilling to divert resources towards livestock production and away from their primary objective, crop production. Livestock are a minor component of the farming system in the humid zone. Usually, they are left to scavenge for themselves and are kept with minimal inputs of time and other resources from farmers. Consequently, researchers began to seek technologies that built on and worked within the farming system. Their methods of diagnosing the main constraints to crop and livestock production, as well as a description of the research area and the farming system are presented here.

Livestock Production-Economics

438
IK
Reynolds, L. and M.A. Jabbar. 1994.
The role of alley farming in African livestock production. Outlook on Agriculture 23 (2): 105–113.

The alley farming system, in which food or forage crops are grown between hedges of multipurpose trees that are regularly pruned for mulch and/or forage, has been studied for over 10 years in Africa. Prunings from leguminous trees such as *Leucaena* and *Gliricidia* can be used for mulch, increasing crop yields, but prunings from the trees may also be used for fodder, especially during fallow periods. The major benefit from supplementing the diet of free-roam small ruminants in West Africa with the foliage of leguminous trees is increased survival, thus forage is best directed at late pregnant and lactating females. In East Africa crossbred dairy cows responded to supplemen-

tation with *Leucaena* in terms of milk production. Economic analyses of livestock production show that continuous alley farming is more profitable than alley farming with fallow, or conventional no-tree farming, even when the labor cost for clearing trees is included.

Economics: Fodder Livestock Production

439
IK
Sumberg, J.E., J. McIntre, C. Okali, and A.N. Atta-Krah. 1987.
Economic analysis of alley farming with small ruminants. ILCA Bulletin 28: 2–6.

Under alley cropping leguminous trees or shrubs are grown between alleys of field crops. In some areas it can replace fallow for soil fertility restoration. Alley farming allows the choice between leaving the tree foliage on the soil as mulch, or of feeding it to animals. Economic models of alley farming, alley cropping, and fallow use experimental and field data from southwest Nigeria. Principal conclusions are that alley cropping is superior to fallow systems; that alley farming in which leaves are fed to sheep or goats is inferior to basic alley cropping; and that sheep or goat supplementation with *Leucaena* or *Gliricidia* needs to achieve a 30 to 40% increase in net productivity per ram to be competitive with leaving foliage for maize production.

Economics: Livestock Production

440
IK
Upton, M. 1985.
Returns from small ruminant production in southwest Nigeria. Agricultural Systems 17(2): 65–83.

In the humid zone of West Africa, dwarf goats and sheep are ubiquitous although only as a supplement to cash and food crop production. Estimates of the returns obtained from these small ruminants under traditional production systems are presented in this paper. On average, high, but variable, returns were found especially with regard to disease risks. In addition to disease control measures to reduce mortality, improved nutrition is needed to intensify production. At current levels of management, neither pasture production nor housing and hand-feeding are likely to yield increased returns. The feeding of shrub trimmings in alley farming to small ruminants seems a promising alternative.

AUXILIARY PRODUCTS

Live Staking

441
J
Budelman, A. 1987.
The above-ground structural compatibility of *Flemingia macrophylla*, *Gliricidia sepium*, and *Leucaena leucocephala* as live stakes for yams, *Dioscorea alata*. Pages 82–89 *in Gliricidia sepium* (Jacq.) Walp.: management and improvement, edited by D. Withington, N. Glover, and J.L. Brewbaker. Nitrogen Fixing Tree Association (NFTA) Special Publication 87-01, Waimanalo, Hawaii, USA.

Yam, *Dioscorea alata*, was grown in combination with three nitrogen-fixing tree/shrub species, *Leucaena leucocephala*, *Gliricidia sepium*, and *Flemingia macrophylla*. Hedgerows of these trees were planted 2 m apart. After three successive cultivation cycles, the yam tuber yields in ha in the third year were: 2.0 (control), 4.3 (*Leucaena*); 6.4 (*Flemingia*), and 12.2 (*Gliricidia*). Differences in yield are explained as a function of the individual qualities of the species in their role as a living support stake for the yam. Only the yam-*Gliricidia* association produced acceptable yields. Tuber yields

per yam plant were approximately twice as high when grown in association with *Gliricidia* as compared to a monoculture yam system that received an equal amount of *Gliricidia* mulch as the *Gliricidia*-yam association. Yields per ha were similar. It is concluded that a yam-*Gliricidia sepium* association is equally efficient in terms of tuber production per unit of area as an unstaked monoculture of yam cultivars that do not require support. The net advantage of the association lies in an improvement of the quality of the cultivation environment.

Live Staking

442
J
Budelman, A. and E.C.M. Pinners. 1987.
The value of *Cassia siamea* and *Gliricidia sepium* as in situ support systems in yam cultivation: experiences from a farm-based trial. Pages 90–91 *in Gliricidia sepium* (Jacq.) Walp.: management and improvement, edited by D. Withington, N. Glover and J.L. Brewbaker. Nitrogen Fixing Tree Association (NFTA) Special Publication 87-01, Waimanalo, Hawaii, USA.

Gliricidia sepium and *Cassia siamea* were introduced into a yam (*Dioscorea alata*) cropping system. Yams were planted a year after the trees were established. Trees were gradually lopped once the yams needed light. *Cassia* was less acceptable than *Gliricidia* as a support because it did not shed its leaves after ringing, its branches were harder to trim, and yam yields were lower than yields in a yam monoculture. Yam yields with *Gliricidia* were equal to yields in a yam monoculture.

SOCIOECONOMICS

Wood Production

443
J
Cutter, B.E. and H.E. Garrett. 1993.
Wood quality in alley cropped eastern black walnut. Agroforestry Systems 22: 25–32.

In the southwest Missouri (USA), the thinnings from a 15-year-old eastern black walnut (*Juglans nigra* L.) agroforestry plantation were evaluated to determine the effect of cropping practices on wood quality. Growth rate was found to be strongly affected by weed control and cropping practices while specific gravity and fiber length were little affected.

Economics

444
K
Ashraf, M. Undated.
Economics of alley cropping for sustainable agriculture in humid West Africa. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 14 pp.

The linear programming (LP) technique can be used to program the agricultural sustainability concept, especially as it relates to the longevity and environmental quality aspects of a new technology such as alley cropping. The biological regenerative effects of alley cropping technology and the use of chemical fertilizers can sustain the productivity of farm systems in humid West Africa. The sustainability features of these technologies are captured in the LP model through the shadow pricing of fallow land and fertilizer nutrients and by indexing the environmental quality for the alternative crop-production systems. Regarding farmers' acceptance of alley cropping technology, it was found to be dependent upon two key factors; the availability of fertilizers and access to farm land. In regions where population pressure on land is not so severe and/or fertilizers are easily accessible, farmers do not find alley crop-

ping economically attractive over the bush-fallow method mainly due to the high opportunity cost of farm labor. Where access to farm land and fertilizers is restricted, alley cropping provides a means of substituting excess family labor for land and cash capital and becomes a viable technology. Similarly, farmers with little or no tree crops and/or who raise small ruminants find alley cropping technology more attractive than farmers with more tree crops or with smaller animals. It seems the promotion of alley cropping will be much easier for resource-poor farmers located in regions where chemical fertilizer inputs are more expensive, where farmers' access to agricultural land is limited, and where small ruminants are part of the farm system. As African countries experience lower land/human ratios in the future, farmers' acceptance of alley cropping will grow. Future research on alley cropping
should concentrate on increasing the productivity of the farm system in terms of both crop yields and returns to family labor and on management practices directed at enhancing the longevity of land use.

Socioeconomics

445
K
Avila, M. 1989.
Socioeconomic issues in alley cropping. Paper prepared for the First General Membership (Inaugural) Meeting of the Alley Farming Network For Tropical Africa, 1–3 Aug 1989, Ibadan, Nigeria. 10 pp.

Any technology, and alley farming is no exception, is a means for farmers to satisfy their goals and objectives. Thus, to design and evaluate appropriate technologies, it is indispensable to understand the environment in which farmers exist and make decisions. Farmers are part of a social (including cultural) milieu which influences their behaviour, aspirations, and decision-making processes. Therefore effective technology, development, and research requires a sound understanding not only of the biological systems but also of the human systems. In this connection, the objective of this paper is to present an appropriate framework for socioeconomic analysis of the alley farming technology (or system), to identify the key socioeconomic determinants of its potential adoption, and to define potential areas of contribution by the social sciences as part of the interdisciplinary approach to alley farming research. Many of the issues and comments in this paper also apply to other agroforestry technologies.

Economic Modeling

446
K
Hoekstra, D.A. 1983.
An economic analysis of a simulated alley cropping system for semiarid conditions using microcomputers. Agroforestry Systems 1: 335–345.

An ex-ante analysis of land-use data was done for the semiarid areas in the Machakos District of Kenya where rainfall is bimodal and averages about 600 mm year. A microcomputer program (MULBUD) for the agroforestry system was used for the simulations and analyses. The graphical display produced by MULBUD illustrates the differences in labor use and flow of net revenue of the two land-use systems, i.e., traditional maize/beans and the *Leucaena* alley cropping system. Net revenue flow increases after the first year. Labor reduction is achieved by reduced labor requirements for field preparation and weeding.

Economics

447
K
Raintree, J.B. and F. Turay. 1980.
Linear programming model of an experimental *Leucaena*/rice alley cropping system. IITA Research Briefs 1(4): 5–7.

The program is based on a model developed to evaluate the economic attractiveness of an experimental *Leucaena*/rice alley cropping system under West Africa smallholder conditions. It is consistently more profitable to grow rice with N from *Leucaena* hedgerows than from either of the two mineral N sources. Furthermore, with labor as the limiting production factor, the two components of the *Leucaena*/rice alley cropping systems always combine in the same economically optimal proportions of 0.37 ha (3700 linear meters) of *Leucaena* hedgerow to 1.28 ha of rice grown in the alleys between the hedgerows, for an optimum field size of 1.65 ha. The stability of the optimum farm plan is indicated by the high and increasing opportunity cost of mineral N-based rice production activities (the profit reduction that would result from forcing such activities into the farm plan). Not only does rice production with mineral N never enter into the maximum profit farm plan, but the relative profitability of the alley cropping alternative increases with time. All computations in the basic model are based on unsubsidized fertilizer prices. A separate set of runs to evaluate the effects of fertilizer subsidies indicated that, in order for rice production with urea or ammonium sulfate to become competitive with *Leucaena*-based rice production, subsidy levels of 97%, would be required.

Alley Economics: Linear Modeling

448
K
Verinumbe, I., H.C. Knipscheer, and E.E. Enabor. 1984.
The economic potential of leguminous tree crops in zero-tillage cropping in Nigeria: a linear programming model. Agroforestry Systems 2: 129–138.

The zero-tillage farming system was economically evaluated at small-scale farmer level in southwest Nigeria on Alfisols using the linear programming method to maximize yearly net return. Alternative crop-rotation systems considered were maize-maize, maize-Stylo, maize-maize/Stylo, maize-pigeon pea, maize/maize/pigeon pea, and maize/*Leucaena*-maize/*Leucaena*. The maximum net profit farm plan, for an individual farmer with N300.00 cash investment, was 1.35 ha (95%) for the maize/*Leucaena*-maize/*Leucaena* and 0.07 ha (5%) for the maize-Stylo rotation systems. Net profit associated with the plan was 978.58 while shadow prices of rejected systems ranged between 66.68 and 168.24, indicating stability of the model. Under severe cash constraints the maize/*Leucaena* alley cropping system was the most promising package where labor was available and cheap. The results suggested a promising future for the combined production of agricultural and forestry crops under an integrated land management system by small-scale farmers in the humid tropics.

Economics

449
K
Vogel, W.O. 1985.
Socioeconomic considerations for alley farming. Paper read at the workshop on Alley farming as an Alternative Production System To Shifting Cultivation, Dec 9–10 1985. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 14 pp.

Benefits from alley farming accrue to the individual farmer as well as to society. Benefits to the farmer can be analyzed by identifying the most important constraints in the environment of the farming system and in the system itself. The value of the benefits differs depending on the relative scarcity of the factors of production. Benefits to society are difficult to measure but ignoring them would lead to a gross underestimation of the benefits of this new technology.

Economics; On-Farm Research

450
KM
Dvorak, K.A. 1990.
On-farm research on adoption potential of alley cropping. Paper presented at the Workshop on Methods For Participatory On-farm Agroforestry Research. 19–23 Feb 1990. International Centre for Research in Agroforestry (ICRAF), Nairobi, Kenya. 10 pp.

An approach to on-farm economic research on alley cropping is described. In the first stage of research, cost-route surveys and field measurements were carried out for a small sample of farmers with recently established alleys. Although research-resource intensive, the cost-route studies and field measurements were necessary to develop a framework for analyzing alley cropping on-farm because rapid methods of assessing intrinsically dynamic technologies are not yet available. Administration of a focused, formal single-visit survey to a large sample of farmers who have participated in alley farming trials at several locations is the second stage. In addition, intensive data collection with a small sample will continue in order to quantify factors identified as key in the first stage. Although still developmental, it is hoped that the combination of methods will contribute to development of more rapid and readily accessible methods of evaluating agroforestry technologies on-farm.

Gender; On-Farm Research

451
KM
Francis, P.A. and A.N. Atta-Krah. 1988.
Incorporating gender concerns into on-farm research: the household and alley farming in southwest Nigeria. *In* Methodologies handbook on intra-household dynamics and farming systems research and extension, edited by H. Feddstein and J. Jiggins.

The high degree of autonomy which farmers were allowed in the management of their alley farms was an essential aspect of the methodology. Farmer control and management allowed institutional, intrahousehold, and management constraints to emerge and to be assessed. This could not have occurred under more researcher-controlled conditions. The fact that farmers were working on their own farms in realistic circumstances meant that the full importance of factors such as land-tenure questions, the competing demands on labor within the context of the farming system, or the appropriateness of new techniques of land and livestock management in farmers' decision-making was revealed. Our experience also underlines the need to distinguish carefully the subgroups which may make up a recommendation domain, and that care should be taken that each should be represented in the on-farm testing of technology. Where the circumstances of farmers differ by gender, which will usually be the case, men and women may not benefit equally from given technologies or extension strategies. Three kinds of lessons about barriers to women's participation emerge from this case study. First, women were underrepresented in the initial on-farm research and extension team. This was remedied through the addition of a woman with research and extension responsibilities. Second, and relatedly, the domination of men at the community level meant that it was they that dealt with outsiders and were thus the first to be exposed to the new technology. This highlighted the need for extension-related efforts targeted specifically at, and implemented by, women. These took place both on an individual basis and through women's associations already existing within the community. Third, the organization of production at the household level had implications for technology adoption and use. Different members of households differed in respect of their rights over land, their control over labor, their production objectives, and the competing economic and domestic activities in which they were engaged. A range of methods was needed to investigate the importance of these factors. We have seen that formal methods of data collection alone were not sufficient, but that more holistic, anthropological approaches were also required.

Adoption; Economics

452
KM
Vogel, W.O. 1989.
Economic returns of alley farming. Pages 196–207 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. Proceedings of an International workshop held 10–14 Mar 1986. International Institute of Tropical Agriculture, (IITA), Ibadan, Nigeria. International Development Research Centre (IDRC), Ottawa, Canada.

To date, economic evaluations of alley farming have focused on how profitable it is for the individual farmer. However, the work of physical scientists indicates that the individual farmer can capture only some of the benefits; others accrue to society as a whole. The decision to invest in alley farming is an individual one. However, as farmers are aggregated to groups and groups to regions, the benefits and costs to these aggregates increase. The paper suggests mathematical programming as a method for the extant evaluation of alley farming at different levels of aggregation. Such models measure the benefits to society and information can be incorporated as it becomes available. Alley farming is compared with other technologies that maintain fertility and control erosion in the long term.

LAND AND TREE TENURE

Land Tenure

453
L
Fabiyi, Y.L., E.O. Idowu, and A.E. Oguntade. 1991.
Land tenure and management constraints to the adoption of alley farming by women in Oyo State of Nigeria. Nigerian Journal of Agricultural Extension 6: 40–46.

The influences of land tenure and management on the adoption of alley farming by women were investigated in some villages in southwestern Nigeria where alley farming had been introduced, but few women compared to men (less than 20%) were found to have adopted the new technique. The study shows that there are slight variations in the socioeconomic profiles of the potential women adopters in both the savanna and forest zones. The majority of the women respondents (80%) were married while 18% were widows. However, most of the women alley farmers were widows and a few were married. Lack of education and membership of group or cooperative societies at the village level by the women tends to influence negatively their access to extension agents which may further prevent their adoption of alley farming. The type of access to land most compatible with alley farming by women is that gained through husbands and inheritance, and tree ownership and management were not very common among women in this study area. Contrary to expectations, women alley farmers are not independent in their land and tree management decision-making, a situation that was found to greatly influence their adoption of alley farming and an indication of male dominance in agricultural decision-making within the study area. Extension work on alley farming should focus on both male and female members of households to encourage alley farming adoption by women.

Tree Tenure

454
L
Fortmann, L. 1985.
The tree tenure factor in agroforestry with particular reference to Africa. Agroforestry Systems 2: 229–251.

In Africa, a clear distinction exists between rights over trees and over land. Tree tenure consists of some rights over trees and their produce which may be held by different people at different times. These rights include the right to own or inherit

trees, the right to plant trees, and the right to use trees and tree products. The nature of the tree, use, and the person or group are factors determining who has what right. Landowners and tree growers tend to be relatively advantaged in terms of their rights to trees. Those with temporary claims to the land and, especially women, tend to be disadvantaged. The implications of tree tenure issues for the design of agroforestry projects are discussed.

Land Tenure

455
L
Francis, P.A. 1987.
Land tenure systems and agricultural innovation. The case of alley farming in Nigeria. Land Use Policy 4: 305–319.

The implications of land-tenure systems in southern Nigeria are discussed in terms of the acceptability and viability of the alley farming system. Differences in the use and control of land within and between the southwest and southeast Nigeria are noted. In the southwest, the rights of tenants over hired land do not automatically confer the right to plant trees. In the southeast, the existence of communal systems of land ownership and management on some classes of land undermines the ability to plant trees.

Land Tenure

456
L
Francis, P.A. 1989.
Land tenure systems and the adoption of alley farming. Pages 182–195 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. International Development Research Centre (IDRC), Ottawa, Canada.

Alley farming is an agroforestry technology that requires access to land and the right to plant, own, and use trees. This paper considers the implications of land-tenure systems in southwest and southeast Nigeria for the acceptability and viability of alley farming. Considerable variation in the rules governing the use and control of land exists within and between the two regions, and any tenure system may include many categories of land to which different patterns of use and tenure apply. Broadly speaking, tenants in parts of southwest Nigeria may be disadvantaged as their rights over rented land do not necessarily include the right to plant trees. In the southeast, communal systems of land ownership and management exist on some categories of land. This undermines both the ability to plant trees and the incentive to invest labor in the maintenance of soil fertility.

Adoption; Land Tenure; Tree Tenure

457
LM
Tonye, J., C. Meke-Me-Ze, and P.C. Titi-Nwel. 1993.
Implications of national land legislation and customary land and tree tenure on the adoption of alley farming. Agroforestry Systems 22: 153–160.

In the forest zone of Cameroon, the increasing population has resulted in the reduction of fallow periods and the diminution of per capita cropping land area. Large-scale adoption of alley farming which is a promising technology for this zone, depends on a host of factors, notably tree and land tenure. A study was therefore conducted in 1990 to determine the implications of national land legislation and customary land and tree tenure on the adoption of alley farming in the forest zone of Cameroon. Results indicate that despite the promulgation of national laws purposing to regulate land and tree use, ownership rights to land and trees are, in practice, determined by customary tenure rules. In forest-zone customs, land is inherited by the son after the father dies. Rights of ownership to such inherited land are rarely revoked. Women are allowed to crop any piece of their husband's land as long as they stay married but

they do not own land. Since women are primarily concerned with food crop production and the amount of land to be given to their sons in the future, their potential of adopting alley farming is still high.

ON-FARM RESEARCH AND EXTENSION

On-Farm Extension

458
M
Adekunle, O.A. 1993.
Analysis of indigenous practices of small-scale plantain farmers for appropriate alley farming technology in Oyo State, Nigeria. PhD thesis, University of Ibadan, Ibadan, Nigeria.

The study was conducted in Oyo State, Nigeria with a view to integrating alley farming technology in the indigenous practices of small-scale plantain farmers. The socioeconomic features of plantain farmers and the constraints to production are described. Ten plantain farmers were monitored for about 6 months to field-test certain empirical concepts. This was followed up using 270 respondents selected through a multi-stage sampling technique. Initial survey indicated that about 26.2% of plantains were intercropped with cassava, cocoyam, maize, or vegetables. Most respondents (91%) had no formal education. The recommended spacing and mulching of plantain was not favored by 98% of the respondents. The cutlass was used by 99.3% of farmers in plantain operations. In 99.3% households, the male farmers were responsible for decisions on planting plantain and plots (98.9%) to be used, while female household heads/wives decided on plantain processing (78.5%), sales (89.6%), and production costs (69.6%). Constraints to plantain production include declining soil fertility (98.5%), insufficient propagules (95.2%), and inadequate extension services (95.9%). The hedgerow species known to plantain farmers were *Senna siamea* (98.1%) and *Gliricidia sepium* (97.0%). Stepwise analysis indicated that 48% of the total variation in indigenous intercropping of plantain was explained by alley farming awareness. These findings have positive implications for the adoptability of alley farming technology in the study area.

On-Farm Research

459
M
Akonde, T.P., N. Lame, and E. Kummerer. 1989.
Adoption of alley cropping in the province of Atlantique, Benin. Pages 141–142 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. International Development Research Centre (IDRC), Ottawa, Canada.

Alley cropping has been tested and adopted by the Centre of Regional Action for Rural Development (CARDER-Atlantique) in the Benin Republic. Results of experiments carried out over 2 years have shown that a farmer using this technique can increase maize yield by 35–52% in the main season and by more than 50% in the minor season. The prospects are good for extending this technique to farmers in the Atlantique Province of Benin Republic.

On-Farm Research

460
M
Arap-Sang, F.K. 1989.
Alley cropping under semiarid conditions in Kenya. Pages 123–130 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. International Development Research Centre (IDRC), Ottawa, Canada.

The Dryland Agroforestry Research Project was designed to test several agroforestry interventions aimed at reversing the constraints that have recently appeared in the semiarid lands of Kenya as a result of population pressure. These constraints were discovered following the application of the International Council for Research in Agroforestry's diagnosis and design methodology to a typically semiarid area in eastern Kenya. One of the intervention technologies designed to counteract these constraints is alley cropping. This paper describes on-station and on-farm alley cropping experiments. The trials are still in their initial stages and it is too early to say whether alley cropping will be successful in the semiarid areas of Kenya.

On-Farm Research

461
M
Atta-Krah, A.N. and P.A. Francis. 1987.
The role of on-farm trials in the evaluation of composite technologies: the case of alley farming in southern Nigeria. Agricultural Systems 23: 133–152.

Based on the experience of the International Livestock Centre for Africa (ILCA's) *Humid Zone Programme, the role of on-farm research in the evaluation of alley farm*ing was discussed. Due to the composite nature of alley farming as a technology, two distinct types of trials are required for its on-farm development. The first is concerned with fine tuning the system and the assessment of its relevance and acceptability to farmers, while the second is concerned with the collection of technical and productivity data under farm conditions. Since the former type of trial is concerned with the evolution and definition of the system, it must be implemented at an early stage, as part of the development of the technology, and must precede the collection of technical data. Feedback from both types of trial is essential to ensure the relevance of on-station research. In order to ensure the successful implementation of this approach, the close involvement of extension agents is required.

On-Farm Research

462
M
Atta-Krah, A.N. and P.A. Francis. 1989.
The role of on-farm trials in the evaluation of alley farming. Pages 92–106 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. International Development Research Centre (IDRC), Ottawa, Canada.

The role of on-farm research in the evaluation of alley farming requires two distinct types of trials: those concerned with the refinement of the system and the assessment of its relevance and acceptability to farmers and those aimed at the collection of technical and productivity data under farm conditions. The first type of trial is concerned with the evolution and definition of the system; therefore, it must be implemented at an early stage, as part of the development of the technology, and must precede the collection of technical data. Feedback from both kinds of trials is essential to ensure the relevance of on-station research. The close involvement of extension is required for the successful implementation of this approach.

Development: On-Farm Research

463
M
Bannister, M.E. and P.K.R. Nair. 1990.
Alley cropping as a sustainable agricultural technology for the hillsides of Haiti: experience of an agroforestry outreach project. American Journal of Alternative Agriculture 5(2): 51–59.

Alley cropping, also known as hedgerow intercropping, involves planting fast-growing leguminous trees at dense within-row spacing with arable crops grown in the alley spaces between the hedgerows. This form of agroforestry technology, with the hedgerows planted on the contours across the slope, seems promising for small farmers on the hillslopes of Haiti. An agroforestry outreach project operating in Haiti since 1981 has helped thousands of farmers plant hedgerows on their farms. The farmers are increasingly accepting the technology: the length of hedgerows planted by the farmers in the project area increased from 11 linear km in 1987 to 140 linear km in 1988. An evaluation from 50 alley farms indicated that this practice results in soil conservation and microsite enrichment between hedgerows; the hedgerows also supply fodder and fuelwood. However, technical aspects of hedgerow management, such as planting patterns, pruning regime, and choice of species need to be refined. The impact of hedgerow intercropping on the sustainability of Haitan farming systems can be assessed if socioeconomic and ecological characteristics are monitored.

Extension

464
M
Cashman, K. 1987.
Seeing the forest for trees: A participatory approach to sustainable food production. Paper presented at farming systems research symposium on "How Systems Work", 18 Sep–1 Oct 1987. University of Arkansas, Fayetteville, Arkansas, USA. 6 pp.

The discipline of agroforestry includes a broad range of techniques, including many capable of easily building on existing local capacities to meet the challenges confronting African farmers today. The agroforestry technique called alley farming introduced woody and herbaceous perennials on the same land management system with domesticated crops and animals. The nutrients provided by periodic pruning and mulching of these perennials on the farm offers African farmers an attractive alternative to shifting cultivation or slash-and-burn agriculture. Many social, scientific, and institutional constraints must be overcome, however, for alley farming to achieve its potential. Many African farmers, for instance, share the conventional attitude that trees have no place on farm fields. Also, small farmers in particular may not perceive or may assign a low priority to the farm system's soil conservation needs and future production requirements. A grass roots' approach to implementing alley farming is described in this paper, emphasizing the participation and cooperation of Nigerian farm households in farming systems research. Strategies were developed to present the critical concepts of alley farming in a culturally acceptable, sustainable, and self-perpetuating manner. These strategies included the use of a local legume in addition to *Leucaena*, downplaying the use of the word "tree", and soliciting community involvement via village theater. Findings are based on 3 years of fieldwork with the International Livestock Centre for Africa and the International Institute of Tropical Agriculture.

Organic Research

465
M
Cashman, K. 1988.
The benefits of alley farming for the Nigerian farmer and her household. Culture and Agriculture 37: 4–8.

Despite the significantly large numbers of women presently engaged in farming in southwestern Nigeria as well as Africa as a whole, recent reports indicate their low participation. Potentially large numbers of rural women (including Yoruba) will be attracted to a system of farming which offers more secure land tenureship and economically profitable alternatives to shifting cultivation. The attractions of alley farming have been summarized and detailed in other reports. The alley farming system should be more actively oriented towards women for several additional reasons. These include the fact that rural women forced out of urban trading markets are seeking alternative forms of generating income. Because women use indigenous mechanisms to secure access to resources, alley farming can be a viable alternative. Women have diminishing access to farmland thereby forcing them to increasingly crop marginal land. Poor soil limits the variety of crops that can be grown. Alley farming can reduce these problems by enhancing soil regeneration, continuous cropping, and greater crop diversification. Heavy economic obligations create a strong incentive among women to protect and secure their own property and income. Often extra capital is invested in livestock, as evidenced in Nigeria, where women often own over 50% of the small ruminants. Livestock purchased with extra income from alley farms will experience increased worth through added vigor and weight gain from the nutritious fodder provided from the alley farm. Finally, women in many parts of Nigeria spend an average of 1 to 2 hours a day collecting firewood. Not only is this a constraint on their time, but increasing population adds to deforestation and greater distances travelled in search of fuel. On a yearly basis, prunings from a one hectare alley farm can produce as much as 88 tonnes of plant staking material and firewood. This paper discusses constraints barring the transfer of alley farming to limited-resource farm women in Nigeria. The paper illustrates how past experiences (of on-farm-research teams, extension personnel, as well as farmers) reinforced by numerous economic, sociocultural, and political variables, are a persistent factor in encouraging or inhibiting the diffusion of alley farming systems.

Adoption

466
M
Cashman, K. 1990.
A grounded theory describing factors of the adoption process of the alley farming technology by Yoruba women in Nigeria. PhD thesis, Iowa State University, Ames, Iowa, USA.

This study aimed to discover a theory from data on rural Yoruba women in southwestern Nigeria. The theory deals with farmers exposed to an agroforestry technology called alley farming. A theory of agricultural change was developed to provide a framework for alley farming research and extension. Grounded theory is an inductive system for generating theory from empirical data. The constant comparative method which alternates data collection and data analysis, was conducted during fieldwork in 1984–86. Before propositions and hypotheses were defined, data were collected, coded, and analyzed to develop concepts or premises. The axiomatic theory of farming women and agricultural innovation consists of four "basic premises, each independent of the others, from which the propositions of the theory were logically derived". Propositions based on premises established during 1984–86, were field-tested in 1988. Data were collected over 4 years, 1984–86 and 1988, from participant observation, open-ended interviews, and document analysis. From the accompanying coding and data analysis during 1984–86, a conceptual framework emerged which corresponded with the Concerns-Based Adoption Model (CBAM) developed by Hall, Wallace, and Dorsett. This model was modified to illuminate the developmental proc-

esses that farmers experience as they implemented the alley farming technology. Questions arising from previous research were framed within the CBAM for a final round of data collection in 1988 to solicit farmers' opinions and reactions to alley farming. Several major factors that inhibit or facilitate the diffusion of alley farming were identified, including: (a) clarification of Yoruba women's role in farming; (b) crucial, but less visible, reasons for specifically targeting women in alley farming outreach; c) sociocultural conflicts and congruence factors; (d) the undermining of local realities by ignoring indigenous, land-tenure norms that give women usufruct rights to farmland; (e) power exerted from outside the cultural system; and (f) compromises negotiated through change facilitators. Examples, grounded empirically, demonstrate that the theoretical framework provided both a diagnosis of farmers' needs and a prescription for further action.

467
M
Cashman, K. 1990.
Promoting the fertilizer bush in agroforestry on-farm research. Agronomy Abstracts (1990): 55.

Alley farming is an ecologically stabilizing process designed for tropical farmers to increase and sustain crop production. Rows of nutrient-rich trees form 5-meter alleys. If farmers regularly use prunings from these trees as mulch for crops grown in the alleys, the trees function as "fertilizer bushes". Farmers can defer fallow on fragile soils, extend and diversify cropping, and increase yields. As an innovation bundle, alley cropping supplies useful by-products such as animal fodder, crop staking material, firewood, and mulch for erosion control and moisture retention. Yet on-farm research (OFR) demonstrates that if the technical aspects of alley cropping outpace essential human components, the practice becomes dysfunctional, and the benefits farmers derive are negligible. This paper examines what sociocultural/economic and organizational components make alley cropping an appealing and sustainable practice by farmers. A framework was developed and tested in collaboration with 286 rural Nigerians to describe and measure the process where farmers become aware of alley cropping, adopt and modify or reject it, integrate and use the practice in their farming system, and disseminate it to others or discontinue the practice.

468
M
Caveness, F.A. and W.O. Vogel. 1987.
An investigative report of on-farm alley cropping trials in east and central Nigeria: considerations for interregional technology transfer. International Institute of Tropical agriculture (IITA), Ibadan, Nigeria. 17 pp.

Population increases in Africa are resulting in a destabilizing of the slash-and-burn agricultural system which operates effectively when land availability is sufficient to allow long fallow periods for soil restoration. Decreased fallow periods increase the rate of deforestation and decrease land productivity. The need for viable alternatives to traditional food-crop and animal-production systems in Africa is being answered by the International Institute of Tropical Agriculture (IITA) and the International Livestock Centre for Africa (ILCA) with on-farm trials of the alley cropping and alley farming systems. Eight years of research station and on-farm research in the Oyo State area of Nigeria have resulted in systems which have been adapted and fine-tuned to the needs and environment of the farmers in the area. Spontaneous adoption is now occurring. Results of on-farm trials in east and central Nigeria have been complicated by experimenting farmers and researchers. System refinement to fit local conditions and an improved two-way flow of information between farmers and researchers is needed to increase acceptability of the system and its effective use.

469
M
Cobbina, J. and A.N. Atta-Krah. 1991.
Methodological and analytical issues in on-farm alley-training research. Pages 76–82 *in* On-farm research theory and practice, edited by H.J.W. Mutsaers and P. Walker. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

The paper introduces alley farming as an example of a composite technology and discusses the objectives and methodology for the conduct of on-farm research on the system. It also looks at the usefulness of on-farm trials in problem identification for on-station research designed to fine-tune the technology. Finally, it presents conclusions on methodologies for on-farm alley farming research.

470
M
***Dvorak*, K.A. 1991.**
Methods of on-farm, diagnostic research on adoption potential of alley cropping. Agroforestry Systems 15: 167–181.

This paper described an on-farm diagnostic research approach on alley cropping. The economic assessment was undertaken to evaluate the adoption potential of the technology. Three activities were included. Firstly, cost-route surveys and field measurements were carried out for a small sample of farmers with recently established alleys. Despite the resource intensiveness of the research, the cost-route studies and field measurements were considered necessary to develop a framework for analyzing on-farm alley cropping due to lack of rapid methods of assessing intrinsically dynamic technologies. Administration of a focused, formal single visit survey to a large sample of farmers who have participated in alley farming trials at several locations was the second activity. Intensive data collection with a small sample continued in order to quantify factors identified as key in the first activity. It is hoped that the combination of methods will contribute to the development of more rapid and readily accessible methods of evaluating agroforestry technologies on-farm.

471
M
Francis, P.A. and A.N. Atta-Krah. 1989.
Sociological and ecological factors in technology adoption: fodder trees in southeast Nigeria. Experimental Agriculture 25: 1–10.

The influences of the complex environmental, management, and institutional factors on farmers' decisions concerning the planting and management of fodder trees to feed sheep and goats are reported in this paper. Farmer-managed plots at two locations in southeast Nigeria, where *Leucaena leucocephala* and *Gliricidia sepium* are planted either as alley farms or feed gardens, were used for the study. Despite good establishment of trees in these farms, the quality of establishment was uneven and the rate of utilization was poor. Poor soil fertility, the incompatibility of established cropping patterns with rotation practices with the planting of trees, the division of labor and organization of decision-making within the household, and land and tree tenure rules were identified as major constraints in these trials. Farmer-managed trials will better reveal the importance of sociological and institutional factors which influence farmers' decision making in traditional farming systems.

Adoption

472
M
Fujisaka, S., E. Jayson, and A. Dapusala. 1994.
Trees, grasses, and weeds: species choices in farmer developed contour hedgerows. Agroforestry Systems 25(1): 13–22.

Adoptions of improved innovations intended to conserve soils and improve soil nutrient cycling have been generally low due to associated technical problems and inappropriateness to farmers' circumstances. The adoption of contour hedgerows by farmers in Claveria, the Philippines was evaluated. Farmers tested different establishment methods and many hedgerow species. They initially planted a combination of *Gliricidia sepium* (a legume tree) and *Pennisetum purpureum* (grass). Later adoptors chose fodder grasses (especially *Setaria* spp.) or naturally occurring vegetation in their hedgerows—either solely or in combination with other species, including weeds such as *Rottboellia cochinchinensis* identified as crop problems. Upland rice and maize farmers who adopted contour hedgerows from 1987 through 1991 were interviewed in 1992. Although hedgerow-crop competition, grazing by neighbors' cattle, and added labor were problems, farmers still viewed hedgerows as a way to reduce soil erosion and provide fodder. Farmers planting mulberries were disappointed after a silkworm project folded. Farmers now face the problem of soil nutrient depletion, leading to fallowing of fields with hedgerows and shifting to other parcels. A model describing the minimum criteria for adoption of contour hedgerows is hypothesized.

Modeling

473
M
Nuberg, I.K. and D.G. Evans. 1993.
Alley cropping and analog forests for soil conservation in the dry uplands of Sri Lanka. Agroforestry Systems 24: 247–269.

Soil erosion control using contour hedgerows of woody legumes has been promoted amongst smallholders in the Upper Mahaweli catchment of Sri Lanka since 1988. The success of this program depends greatly on the properties of the different production systems occupying the alleys created by these hedgerows such as: profitability, time taken for profit to be realized, labor requirements, seasonal distribution of labor, environmental and economic stability, biophysical sustainability, the contribution of the system to the domestic needs of the farm family, adoptability of the system, and successful management of the hedgerows. These properties were used to evaluate seven desktop farm models with different combinations of: seasonal crops, coffee-pepper intercrop, fodder-dairy, woodlot, and analog forest established in the alleys. The analog forest is a perennial polyculture which, like the traditional forest garden, is structurally and functionally analogous to the natural forest. It was found that a model with 40% seasonal crops, 20% perennial crops (coffee-pepper), and 40% analog forest made the best compromise between the properties under consideration. The socioeconomic conditions that determine the suitability of this model in the Sri Lankan context are not universal and the application of the analog forest concept into other tropical uplands is discussed.

Adoption

474
M
Osungbade, A.B. 1990.
Diffusion of agroforestry ideas to farms adjoining alley farming projects. MSc thesis, University of Ibadan, Nigeria. 116 pp.

To obtain information on the extent of diffusion of the new technology of alley farming on the study area, this study was conducted with the aid of structured questionnaires, administered on three stations—Ayepe, Alabata, and Wasimi. Wasimi served as a control for comparison with the other two stations which are sites of alley farm-

ing research. Four villages of ten farmers (respondents) were randomly selected and interviewed. This made a total of 120 randomly selected respondents altogether. The study examined essentially, the tendencies for (a) diffusion/adoption of agroforestry ideas, (b) the persistence of shifting cultivation, and (c) reasons for non-adoption of agroforestry practices. The background of the farmers gave positive indications in the areas of land ownership; infertile soil conditions against yield; fuelwood shortages; insecure sources of inorganic fertilizers; types of crops; and techniques of introduction. However, the result obtained highlighted a gradual drift to agroforestry over the years. With the noticeable drift over the years, most farmers can be classified as potential adopters of agroforestry. This can be promoted by (a) bringing more areas within the scope of IITA experiments, (b) reviewing government policy on land tenure, and (c) government participation to encourage the adoption of the system.

475
M
Palada, M.C. 1985.
On-farm research methods in alley cropping. A lecture presented to participants of alley cropping workshop/training course, 2 Apr–3 May 1985. International Institute of Tropical Agriculture, Ibadan, Nigeria. 12 pp.

On-farm research is an approach in determining whether a technology can be transferred and adopted by farmers. The scope of on-farm research is broad and includes a description of the existing system and verification studies with the objective of identifying and proving technical interventions that improve the productivity of local farming systems and to help guide priorities in component research. This paper describes, in general, methods of on-farm research and how it can be used as a guideline for conducting on-farm experiments with alley cropping.

476
M
Palada, M.C. 1989.
On-farm research methods for alley cropping. Pages 84–91 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. Proceedings of International workshop held 10–14 Mar 1986, Ibadan, Nigeria. International Development Research Centre (IDRC), Ottawa, Canada.

On-farm research methods which follow a sequence of events until the technology is ready for adoption by farmers, can be applied in alley cropping research and development. Well-focused, on-farm research consists of sharply defined objectives, criteria for site selection, identification of target groups, accurate descriptions of the farming system, constraints and opportunities, appropriate design of on-farm trials, and a well-established, on-farm testing program. As a composite technology, alley cropping needs to be tested under real farm conditions. On-farm trials can be researcher-managed or farmer-managed, depending on the complexity of the technology and to what extent the technology has been tested under farmers' field conditions. Researcher-managed trials are usually conducted in the early stages of alley farming research and provide information mainly of a biological nature. Farmer-managed trials usually give indications of both the biological and socioeconomic aspects of alley cropping applications.

Networking

477
M
Pendleton, J.W. 1989.
Collaboration in alley farming research. Pages 222–227 *in* Alley farming in the humid and subhumid tropics, edited by B.T. Kang and L. Reynolds. Proceedings of an international workshop held 10–14 Mar 1986, Ibadan, Nigeria. International Development Research Centre (IDRC), Ottawa, Canada.

Alley farming affords the opportunity for agronomists, animal scientists, socioeconomists, and foresters to collaborate to improve the livelihood of farmers of Africa. The history of alley farming and alley cropping is discussed. Concepts of networking for Africa are presented.

On-Farm Evaluation

478
M
Scherr, S.J., J.H. Rogers, and P.A. Oduol. 1990.
Surveying farmers' agroforestry plots: experiences in evaluating alley cropping and tree-border technologies in Western Kenya. Agroforestry Systems 11: 141–173.

On-farm evaluation of agroforestry systems has been little used largely due to the methodological difficulties of surveying highly variable on-farm plots and difficulties in identifying key variables for measurement. This paper describes a set of methods and tools used in evaluating plots of alley cropping and tree borders around crop fields established by farmers working with the Cooperative Assistance Relief Everywhere (CARE) Agroforestry Extension Project in western Kenya. Details of survey design, sampling, and implementation are discussed and suggestions made for carrying out agroforestry surveys in similar research and/or development projects. The questionnaire is condensed and appended.

On-Farm Research

479
M
Scherr, S. and P.A. Oduol. 1989.
Alley cropping and tree borders in crop fields in Siaya District, Kenya. International Centre for Research in Agroforestry (ICRAF), Kenya. 24 pp.

One hundred and twenty-six CARE-assisted farmers in Siaya District were interviewed to find out more about their alley cropping plots and field borders in crop land. The survey was carried out to estimate how many farmers were trying the agroforestry innovations, to determine the management practices employed, and to identify areas where improved extension recommendation may be needed. The survey would also help the International Centre for Research in Agroforestry (ICRAF) develop better methods for evaluating farmers' agroforestry plots. The results illustrate recent experiences in Siaya District with alley cropping and tree borders. In some cases, suggestions are made to improve extension recommendations. Continued experience by farmers, extension agents, and research will surely lead to new insights and evaluations.

480
M
Whittome, M.P.B. 1994.
The adoption of alley farming in Nigeria and Benin: the on-farm experience of the International Institute of Tropical Agriculture (IITA) and the International Livestock Centre for Africa (ILCA). PhD thesis, University of Cambridge, UK. 462 pp.

Alley farming is an agroforestry technology in which food crops are grown in "alleys" between rows of trees. The trees are regularly pruned to prevent them from shading the companion crops and the prunings are used primarily as a mulch to restore soil fertility, but also to supply firewood, fodder, yam stakes, and construction wood. During the 1980s, alley farming caused considerable interest in the scientific community as a low-cost innovation capable of stabilizing the crop yields of resource-poor farmers in tropical countries. With huge financial backing, many research centers carried out extensive on-station trials in an attempt to evaluate the agronomic potential of the technology and determine appropriate management practices. The International Institute of Tropical Agriculture (IITA) and the Humid Zone Programme of the International Livestock Centre for Africa (ILCA) both located in Ibadan, Nigeria, were instrumental in raising awareness of the potential of the technology. However, donor organizations are now concerned that the initial promising on-station results have not been matched by the rapid adoption of the technology by farmers. The thesis reviews IITA's and ILCA's on-farm research with alley farming and attempts to understand the farmers' responses to the technology and provide guidelines for future extension projects. A comprehensive formal questionnaire with all the known alley farmers was combined with more informal rapid and participatory methods of data collection and the data was crosschecked with IITA's and ILCA's available records. The research has revealed that the majority of the farmers only cropped their alley fields for the first few years, after which the land was left fallow. IITA and ILCA have failed to introduce alley farming into areas to which the technology is most suited and the farmer participation was achieved through the provision of incentives such as free fertilizer, improved crop materials, and livestock vaccination. Although IITA and ILCA are responsible for research and not extension, valuable lessons for extension organizations can be obtained by examining their work and analyzing the experiences of farmers who have so far had experience with alley farming.

481
M
Yamoah, C.F. 1985.
The use of shrub legume alleys for crop production. PhD thesis, University of Ibadan, Nigeria. 233 pp.

Field surveys, on-farm monitoring of the use of *Gliricidia* and agronomic experiments at the Ilorin Agricultural Development Project (IADP) area in the Guinea savanna zone of Nigeria, and on-station agronomic experiments at IITA in the rain forest/savanna zone were combined for the methodology of this study. At the Ilorin site, interplanting of *Gliricidia* with maize, rice, and yam during the establishment of the shrub did not affect the food crop performance. About 75% of farmers using *Gliricidia* for yam staking at Ilorin did not recognize the value of the shrub as a soil improver. About 30% of the farmers preferred *Cassia* to *Gliricidia* for yam staking. The fast shoot growth of the shrub resulting in shading of food crops and extensive root growth were major obstacles to the use of *Gliricidia* for alley cropping. Land tenure and insects, particularly aphids and termites, were mentioned as problems associated with the use of *Gliricidia*. In the field at IITA, *Cassia* admitted less light (4 PAR) down its canopy compared to *Gliricidia* (17 PAR), and *Flemingia* (43 PAR); consequently weed control prior to cutback was better under *Cassia*. Gravimetric moisture content was highest under *Cassia* during the growing season. Soil properties were upgraded in the alley cropped sites. Soils under *Cassia* had the highest content of N, P, K, and organic carbon with

values of 0.344, 4.6 ppm; 0.55 meq/100q, and 2.32, respectively, after the end of the second crop. Maize-grain yield at the alley cropped sites was better than the control sites. Among the shrubs used for the study, *Cassia* exhibited the highest potential for use in alley cropping in terms of soil fertility maintenance and the provision of wood. This was followed by *Gliricidia* and then *Flemingia*.

482
MBF
Rosseau, P.M., A.G. Hunter, and G.L. Somers. 1994.
Methodology for on-farm evaluation of crop performance and soil conservation in agroforestry. Agronomy Abstracts (1994) : 74.

The study involves 27 farmers practising mixed cropping and hedgerow farming in Haiti. Hedgerows add variability to heterogenous cropping conditions. Crop-management decisions (plant density) and selected crop attributes (plant height), related to soil fertility, were used as covariance and provided acceptable models. Conventional and mixed models were compared. This technique allows accurate measures of on-farm performances and is well suited when high spatial variability is present. Extension-oriented agricultural projects can implement this approach, provided they allow for intensive data collection and analysis. Researchers and extension personnel now have tools to work harmoniously towards efficient technology transfer. Also, a very simple and innovative technique using simple geometry and trigonometry was designed to measure the amount of soil saved by the hedgerow.

483
MF
K.F. Wiersum 1994.
Farmer adoption of contour hedgerow intercropping: a case study from east Indonesia. Agroforestry Systems 27: 163–182.

The initial impact of the contour hedgerow intercropping was assessed on the Indonesian islands of Lombok and Sumbawa. The results from four villages indicated that the adoption process is heterogeneous. There was more diverse and dynamic land use in the area than expected. The farmers' ability to adapt the practice of hedgerow intercropping to their specific farming conditions was an important motive for its adoption. In some cases, the introduction of this practice competed with the extension of other promising land-use practices. However, several farmers adopted the technique not because of its productive benefits, but as a means to gain access to land or credit, or to demonstrate their allegiance to social networks. The results indicate that there was disparity between what the goals of the project by introducing the technique were and the farmers' motives for adopting it.

484
MH
Lefroy, T. 1994.
A table of two alleys' parallel evolution in agroforestry. Agroforestry Today 6 (3): 5–7.

The paper presents experience with two apparently emerging farmer-based alley farming innovations in the semiarid parts of southern Australia and South Africa. In South Africa, about 6000–7000 ha of land has been planted (since 1970s) to annual pasture grown in alleys (20–30 m wide) formed between hedgerows of a fodder shrub (*Atriplex mumularia*) or old man saltbrush, with an additional 1000 ha converted to alley farming each year. Similarly, in Western Australia, an estimated 5000 ha have been planted to alley farming with a fodder shrub (*Chamdecytisus palmensis*) or tagasaste. Although several hundred farmers have adopted these forms of alley farming with ac-

knowledged benefits, there is yet no systemmatic research information on the practice. There is need for research addressing issues of ecological processes and economic impacts.

485
MN
Bannister, M.E. and S.J. Josiah. 1993.
Agroforestry training and extension: the experience from Haiti. Agroforestry Systems 23: 239–251.

The Pan American Development Foundation in Haiti implemented an agroforestry project from 1981 to 1991. This project is ranked as an outstanding success in Haiti and in the tropics as a whole. Over the 10 years of its implementation, the project, locally known as *Pwoje Pyebwa* (Tree Project), evolved from a tree production and planting project to a much broader soil-conservation based program involving trees. The training and extension system that developed during that period is summarized in this paper. The socioeconomic background studies that were done before the project began and the flexible, consultative mode of field-team implementation, incorporating elements of the "learning process" approach, were important to the success of the project. During the implementation of the project, however, concern for farmer input and participation should have been better incorporated into the field operations of the regional teams.

TRAINING

486
N
Gutteridge, R.C. and H. M. Shelton. 1993.
Forage tree legumes in tropical agriculture. CAB International, Wallingford, UK. 389 pp.

A compilation of a series of lectures on production and use of tree legumes together with contributions from leading scientists in other regions of the world. The book therefore provides a comprehensive coverage of the latest information on the major tropical forage tree legume species and their evaluation and utilization in sustainable agricultural production systems.

487
N
Triparthi, B.R. and P.T. Psychas. 1992.
The AFNETA alley farming training manual volume 1. Core course in alley farming. Alley Farming Network for Tropical Africa (AFNETA), Ibadan, Nigeria.

This volume covers the basic aspects of alley farming in six chapters; introduction to alley farming; multipurpose tree species and evaluation; establishment and management of alley farming systems; integration of livestock production in alley farming; on-farm research, and socioeconomic assessment of alley farming.

Training

488
N
Triparthi, B.R. and P.T. Psychas. 1992.
The AFNETA alley farming training manua, volume 2. Source book for alley farming research. Alley Farming Network for Tropical Africa (AFNETA), IITA, Ibadan, Nigeria.

This volume contains technical chapters serving as reference materials for volume 1 of the manual in the following areas: soil science; planning agroforestry systems; research tools for socioeconomic assessment; designing alley farming experiments.

Modeling

489
N
Acock, B. and A.S.R. Juo. 1988.
Modeling the alley cropping system. Agronomy Abstracts (1988) : 51.

The alley cropping system is greatly extending the productive life to land after clearing in some parts of the world where slash-and-burn agriculture is traditional. The reason for the success of the system is not fully understood, partly because it has never been examined as a complete system. Specialists from various disciplines have each examined their part of the system in isolation. Modeling offers a way of integrating their knowledge, finding the gaps in that knowledge, directing further research, revealing why the system is successful, and predicting the circumstances under which it might fail. The model used must describe the soil as a 2-dimensional matrix to deal with the relative positions of the roots of hedgerow and crop plants and must describe competition between hedgerow and crop for light, water, and nutrients. The decay of organic matter laid on the soil surface and the results this has on arthropod activity and hence soil macroporosity must be simulated. The model must also deal realistically with deep rapid drainage through macropores.

Simulation; Intercropping; Hedgerow Spacing

490
ODC
Scholes, R.J., C.A. Palm, A. Salazar, and L.T. Szott. 1988.
A procedure to optimize the spacing of hedgerow intercropping systems. Agronomy Abstracts (1988): 62.

A procedure for optimizing the design of hedgerow intercropping systems is described and illustrated with examples for upland rice grown on a Typic Paleudult in the Peruvian Amazon. The procedure involves fitting yield response curves to data from hedgerow-crop interface trials at several levels of applied hedgerow mulch. This is followed by numerical simulation of yields from alleys of increasing width. With *Inga edulis* as the hedgerow, the optimum alley width for the second rice crop after clearing was 30 m (60 rows of rice), giving a yield maximum of only 0.1% above traditionally planted rice. For the third crop the optimum was 8 m, with a yield increase of 18%. There was no optimum when the hedgerow was *Erythina* sp., since the yield suppression due to competition exceeded the yield enhancement due to mulch. A comparison is presented for upland rice grown with the same hedgerow species on a Typic Tropudalf. The procedure is recommended as an efficient way of designing hedgerow intercropping systems.

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