867 91 - 4/113

Cropping systems
Asia, Indonesia, agricultural sustainability, labour requirements, mulch rotation system, deforestation, GTZ

LORENZ, C. and A. ERRINGTON

Achieving sustainability in cropping systems: the labour requirements of a mulch rotation system in Kalimantan, Indonesia.

Trop. Agric. (Trinidad), 68, 3, 1991, pp. 249-253

This paper shows how labour profile techniques can be used to evaluate the aspect of the mulch rotation system.
In order to overcome the considerable problems of replacing rainforest with sustainable agricultural systems, the IITA has developed a "Living Mulch" system. The results have shown that in contrast to a conventional till system, sustainable yields of food crops can be achieved under a live mulch which tends to take over most of the functions of the natural vegetation. The soil is covered, thus preventing heavy erosion, and it is kept cool and moist. Leached nutrients are brought up into the upper soil layers and biological activities increase.
A somewhat different approach, best described as a "Mulch Rotation" system has been proposed.
In addition to plant nutrients, the sustainability of a farming system depends on the availability of a whole range of inputs. One such input is labour.
Both the Living Rotation Systems use no-till methods; and because the mulch, whether living or dead, tends to suppress weed growth, two of the most labour-intensive operations, soil tillage and weeding, are markedly reduced.
The trials confirmed the greater sustainability of the system through reduced requirements for inorganic fertilizer.
The results show that the introduction of the Mulch Rotation System can reduce the labour peaks dramatically. All the data for this system show a profile with less severe peaks and some extended troughs giving time for social activities and leisure. However, it should be noted that the Mulch Rotation System does include a one-year fallow. This implies the need for some additional land though the actual amount required depends on the yield improvement of food crops grown after the legume cover crop.
Concluding the authors say that the maintainance of soil fertility forms the primary objective of any farming system which is designed to be sustainable. This paper has shown that other resources such as labour must also be taken into account. In the Kalimantan settlement schemes, where most labour is supplied by the family, the appropriate farming system must be so designed that the available labour supply matches the system's labour requirement, not only during different times of the year but also through the different stages of the settlement scheme's development and of the farm family life-cycle.

868 91 - 4/114

Cropping systems
Africa, Burkina Faso, experiments, sorghum, soil fertility, water retention, tied ridges, fertilizer technology

NAGY, J.G.

Farmer-researcher collaboration in developing cropping practices that involve the complementary use of mechanical tied ridge and fertilizer technology for sorghum in Burkina Faso.

Expl. Agric., 26, 1990, pp. 161-169

Agronomic and socio-economic research was conducted on crops of sorghum in the village of Nedogo on the Central Plateau, Burkina Faso.
Farmer managed fertilizer application and tied ridging trials were therefore conducted to obtain an evaluation of the viability of the technologies under actual farming conditions, their profitability and financial risk, and their suitability with respect to labour availability and farmer acceptance.
Poor soil fertility, high rainfall losses due to surface runoff, highly variable inter- and intra-year rainfall, and labour shortages in the critical planting and weeding periods are major constraints to increased cereal production in the subsistence-oriented farming systems in Burkina Faso.
The ridges are small depressions between crop rows constructed either by hand or by a combination of animal traction and hand tillage.
The depressions catch and hold water after rain and increase soil water infiltration and retention.
Trials in Burkina Faso have indicated that both tied ridging and the use of fertilizer can result in significant increases in the grain yield of cereal crops but that the greatest effect on yields is obtained when both are used together.
The results demonstrate that the on-farm, farmer-managed trial results agreed with those from researcher-managed trials and indicated that the combination of tied ridging and fertilizer was technically viable in the field. The farmer-managed trials also indicated that the combination of both treatments was profitable, with a level of financial risk acceptable to most farmers. When only ridges or an increased level of fertilizer was used, yields were constrained by the absence of the other treatment and when fertilizer was used alone, the financial risk was very high.
Farmers accepted that both treatments were useful in principle, but they found that they did not fit into the existing labour profile of the farming system, suggesting the need for a labour-saving device such as the mechanical ridge tier (MTR).
The MTR is technically viable in the field and profitable. It is very labour-saving, and could allow a substantial increase in the area under tied ridge construction per household.

869 91 - 4/115

Cropping systems
USA, study, harvest management, legume cover crops, crimson clover, no-tillage production, maize, soil conservation, nitrogen fixation, grain yield, silage yield, forage production

HOLDERBAUM, J.F.

Harvest management of a crimson clover crop for no-tillage corn production.

Agron. J., 82, 1990, pp. 918-923

The goals of the study were to examine the potential of a crimson clover as a forage and as a N source for no-tillage corn.
Field studies were conducted on a Coastal Plain Matapeake silt loam soil (fine-silty, mixed, mesic Typic Hapludult) from 1983 through 1986 to determine the effects of various harvest management schedules on total N contribution of legume cover crops, subsequent corn grain and silage yields, and total forage (combined cover crop and corn herbage) production.
In addition to their soil conservation attributes, legume covers can supply significant amounts of biologically fixed atmospheric N to the succeeding corn crop.
The quantity of legume N contributed to the subsequent crop, however, can be dramatically affected by the harvest management of the legume cover crop.
A crimson clover (*Trifolium incarnatum* L.) cover crop was subjected to no harvest; spring silage harvest with clippings removed (spring silage);and simulated pasture harvests with clippings from multiple harvests removed (pasture removed) or returned (pasture returned). A no-cover control treatment was also included. No-tillage corn was grown in the cover crop residues and two fertilizer N (FN) rates (0 and 90 kg ha^{-1}) were applied in a split-block design to each harvest management treatment. Averaged over 3 yr, multiple harvests of the cover crop vs. a spring silage harvest resulted in lower cover crop herbage yields (3.0 vs. 4.7 Mg ha^{-1}) and total N content (114 vs.146 kg N ha^{-1}) for the multiple harvests. Corn grain and silage yields and corn N uptake were consistently higher following crimson clover than for no cover, regardless of harvest management, and were generally higher when the cover was left in place than following removal of the cover. There were FN responses regardless of harvest management treatment. The reduction in corn silage yield when the cover crop was harvested and removed was less than the cover crop herbage dry matter yield, resulting in greater total forage production when the cover crop was harvested as forage. Results suggest that harvest management options of a crimson clover cover crop offer flexibility in either optimizing subsequent corn grain yields or total forage production for no-tillage cropping systems and provide control over how cover crop N is utilized in the overall cropping system.

870 91 - 4/116

Cropping systems
Asia, Taiwan, field trials, paddy rice, vegetable, crop rotation, crop duration, agricultural sustainability

AVRDC

Rotation of vegetables with paddy rice.

In: AVRDC 1990 Progress Report, Shanhua, Tainan; AVRDC, P.O.B. 205, Taipei 100, Taiwan; 1991, pp. 205-208

A long-term field trial on rotation of vegetables with cereal crops was conducted to incorporate AVRDC principal crops into rice-based cropping systems and increase the productivity per unit of land, and to develop principles and methodology for such rotations.
The effects of different rotations on crop yield, soil characteristics, and pests were investigated.
The field trial started during the autumn planting in 1987 on the same plots. A randomized complete block design with two replications was applied. Yield data and soil samples after each harvest were collected and analyzed.
In tropical Asia, the prospect for new agricultural land is limited and vegetable availability is low. Considering the low ratio of irrigated land planted to vegetables and the successful vegetable production in Taiwan where the tropical and subtropical conditions are both conducive to vegetable production, there is a great potential in tropical Asia to increase vegetable production and hence, the farmers' income, thus incorporating vegetable production into existing staple food-based cropping systems.
Annual food production from a given land area can be increased by improving the yield of a crop and increasing the cropping intensity. In most tropical regions with long growing seasons, small land holdings, and high labor-land ratios, multiple cropping systems could be one of the most effective means of increasing farm productivity, especially for those areas under irrigation.
Vegetables are versatile and can be easily incorporated into different cropping systems and produce yields even at short intervals between staple crops. They can also be potential contributors to sustainable agriculture due to the great variation in vegetable genetic resources. Vegetable production also provides opportunity for high returns while improving soil properties. These make vegetables an important and as yet under-exploited resource for farm production systems in the tropics.
An accurate estimate of crop growth duration in a given environment was found important in designing a cropping pattern to fully utilize the land. In this project, the total crop growth duration was less than 365 days a year. However, four patterns had an average beyond that limit between croppings caused by delays in land preparation due to heavy rain and social activities. Total crop duration including these periods should be calculated in a cropping systems study.

Results also showed that there was great variation in yield due to changes in environmental conditions. To predict successful yield of a certain crop in a given environment, data on long term weather should be collected. There was no clear crop-crop interaction observed in three-year trial. Vegetables such as tomato and Chinese cabbage seemed more sensitive to the environment than cereal crops. This implied that crop management techniques should be developed to mitigate these abiotic constraints in addition to the development of tolerant varieties.
Total amount of soil nitrogen in soil indicated that those cropping patterns which included soybean or mungbean in the summer planting apparently increased soil fertility. Thus, leguminous crops should be incorporated into multiple cropping systems in the tropics to sustain soil productivity.

871 91 - 4/117

Cropping systems
Asia, China, crop production, farm productivity, government policies, land-use, rural economic reform, courtyard agriculture, double crop rice, farm crop hospitals, water conservation, farm machinery, constraints

TAO, S.

Crop production on Chinese farms.

Outlook on Agriculture, 20, 1991, pp. 25-29

This paper deals with the changing face of Chinese agriculture, looking at the effects of government policies on the productivity of farms. Rural economic reform since 1980 has done much to improve performance, and output of major crops such as grain, cotton and oilseeds has increased by a large margin.
In the early 1980s, government investigation into the rural economy showed that poor morale among farmers was due to the poor organization of agricultural production and the system of land use.
Before 1980, farmers in the broad rural areas were organized according to the system of the People's Commune.
Under the old system, land belonged to the People's Commune and was assigned to the production teams on the basis of the number of people in each one. The production teams were obliged to use the land in accordance with the production plans drawn up by the Commune, and were not allowed to use any of it for private purposes, except for their own small gardens.
After 1980, the central government decided that economic reform was necessary in the rural areas. The Communes were replaced by a township government, the production brigade gave way to a village government, and the production teams were disbanded. Farmland was allocated to each peasant household on the basis of the number of people in it. The township governments allow the farmers of each household to make all the decisions about production, although they are still required to hand in a quota of public grain and sell a quota of surplus grain to the State. Towns in rural areas are allowed to hold markets once every 3 days where farmers can sell their produce at their own prices.
This economic reform has been supported by the broad mass of farmers, and their enthusiasm for crop production has increased unprecedently. They have not only put greater efforts into grain production, supporting the state, but also planted a greater number of economic crops such as cotton, ramie, sugar cane, vegetables and fruit trees, and have increased their personal wealth.
Since the economic system was restructured to reward farmers' efforts, they have used various methods to improve their yields.
- Cubic agriculture:
  Under this system, two or three crops with different stem heights are grown in separate line in the same field. For

instance, sweet potato might be grown in the first line or pair of lines, maize in the second, and another crop in the third. This operation makes full use of available space and sunshine and is particularly important in areas such as Sichuan province, where the area of cultivated land available for each person is only 0.06 ha, and much of the land is hilly.

- Courtyard agriculture:
This is the most intensive form of agriculture. Each household in the rural areas has at least 0.007 ha of courtyard land on which vegetables, grapes, melons, mushrooms and fruit trees are grown, and chickens, ducks, pigs, rabbits and fish are raised.
- Double crop hybrid rice:
Not long ago, it would have been impossible in China to grow one tonne of grain on one mu, a figure equivalent to 14.3 t/ha, but now this figure has been achieved in many provinces including Hunan, Hubei, Sichuan, Shantong and Hebei. A double crop of hybrid rice in one year, sometimes in addition to a single crop of barley is grown, which gives an average yield of 1.027 t/mu.
- Setting up farm crop hospitals:
Farm crop ' hospitals' are a new idea started by rice experts in Sichuan province. First, they set up a rice hospital in their local village to cure rice diseases for peasant households, after learning that many young farmers knew nothing about rice diseases and pests. Later, agricultural experts and technicians in other villages and towns began to set up maize, wheat and cotton hospitals. A survey in Sichuan province showed that wheat yields had increased where wheat hospitals had been set up.

There are many problems yet to be faced in Chinese agricultural production but recent experiences suggest that cooperation between the state and farmers is proving beneficial.

872 91 - 4/118

Cropping systems
Review, book, intercropping, ecology

VANDERMEER, J.

The ecology of intercropping.

Cambridge University Press, Cambridge, UK; ISBN 0-521-34592-8; 1989, 237 p., price £30.00

Intercropping is the deliberate culture of two or more crop species in such close proximity that they compete. It is almost universal practice of smallscale farmers in all tropical environments except that of flooded rice fields. For this reason alone, the study of intercropping must be important and the absence of a theoretical framework for that study must be a block on development in those parts of the world which most need it.
John Vandermeer, with an ecologist's refreshing insight, has set himself the target of developing "theoretical formulations aimed at understanding those aspects of intercropping that might be called `strictly biological'". His capacity for elegant theoretical formulations ('models' for short) is considerable. By his own honest admission, the existing body of experimental data can rarely be shown to conform to the models, partly because the data are derived from experiments for which the testing of models was not the primary aim. However, even where data is usable,it rarely fits. Hard though it may be for an empiricist to admit, it is not a weakness but rather a strength of this book that the author is not detered from his pursuit by any failure to reconcile theory and practice. Rather he is inclined to admit the failure and move on. Agronomists have been reluctant to subject intercropping models to peer review because they were detered by irreconcilable data. He has no such inhibitions and, at the end of this stimulating book, it has to be acknowledged that the models are so persuasively argued and so intrinsically elegant, that it may be more appropriate to query the empiricists' data.
The aims are clearly laid out in the opening chapter, which is followed by a necessary but mundane chapter on the measurement of intercrop performance. The 'competitive production principle', 'facilitation' and their mechanisms are then discussed in four chapters covering fairly well-worn paths, with occasional illuminating departures such as that of 'grain', the scale of environmental variation in space or time. Intercrops with perennials are dealt with largely in terms of light interception, and a heroic chapter attempts to develop models which will encompass the additional complication of weediness. In the chapter on 'variability in intercrops' a tilt is taken at conventional wisdom by presenting a theoretical argument to show that "under a competitive model, intercrops will tend to be more variable rather than less so....". The mathematics are complex but the conclusion should stimulate some debate.

Vandermeer's 'phenomenological approach' to the planning of intercrops is a valuable contribution, but the next chapter with an alternative 'mechanistic approach' is less convincing. Perhaps for the immediate future, adequate mathematical descriptions of competition effects which do not attempt to explain mechanisms are the best that can be used empirically. The final chapter is something of a mixture. It contains a robust and most eloquent defence of intercropping and its weaker point, problems of mechanisation. In contrast, 'the question of genetic improvement' is rather shoddily dealt with and will convince no-one. A pity to end on such a weak note.
But to make carping criticisms would be to miss the point that here is an author who is prepared to go out on a limb to provide a theoretical framework. That framework must not be expected to unify all existing intercropping experience, but rather to direct future experimental design. To this end, The Ecology of Intercropping is a major, elegant and much needed contribution.
Abstract by N.M. Fisher, UK

873 91 - 4/119

Cropping systems
Asia, Sri Lanka, experiment, cropping systems, intercropping, coconut, food legumes, utilization of land, natural resources

LIYANAGE, M. de S. and H.P.S. JAYASUNDARA

Intercropping food legumes under coconut.

In: Proc. of Improved Production and Utilization of Food Legumes in Sri Lanka, Peradeniya, 1987, 37-41

Coconut (*Cocos nucifera* L.) is the most widespread plantation crop in the intermediate and dry zones of Sri Lanka. In coconut monocultures, it has been shown that the palms cannot make optimal use of available resources.
Food legumes fit in well to the rainfall pattern experienced in the intermediate and dry zones.
This paper presents the results of a study made to compare the relative growth and yield of five species of food legumes under a mature coconut plantation.
The experiment was conducted in a mature coconut plantation at Bandirippuwa Estate Lunuwila during the dry (yala) season, 1982. The coconut palms were about 55 years old and planted at a spacing of 7.8 m x 7.8 which transmitted approximately 65% photo-synthetically active radiation (PAR) through its canopy measured at solar noon on clear days.
Five species namely, cowpea (*Vigna unguiculata*) cv. MI 3354, mungbean (*Vigna radiata*) cv MI 4, groundnut (*Arachis hypogeae*) cv. MI I, soybean (*Glycine max*) cv. Pb-1 and winged bean (*Psophocarpus tetragonolobus*) cv. SLS 47, were grown in plots of 3.6m x 3.6 m between two coconut rows. A basal fertilizer mixture containing 20 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied a day before planting. Seeds of different species were sown in rows 30 cm x 15 cm apart (280,000 plants ha^{-1}), except winged bean which was planted 120 cm apart (6950 plants ha^{-1}) and oriented in East-West direction. The plots were arranged in a randomized block design with three replications.
To assess the growth and development, data were collected on plant height, days to 50% flowering, shoot/root ratio and maturity period:
Days to maturity: The number of days to reach physiological maturity varied significantly among different legume species. While mungbean pods matured in 60 days, winged bean took 144 days to reach maturity. However, mungbean, cowpea and groundnut matured in less than 90 days whereas soybean and winged bean took more than 90 days. Since early maturing species have the advantage of escaping stress conditions, cowpea, groundnut and mungbean seem to be better adapted to cropping systems under rainfed conditions than soybean or winged bean.
Seed yield: Mungbean crop produced the lowest yield compared with other species. Among them, groundnut produced the highest yield which was significantly ($P = 0.001$) greater than that of winged

bean. Although the yield of cowpea was higher than soybean, the differences were not significant.
However, when seed yield was expressed in terms of crop productivity, both groundnut (16 kg ha^{-1} day^{-1}) and cowpea (12 kg ha^{-1} day^{-1}) were more productive as intercrops than mungbean, soybean or winged bean. It would also appear that although winged bean produced the highest yield, it was less productive than even soybean and mungbean. These differences may be due largely to differences in the maturity period. Thus, in selecting food legumes for intercropping, an estimate of productivity of the crop species seems to be a better criterion than the yield ha^{-1}.
Pods per plant: The number of pods per plant varied significantly ($P = 0.001$) among legume species which is a genetical characteristic. Soybean produced the highest pod number which was significantly greater than those recorded for groundnut and winged bean. Cowpea and mungbean produced the lowest number of pods per plant.
Seeds per pod: Although groundnut and soybean produced significantly more pods plant per than cowpea, mungbean or winged bean, the number of seeds per pod was lowest in groundnut and soybean. In contrast, fewer number of pods in cowpea contained significantly more seeds than those of mungbean and soybean.
100 seed weight: Among legumes seeds of both groundnut and winged bean were significantly ($P = 0.001$) larger than other species. Although size of cowpea seed was greater than that of mungbean, it was markedly less than that of soybean.
Protein yield: Since food legumes provide the major source of protein in the diet, estimation of protein yield per ha is a useful parameter in the selection of species. According to the results furnished, seed protein yield estimated for groundnut and winged bean was considerably greater than that of soybean. Meanwhile, protein yield of cowpea was higher than that of mungbean. Further, it would appear that protein yield in these legumes was more or less related to the protein content in the seeds. In this context, seed protein content would be an important yield parameter in the selection of legume species for intercropping.

874 91 - 4/120

Cropping systems
Asia, Philippines, IRRI, field trials, rice, cowpea, grain yields, intercropping

MORRIS, R.A. et al.

Effects of crop proportion on intercropped upland rice and cowpea. 1. grain yields.

Field Crops Res., 24, 1990, pp. 33-49

This study was designed to measure grain-yield sensitivities of intercropped upland rice and cowpea to crop proportion, cowpea cultivar and seeding rate, and the interaction of crop proportion with two factors (N and water) critical to rice yield.
One-fourth of the world's rice (*Oryza sativa* L.) area is cultivated on upland fields without puddling or bunding. Almost 12 million ha of upland rice is in South and Southeast Asia. The largest areas are in India, Indonesia, Thailand, Bangladesh, and Burma. Farmers seldom apply nitrogen fertilizer to upland rice.
Drought stress frequently limits yield. Cowpea [*Vigna unguiculata* (L.) Walp] is also planted extensively in Asia, but not on large tracts. It is often intercropped with maize (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench], pearl millet [*Pennisetum americanum* (L.) Leeke] and other annual crops. Although cowpea and rice are common components in intercropping, they are seldom intercropped together.
Symbiotic N fixation can supply most of the N required by cowpea. If cowpea N requirements can be met primarily by symbiotic N fixation, intercropped rice may accumulate soil N spared by cowpea and also N fixed by cowpea which is exuded from cowpea roots or released from decaying cowpea plant parts.
Six rice/cowpea experiments were conducted to explore rice and cowpea yield sensitivities to species proportion, cowpea cultivar, seeding rate, water stress and N fertility. Five experiments were on moderately productive Typic Tropudalfs (pH 5.3), and one was on an unproductive Oxic Dystropept (pH 4.3). Cowpea grain-yield responses to increased cowpea proportion consistently exceeded crop proportionate area increases (0.49 and 0.85 relative yields at 25 and 50% cowpea) whereas rice grain-yield responses proved to be sensitive to cowpea cultivar and other factors. However, an early-maturing, nonviney determinate cowpea line (IT82D-889) was compatible with rice. Grain-yields responded to seeding rates, but increases to rates that were only 10-15% above monocrop optima for each species were adequate to obtain most benefit from intercropping. Neither irrigation nor fertility effects markedly altered relative competitive abilities of the species. The experiments demonstrated that rice can be advantageously intercropped with early-maturing nonviney cowpeas. Within soil-fertility and water-stress ranges of this study, highest combined relative yields should be obtained from an intercrop composed of

rice and cowpea planted at a 50:50 proportion with seeding rates about 15% above the monocrop optima.
With the provision that the intercrop includes a compatible cowpea cultivar, neither water availability nor soil N fertility appear to increase the competitiveness of either species to the detriment of the other. The absence of a strong competitive shift favoring one species as organic N or water became more available, and the similarities of responses on unproductive and moderately productive soils suggest that the relative yield relationships between the two species should be stable over a range of environments.
Although the grain-yield/crop-proportion and other relationships observed in this study were encouraging, they should be regarded as exploratory. To confirm the relationships and to examine the influence of other environmental factors on yields of the two crops, experiments must be conducted across a wider range of soil and weather conditions.
Authors' Abstract, extended.

875 91 - 4/121

Cropping systems
Asia, Philippines, IRRI, field trials, rice, cowpea, intercropping, nitrogen yields

SIRI-UBOMPAS, C. and R.A. MORRIS

Effects of crop proportion on intercropped upland rice and cowpea. 2. Nitrogen yields.

Field Crops Research, 25, 1990, pp. 233-246

This study examined the sensitivity of total N and component N yields in intercropped rice and cowpea to crop proportion, seeding rate, cowpea cultivar, N fertility, and water availability.
In Asia, upland rice is predominantly a subsistence crop grown on small farms. Few farmers grow modern upland rice varieties, and nitrogen fertilizer is seldom applied to either traditional or modern upland varieties. When N fertilizer is applied, rates seldom exceed 40 kg N ha^{-1}.
Cowpea, which can fix N abundantly in symbiotic association with *Rhizobium* spp., is a compatible intercrop with modern upland rice varieties. Although intercropped cowpea and rice should take up N from different sources spatially and temporally, the two species would probably compete for some common N sources.
Nitrogen fixation potentials exceeding 100 kg N ha^{-1} per crop have been reported. Moreover, the proportion of biologically fixed N in legumes has been shown to increase when the legume is in competition with a grass species.
Uptake of soil N by cowpea should cease as early as 60 days after emergence, depending on cultivar characteristics. After cowpea harvest, N in abscised leaves and other plant parts should become available to rice as plant N leaches into the soil.
Six field experiments were conducted in The Philippines between January 1984 and April 1985.
Early-maturing, determinate cowpeas [*Vigna unguiculate* (L.) Walp] intercrop well with upland rice (*Oryza sativa* L.).
The effects of crop proportion, seeding rate, cowpea lines, organic amendment, and water availability on N yields of the two species were examined.
When intercropped with cowpea line IT82D-889, rice N yield consistently increased as cowpea replaced up to 50% rice. Above 50%, the effect on rice N yield was not consistent. Cowpea N yield increased sharply as cowpea proportion increased. At the 50:50 species ratio, N yields relative to those of monocrops were 0.70 for rice and 0.71 for cowpea. In a comparison of cowpea lines at a 50:50 species ratio, the early-maturing, determinate IT82D-889 accumulated 68 kg N ha^{-1}, whereas later-maturing lines accumulated as much as 40% more N. The viney habit of the late-maturing lines, however, made them incompatible with rice. Seeding rates affected N yields of both species. Rice and cowpea yields increased 0.54 and 0.88 kg N ha^{-1} for each kg ha^{-1} cowpea seed increase. However, for each 10 kg ha^{-1} rice seed increase, rice N yield increased

1.06 kg ha^{-1} but cowpea N yield decreased 0.54 kg ha^{-1}. Water stress imposed by a line-sources irrigation system increased N yields of both species, but organic N amendment (75 kg N ha^{-1} from manures) had only a small effect on N yields. Neither water availability nor soil fertility status strongly interacted with crop proportion to influence the N benefit from intercropping. This study demonstrated that, with appropriate management, cowpea can be intercropped with upland rice to increase N yield of a modern upland rice variety. Total N yield exceeding that obtained from sole-cropped cowpea can be expected when the rice: cowpea ratio is approximately 50:50. An early-maturing, nonviney cowpea cultivar appears to be essential for maximum N benefit. Seeding rates about 15 % above the sole-crop optima for each species are probably desirable. Although this study demonstrated that upland rice and early-maturing, nonviney cowpeas can be compatibly intercropped, and will increase the N available to rice, there are few studies with which this one is readily compared. There is therefore a need to examine the relationships reported here in more detail and over a wider range of management variables and environments.
Authors' Abstract, extended.

876

91 - 4/122

Cropping systems
Africa, Ghana, Alfisol, summer-humid dry climate, crop rotation, monocropping, intercropping, cowpea, maize, GTZ

HARDTER, R. et al.

Yields and land-use efficiency of maize-cowpea crop rotation in comparison to mixed and monocropping on an Alfisol in Northern Ghana.

J. Agronomy & Crop Science, 166, 1991, pp. 326-337

The objective of the present study was to compare two maize/cowpea intercropping systems with maize monocropping and a crop rotation system involving maize and cowpea. The productivity levels of the cropping systems were compared on the basis of yields of the component crops and the Land Equivalent Ratio (LER). The Area x Time Equivalency Ratio (ATER) was also employed as a parameter in the study in order to take into account duration of land occupancy by the crops.
The experiment was conducted at the Nyankpala Agricultural Experiment Station, which is located at an elevation of 171 m a.m.s.l., in the northern part of the West African Guinea Savanna. The climate there is characterized by 5 to 6 humid months with average annual precipitation of 1095 mm.
The treatments included two levels of nitrogen (0 and 80 kg of N $ha^{-1}y^{-1}$ as urea) and two levels of phosphorus application (0 and 60 kg of P $ha^{-1}y^{-1}$ as Volta phosphate rock).
Most of the studies reported on in the literature have used the concept of Land Equivalent Ratio (LER) for comparing intercropping and sole cropping systems. This measure has established overall higher productivity of intercropping, although the yields of the component crops were lower than when these were grown by themselves.
In many of the cases reported on in the literature, the superior results attributed to intercropping could be due to the fact that most of the studies focused on comparing intercropping with monocultures, without taking into account the possible positive impact of crop rotation on yields.
At all levels of N and P application, maize yields of the intercropping systems, especially of maize/cowpea mixed cropping, were significantly lower than in sole cropping. Highest maize yields were obtained in maize/cowpea rotation, which in contrast to the other cropping systems did not show any reductions in yields over years. Cowpea yields were generally less affected by the cropping system, but were notably depressed when cowpea was relay-intercropped with maize. In treatments without fertilizer application (N and P) Land Equivalent Ratios (LER) and Area x Time Equivalency Ratios (ATER) generally indicated lower productivity of the intercropping systems as compared to sole cropping, with the maize/cowpea rotation showing the highest productivity. Conversely, fertilizer application resulted in higher productivity

of the intercropping systems over the 4-year period. Productivity on the basis of ATER was generally lowest in maize/cowpea relay-intercropping as a consequence of the long time of land occupation.
The results of this study clearly show that, besides fertilizer application, crop sequence is also an important element bearing on the maintenance of higher production levels at this location.

877 91 - 4/123

Cropping systems
Latin America, Colombia, CIAT, experiments, intercropping, cassava, cowpea, phosphorus rates, yield, land-use efficiency

MASON, S.C. and D.E. LEIHNER

Yield and land-use efficiency of a cassava/cowpea intercropping system grown at different phosphorus rates.

Field Crops Res., 18, 1988, 215-226

Cassava (*Manihot esculenta* Crantz) is frequently intercropped with cowpea [*Vigna unguiculata* (L.) Walp subsp. *unguiculata*] in the tropics. Little is known about the influence of P fertilization practices on the efficiency of land use and yields in cassava/cowpea intercropping systems. Two experiments were conducted on a Typic Dystropept soil with the objective of determining the influence of P application rate on yield and P status of cassava and cowpea grown in sole and intercropping systems, and the influence on land use efficiency. Cassava yields averaged across P rates were reduced 29% from the 28 mg ha^{-1} sole crop yield when intercropped with cowpea in 1979-1980. Cowpea yields were reduced by 19-38% from a sole crop yield of 1522 kg ha^{1} when intercropped in 1979, and 29-38% from a sole crop yield of 1277 kg ha^{-1} in 1980. The rate of P application had little influence on cassava yield, except in 1981 when intercropped cassava yields were greater than 40 mg ha^{-1}. In 1981, increasing the rate of P application from 0 to 44 kg ha^{-1} resulted in a cassava yield increase from 41 to 47 mg ha^{-1}. In 1979 and 1980, increasing the rate of P application from 0 to 22 kg ha^{-1} increased cowpea yield 44 and 92%, respectively, while increasing P rate from 66 to 132 kg ha^{-1} increased cowpea yield 28 and 18, respectively. In 1981 and 1982, increasing the rate of P application from 0 to 44 kg ha^{-1} increased cowpea yield by 1052 ka ha^{-1}. Phosphorus concentration of cassava and cowpea leaf blades increased with increases in rate of P application from 66 to 132 kg ha^{-1} in 1979 and 1980, and from 0 to 44 kg ha^{-1} in 1981 and 1982. Intercropping cassava with cowpea resulted in a 30% increase in land-use efficiency when no P was applied, while land-use efficiencies resulting from intercropping were increased by 41-50% with P application rates of 22-132 kg ha^{-1}. Cassava proved to be well-adapted to low-P soils and very competitive even without P application, whereas cowpea required the addition of P for adequate growth and yield. High productivity and a good competitive balance between the two crops were reached with only 22 kg ha^{-1} of P, showing the great potential of cassava/cowpea intercropping on acid, infertile soils in the tropics.
Authors' Abstract.

878 91 4/124

Cropping systems
Asia, Thailand, studies, mungbean, rubber, rice, crop rotation, intercropping, yield, weeding, pesticides, fertilizer, AVRDC

LAOSUWAN, P. et al.

Research on mungbean as intercrop with young rubber and as sequential crop with rice.

In: Proc. of the 2nd Int. Symposium on Mungbeans, Bangkok, Thailand, 1987, AVRDC Publ. No. 88-304; 1988, pp. 392-397

A series of experiments was conducted in between rows of young rubber plants and in paddy fields after rice to evaluate mungbean lines or cultivars. A study on input and management was also carried out to determine their suitable levels for mungbean production in southern Thailand.
The production area of mungbean in southern Thailand varies between 5,000 to 10,000 ha. Since most of the upland and lowland areas in the south are devoted to first rubber and next rice production, mungbean is usually planted as an intercrop with young rubber plants and as a sequential crop with rice.
In southern Thailand, mungbean is planted as an intercrop with young rubber plants and as a sequential crop with rice. In 1985-86 the mungbean project conducted yield trials of mungbean between rows of young rubber plants, and in the paddy field after rice. The average yield of mungbeans planted between rows of young rubber plants and in the paddy field were 1,311 and 1,400 kg/ha, respectively. Either AVRDC mungbean line VC 2768A or VC 2755A gave the highest average yield during the four trials. The effects of levels of different management inputs including weeding, application of fungicide, insecticide, fertilizers, etc., were also studied. There was a very high response to weeding and fertilizer application but low response to other management inputs including fungicide and insecticide applications.
These studies show that mungbean responds very well to weeding, fertilizer application and planting methods, but response to pest and disease controls was not obvious. Farmers producing mungbean in southern Thailand as well as in other regions of the country, usually practice minimum weeding, and apply very little fertilizer to their plots. Most of them grow mungbean by broadcasting. All of these traditional practices result in low mungbean yields.

879 91 - 4/125

Cropping systems
Asia, India, intercropping, tree growth rate, tree interspace, monoculture, agroforestry, field crops, foddergrass

SURESH, K.K. and R.S. VINAYA RAI

Studies on intercropping with silk cotton trees (*Ceiba pentandra* (L.) Gaertn.).

Trop. Agric. (Trinidad), 68, No. 1, 1991, pp. 37-40

Studies were carried out to elicit information on the effect of intercropping on sapling tree growth and that of the tree on the intercrop; the results are reported herein.
Most studies on intercropping with tree species have focused attention on the effect of the arboreal component on the arable;in the mixed system on the reciprocal effect of the crop on the tree studies are scant. The silk cotton tree (*Ceiba pentandra* (L.) Gaertn.) is an important agroforestry species whose pods yield valuable floss used in upholstery.
Eight-month-old container-grown seedlings of silk cotton were planted at a spacing of 8 x 8 m in plots measuring 16 x 16 m. In the inter-row spaces, crops were raised twice in a year for three successive years.
The growth during the initial six months of planting was not affected by any of the associated crops but was as good as that under monoculture, but during the next six months, trees in association with the fodder grass (cv. BN 2,a Pearl millet X Napier grass hybrid) were severely inhibited in their growth and were eliminated in the 11th month. Cotton had a beneficial effect on tree height increment, though not on that of diameter, during this period. From months 19 to 36, however, the growth rate of the arboreal component was unaffected by intercropping.
The current study has shown fodder grass (cv. BN 2) to be harmful to silk cotton saplings during the initial six months; in the next six months, the growth rate of the tree increased in the cotton treatment; thereafter, intercropping had no influence on tree growth.
Proximity of the tree had no appreciable effect on the crop.
None of the intercrops sustained any yield impairment during the six rotations.
This study, clearly establishes that with the silk cotton tree, intercrops record normal yield up to three years of the trees' growth. This may possibly be attributed to its open, sparse canopy which allows sufficient light to penetrate to the understorey.
Concluding, the authors state that growth of the silk cotton tree was suppressed by a fodder grass during 7 to 11 months after planting of the tree. Height growth was good in the cotton treatment during the corresponding period (7-12 months). Intercropping of field crops with the silk cotton tree had no adverse effect on the crops during the first three years.

880 91 - 4/126

Cropping systems
Asia, Philippines, monoculture, intercropping, pineapple, banana, Carica papaya, root distribution, root activity

ANGELES, D.E. and H.P. SAMONTE

Root activity of banana under monoculture and as intercrop with papaya and pineapple.

The Philippine Agriculturist, 73, No. 1, 1990, pp. 47-53

Banana is generally planted as a monocrop in commercial farms and as an intercrop with papaya, pineapple and coconut in small farms in the Philippines. Banana under intercropping system grows and yields better than banana in monocropping system. This observation can be attributed to better nutrition with banana getting additional nutrients from the fertilizer applied to intercrops particularly pineapple. With better nutrition, growth is promoted and roots are assumed bigger, larger and denser. Aside from nutrition, water may be conserved better. Soil temperature and evaporation are much reduced especially in areas covered by papaya and pineapple leaves. Since pineapple is raised alongside banana, the shady condition is conducive to better root growth.
This experiment evaluates the zones of root activity of banana in different cropping systems and determines the appropriate time of leaf sample collection to determine ^{32}P activity in the leaf.
The rootzone of banana can be found in various points from the trunk depending on soil conditions and the cultural practices applied to the plant during its growth.
The determination of root distribution is important in the selection of an appropriate technique of fertilization and irrigation.
At what soil depth should irrigation be made to wet the soil and the depth fertilizers should be applied would depend on the depth of the rootzone.
The active rootzone of 11-month-old banana grown as monocrop and as intercrop with papaya and pineapple was determined using radioactive phosphorus (^{32}P). The tracer was applied at 20, 40, 60 and 80 cm from the trunk, 15 and 30 cm deep and the activity of the third leaf was determined on the 8th, 16th and 24th day after application. Regardless of depth and distance of the placement, leaf activity increased from the 8th and 24th day after application. Under both cropping systems, about uniform activity was observed at 15 cm deep within 20 to 80 cm radius. Higher root activity of banana was observed at 30 cm deep within a 20 to 40 cm radius.
Summarizing, fertilizer should be applied properly especially in the zone of highest root concentration.

881 91 4/127

Cropping systems
Africa, Nigeria, humid zone, cacao, cola, oil palm, intercropping, traditional cropping systems, agroforestry

EGBE, N.E. and S.A. ADENIKINJU

Effet de cultures intercalaires sur le rendement potentiel du cacaoyer dans le Sud-Ouest du Nigeria. (Effect of intercropping on potential yield of cacao in South Western Nigeria).

Café, Cacao, Thé, 34, No. 4, 1990, pp. 281-284

This paper reports and discusses yield data collected from some experimental planting of cacao in combination with other tree crops at Nigeria.
In the traditional cacao growing areas of South Western Nigeria, cultivation of cacao with other tree crops like oil palm, kola, rubber and cashew is very popular. This is in spite of the monocultural system recommended by the agricultural stations and practiced in modern plantations.
Cacao being a shade tolerant plant, is grown in combination with other tree crops such as oil palm, citrus, kola and plantain, or more commonly along with food crops like cassava and cocoyams. These crops among others provide some shade, help suppress weed growth, supplement income at the early stages of establishment.
At the Cocoa Research Institute of Nigeria, Ibadan, several sole cropped cacao and kola plots were established for experimental purposes. To test the possible effect of intercropping cacao with kola (*Cola nitida* (Vent.) Schott and Endlicher), oil palm (*Elaeis guineensis* Jacq.), and *Terminalia ivorensis* L., some plots were established in 1965 on Egbeda series. No fertilizer was applied to any plot.
Cacao production in the cacao/kola and cacao/*T. ivorensis* mixtures was lower than in the sole crop, while cacao production in the cacao/oil palm system was higher.
In the farmer's situation, yield of the cacao in intercropped plots is lower than those reported here, because of haphazard spatial arrangement of the intercrops and substandard maintenance.
Although it is known that cacao can be grown without permanent shade, the management of such unshaded cacao is highly technical and costly in terms of pests and weed control, as well as fertilizer requirement. The intercropping of oil palm with cacao is however considered a more profitable proposition than sole cropping. This is confirmed by the Land Equivalent Ratio (LER) of 3,3 obtained from the oil palm/cacao trial.
The results could be explained by the observed heavy overhead shade of *T. ivorensis* which must have depressed cacao yield in that mixture. The surface feeding roots of the two crops were also apparently in mutual competition at the spacings used. The same factors were observed to have accounted for the depressed cacao yield also recorded in the cacao/kola mixture. In the cacao/oil palm mixture the "synergistic" or mutually beneficial effects of

the two crops could explain the enhanced cacao yield. This could have resulted from the absence of any adverse competition between the oil palm's restricted fibrous roots and the extensive superficial feeding roots of the cacao. The relatively high and porous canopy of the oil palm could also have been more beneficial to the cacao than otherwise.
It is therefore to be deduced from the results that the cacao/oil palm mixture offers the best prospect to the peasant farmer under the circumstances. A farmer's choice of any particular system is however most likely to be determined by his resources base as well as the relative producer prices.

882 91 - 4/128

Cropping systems
USA, Florida, study, maize, bean, intercropping, planting, maize density, bean type

GARDNER, F.P. and J. KISAKYE

Productivity of bean/maize intercrops as influenced by bean type and planting date and maize density.

In: Proceedings of Soil and Crop Science Society of Florida, USA, Vol. 49, 1990, pp. 139-146

The objective of this study was to assess the effect of bean (*Phaseolus vulgaris* L.) growth type, bean planting date, and maize (*Zea mays* L.) plant population density (PPD) on the growth, development, and yield of maize and bean grown in intercrop and the respective sole crops.
It has been observed that maize is the most competitive of the two components. The adverse effects of climbing bean on maize yields was associated with lodging of the maize, so that lodging-resistant maize genotypes should be superior for intercropping.
The quantity of light available to the bean canopy decreased as the maize increased, reducing leaf area index (LAI), growth rate and yield of bean intercrop.
Climbing bean varieties are more sensitive than bush bean to shading, however, climbing bean was more competitive than bush bean in maize/bean intercrop. Therefore, the relative planting date and maize/bean proportions must be manipulated to irradiate both crops sufficient for acceptable growth of the two.
A field study was conducted in 1988 at the University of Florida, Gainesville (29°38'N) with maize cultivar Pioneer '3192' seeded in 0.9-m rows on 1 April at five PPDs: 0,1, 3. 6, and 9 plants m^{-2}. Two bean cultivars 'Blue Lake' (determinate bush) and 'Kentucky Wonder' (indeterminate climber) were interplanted in twin rows between the maize rows on 1 April, 2 May, and 1 June. The leaf area index (LAI), crop growth rate, light interception, total dry matter, and seed yield of both sole and intercrop maize generally increased with increasing maize PPD, whereas these parameters for bush and climber intercrop bean decreased with increasing maize PPD. Maize seed yield was reduced ($P < 0.10$) by only simultaneous (1 April and 1 May) planting of bean at the PPD 1 of maize. Total plant dry matter yield was not affected by bean intercrop treatments. Planting bean 60 d after planting maize compared to simultaneously planting of bean reduced pod number, seed size, and yield in both bean types. The climbing bean was generally more productive than the bush bean. At the PPD 3 of maize and May planting of bush bean, intercropping was more land-area efficient (land equivalency ratio = 1.57) and area-time efficient (area-time equivalency ratio =1.39) than bean and maize in sole crop.

883 91 - 4/129

Cropping systems
Asia, India, study, sandy loam, randomized block design, rice, mungbean, soybean, peanut, ricebean, blackgram, intercropping systems

MANDAL, B.K.

Rice, mungbean, soybean, peanut, ricebean, and blackgram yields under different intercropping systems.

Agron. J., 82, 1990, pp. 1063-1066

This study was designed to determine the yield of main crop of rice and subsidiary crops like mungbean, soybean, peanut, ricebean, and blackgram as influenced by intercropping and to ascertain if such systems would be a viable means for improving yield efficiency of these crops in eastern India.
A study was conducted in 1985 and 1986 during Kharif (crops that are usually planted between June and July and harvested from October to November) season at Kalyani, West Bengal, India, located at 9.75 m above sea level on a well-drained sandy loam soil in the Gangetic Alluvial Plains.
Rice was intercropped with mungbean (*Vigna radiata* L.), soybean [*Glycine max* (L.) Merr.], peanut (*Arachis hypogaea* L.), ricebean (*Vigna umbellata* L.) and blackgram [*Vigna mungo* (L.) Hepper.]. Rice/legume planting ratios (row basis) were 2:1, 4:1 simultaneously planted or legumes were planted (2:1 planting ratio) at 30 d after planting of rice (deferred planting). Control plots were monocrops of rice and legumes with each species fertilized according to soil test recommendations. Rice + mungbean, rice + soybean, rice + peanut and rice + blackgram intercroppings resulted in hihger yields than that of rice + ricebean intercropping. Rice + ricebean and rice + blackgram-yielded higher when deferred planting was practised.
All intercropping treatments of rice + legumes save rice + ricebean (simultaneous planting) were greater in land equivalent ratio (LER) and relative net return (RNR). The competitive ratios (CR) of rice was above one in deferred planting except rice + blackgram and rice + mungbean in 1985 and only rice + blackgram in 1986.
The monetary advantage followed the same trend as that of LER. Rice + blackgram in deferred planted condition recorded the maximum monetary advantage.
Results compare the differential cost of cultivation of intercropping system, along with monocropping of rice, indicating that rice + mungbean, rice + soybean, rice + peanut, and rice + blackgram were all economically advantageous.
Both functions of LER and Area x Time Equivalency Ratio indicated that intercropping could improve the productivity in an intensive cropping system in the state of West Bengal.
Rice was less competitive than the legumes in the rice-legume intercropping systems except soybean and ricebean in deferred

planted condition during both the years and rice + mungbean with deferred planting only in 1986. It could be concluded that with available resources, rice was less competitive if simultaneous planting was practised. In deferred planting conditions rice became more competitive in some cases.
Relative value totals (RVT) of rice + peanut combination were higher than that for other combinations due to the higher price paid of peanut. It could be concluded that in simultaneously planted conditions, rice + legumes with 2:1 planting ratio were more profitable over the 4:1 planting ratio with the exception of rice + ricebean.
From this study, it appears that rice + peanut, rice + soybean, rice + mungbean, and rice + blackgram intercroppings were found to be profitable under simultaneous planting while rice + blackgram in deferred planting conditions was more remunerative under West Bengal conditions.

884 91 - 4/130

Cropping systems
Africa, Nigeria, studies, humid zone, Alfisol, cassava, maize, intercropping systems, compensatory relationship, land equivalent ratio, relative yield, IITA

EZUMAH, H.C. and T.L. LAWSON

Cassava and maize intercropping systems - the effects of varieties and plant populations.

J. Agron. & Crop Sc., 164, 1990, pp. 334-342

The present studies conducted in 2 phases were undertaken to determine the performance of two maize and two cassava cultivars of contrasting growth habits under intercropped conditions and to identify the nature of plant interaction and the factors responsible for competition in cassava and maize intercrops.
Cassava (*Manihot esculenta*) is usually intercropped or relay-intercropped with maize (*Zea mays* L.), yams (Dioscorea spp. L.), vegetables such as okra and melon and African spinach in humid tropical zone of Africa.
In South Western Nigeria, dominated by Alfisol, cassava is more commonly grown in two crop mixtures with maize while in Eastern Nigeria, an acid-Ultisol area, complex mixtures of cassava with yam and melon as well as maize are more common.
The cassava + maize intercropping is usually planted at the beginning of the rains.
In Western Zaire and S.W. Nigeria, planting of cassava at monthly intervals for up to 4 months through maize (3 months) or in sequence with maize (at 4th month) may result in 20-30% yield reduction.
In general, the yields of the associated maize are not affected while those of cassava may be reduced by as much as 50-70% compared with sole cassava.
Two cassava varieties, TMS 30572 and TMS 30001, of contrasting growth habits (the first branching and the second relatively erect) were intercropped with two maize cultivars TZSR-W and TZE of different growth habits and maturities. The maize and cassava were grown at three different population densities. The treatments were arranged in factorial combinations and replicated three times. The experiment was established at the IITA site in an Alfisol.
Summarizing the results, it can be said that maize dominated cassava irrespective of cassava or maize growth habit, and the optimum maize population giving the highest production based on relative yield total or land equivalent ratio varied with maize variety in a tropical Alfisol at Ibadan, transition humid/subhumid zone in West Africa. The sparsely vegetative, early maize supported higher intercrop maize population (up to 80,000 ha^{-1}) than the late maturing, highly vegetative TZSR-W. Because there is a compensatory relationship in the yields of the two crop components, the choice of an appropriate crop type and maize

population in cassava + maize intercrop system will depend on the relative economic importance of each crop component.
Based on data from these studies, it can be concluded that:
- Cassava and maize intercropping is a highly efficient crop combination based on total economic yield and land use efficiency.
- Cassava growth habit, whether low branching e.g. TMS 30572 or relatively tall non-branching TMS 30001 does not reduce the efficiency of the intercrop system significantly.
- Increasing maize population beyond 40,000 plants ha^{-1} resulted in increased total relative yield by 13% (with TMS 30572) and by 27% (with TMS 30001). Therefore the optimum maize population for intercropping with cassava varies with maize types.
- Shortness of maize, early maturity and sparse leaf area appear to be more compatible for intercropping with cassava since these characteristics tend to reduce competitiveness with cassava, the dominated crop.

885 91 4/131

Cropping systems
Asia, Sri Lanka, field trial, semihumid zone, chilli, pigeonpea, intercropping, fruit quality

ARULNANDHY, V.

Improvement of fruit quality in chilli under chilli/pigeonpea intercropping.

Int. Pigeonpea Newsletter (IPN), 1991, February, p. 15

Chilli (*Capsicum annum* L.) is a leading commercial crop of Sri Lanka. Recently, the Agricultural Research Station, at Maha Illuppallama developed a new short-duration chilli variety, MICH 20, having erect fruits positioned at the top of the canopy. The fruits of this variety, when ripe, do not develop the required bright red color because of direct exposure to the hot sun. Hence, a preliminary study was conducted to improve the fruit quality of this variety with respect to color by using tall pigeonpea (*Cajanus cajan* L.) to provide partial shade. In addition, the shading effect of pigeonpea on the fruit yield of chilli was studied.
In an nonreplicated experiment conducted at Maha Illuppallama in the 1989/90 Maha (wet) season, seeds of a tall pigeonpea variety ICP 7035 were sown in 25-m long rows 4.8-m apart. The emerged seedlings were thinned to 8 plants per 1-m row. After 1 month, 30 day-old chilli seedlings were transplanted at a spacing of 60 cm x 45 cm between the two pigeonpea rows, as well as in an open plot of size 25 m x 4.8 m as a control. The chilli crop was managed according to the recommended cultural practices of the Department of Agriculture, Sri Lanka. The pigeonpea was allowed to grow virtually undisturbed; however, it received four irrigations along with chilli crop.
It was impressive to observe that the ripe fruits of chilli grown with pigeonpea were of excellent quality, glossy and bright red in color. On the contrary, the fruits of chilli from the control plot were light red in color and showed slight scorching. There was also no apparent reduction in the fruit yield of chilli that was grown with pigeonpea. Chilli grown with pigeonpea produced 1.7 t of dry fruits ha^{-1}, compared to 1.8 ha^{-1} the pure stand of chilli.
In addition to chilli fruits, 440 g of shelled green peas or 60 g of dry pigeonpea seeds per 1-m row were also obtained from the plots where pigeonpea was grown. Three kilograms of fresh green matter (leaves and stems) per 1-m row was also harvested from the pigeonpea after 5 months.
From the results of this experiment, it is apparent that the fruit quality of erect fruit type chilli, especially the fruit color, can be upgraded by growing it as an intercrop with tall pigeonpea without any reduction in the yield of chilli. This is the first study of its kind and the chilli farmers can benefit in various ways by intercropping chilli with pigeonpea. They can obtain the same fruit yield but with improved fruit quality, resulting in

higher returns. In addition, farmers can harvest green peas or dry seeds from pigeonpea along with green matter (leaves and stems) that may be used for animal feed. Besides these benefits, pigeonpea, being a deep-rooted legume, is likely to improve the soil structure and fertility.
Detailed experiments have been planned for the next cropping season to study the efficiency of pigeonpea over other field crops such as okra and maize in improving the fruit quality of chili and other characteristics of economic importance.
Author's Abstract, altered.

886 91 - 4/132

Cropping systems
Africa, Uganda, study, highlands, Oxisols, semihumid zone, sorghum, finger millet, intercropping, row arrangement, yield advantage

SSEKABEMBE, C.K.

Effect of row arrangement on yield and yield advantages in sorghum/finger millet intercrops.

Trop. Agric. (Trinidad) 68, No. 1, 1991, pp. 19-22

A study was conducted to determine the effect of row arrangement on the yield and yield advantages in a sorghum-finger millet mixture grown at four different plant population densities.
The study was carried out at the Makerere University Farm at an altitude of approximately 1200 m. Most of the soils are oxisols and highly weathered, but are deep, firmly heavy and well drained. The mean daily maximum and minimum temperatures of the area are approximately 27 and 17°C. The annual rainfall averages 1300 mm and is bimodal in distribution.
An agronomic factor influencing the relative yield advantages from intercropping related to the spatial (row) arrangement of the crops.
These differences in relative yield advantages from different row arrangements could be due to better light interception and/or utilization in one row arrangement compared with the other.
In wheat/soya bean mixtures, alternate narrow rows were more efficient than wide rows, in terms of photosynthetically active radiation (PAR) intercepted and crop growth rate per unit of leaf area index or per unit of PAR intercepted. Because of the marked effect spatial (row) arrangement can have on the relative yield of intercrops, it was thought necessary to study this aspect in sorghum + finger millet intercrops.
The results indicated that the yield of each species increased with increase in planting density. The sorghum yield and the total yield of the mixture were reduced when a proportion of sorghum was replaced by an increasing number of millet rows. However, the total yield of the mixture was increased when pure-stand finger millet was replaced by an increasing number of sorghum rows. Calculation of Land Equivalent Ratios (LER) revealed that the differences among the various row arrangements in terms of yield were not significant, although the 1:2 sorghum + millet row arrangement gave an exceptionally higher overall yield advantage at all planting densities tested.
The present experiment has shown that total yield of each species was highest when grown in pure stand, and this decreased when a proportion of it was replaced by the other species. For instance, replacing sorghum with an increasing number of millet rows reduced sorghum yield as well as total yield because the millet yield could not compensate for the reduction in sorghum rows. This pattern of yield was reflected at all planting densities. The

reduction in yield of each species in the mixture is partly due to a reduction in its proportion in the mixture. The yield of both species increased with increase in plant population density.
On the basis of the results of the present experiment it is advisable for a farmer interested in maximum yield, irrespective of which species, to grow pure stand sorghum.
Farmers interested in some yield from both species should grow them in a 1:2 sorghum:millet row arrangement. This is suitable for farmers who use a mixture of sorghum and millet in preparing a thick porridge, a kind of food.

V AGROECOLOGY

887 91 - 5/81

Agroecology
Review, book, sustainable development, agro-ecology, natural resources, productivity, ecological approach, future priorities, WRI

DOVER, M.J. and M.L. TALBOT

To feed the earth: agro-ecology for sustainable development.

World Resources Institute, Washington D.C., USA; ISBN 0915825-19-8, 1987, 88 p.

This book lays out steps stretching from basic research to the mechanics of international assistance that must be taken if ecologically based agriculture is to contribute to feeding the earth.
Sustainability has come to mean different things to different people, but it most clearly has an ecological basis. Long before it was applied to agriculture, the concept of sustained yield was used in fisheries management to mean an annual harvest that could be taken in perpetuity.
A similar idea can be applied to sustainable agriculture, though intensively managed systems and self-renewing natural systems differ in many ways. More generally, understanding the ecological basis of sustainability should lead to agricultural systems whose productivity can be continued indefinitely without undue degradation of other ecosystems.
The ecological approach considers cycles as well as flows in the system, and maintenance as well as productive functions. Its performance criteria are cycling rates, stability measures, and energy efficiency.
The growing need for a productive and sustainable agriculture calls for a new view of agricultural development that builds upon the risk-reducing, resource-conserving aspects of traditional farming, and draws on the advances of modern biology and technology.
The book is organized in 6 chapters:

- **I. Introduction**
  Shrinking resources, future priorities
  An ecological approach
- **II. Environmental constraints and problems**
- **III. Ecological paradigms and principles for agriculture**
  The meanings of sustainability
  Ecology: The integrative science
  Ecosystem development
  Diversity and stability
  Population concepts: Dynamics and interactions
- **IV. Applications of ecological concepts to agriculture**
  Analysis and design of polyculture systems
  A modified polycultural agroecosystem in Mexico

  Agroforestry: Farming with trees
  Emerging agroecological principles
- **V. Policy issues by an ecological approach**
  The state of knowledge: Definitions, assumptions and experts
  Research
  National agricultural development policies
  Development assistance
- **VI. An action plan for sustainable agriculture**
  Ecological principles for agricultural development
  Development criteria
  Assessing agriculture's sustainability
  Research and education
  National agricultural development policies
  International programs

The idea of the authors of this book is not to abandon the methods of industrial agriculture that have been so successful in the economic and ecological conditions for which they were designed, but to determine where such methods as mechanization, use of agricultural chemicals, and monoculture are and are not appropriate, and to develop alternative systems better suited to tropical climates and developing economies.

888 91 - 5/82

Agroecology
Review, book, developing countries, developed countries, agricultural biotechnology, international development, CAB

PERSLEY, G.J.

Agricultural biotechnology: opportunities for international development.

Biotechnology in Agriculture Series No. 2, CAB International, Wallingford, Oxon OX 10 8DE, UK; ISBN 0-85198-643-9, 1990, 495 p + xv, price USD 114.-

Agricultural biotechnology is the second volume in a series on biotechnology in agriculture. It is aimed primarily at policy makers and research managers and divided into seven sections including a 33 page bibliography and a detailed index.
The first section gives an elementary introduction into biotechnology for non-scientists. Sections two to four deal with plant production and agricultural microbiology; forestry, livestock and fisheries respectively. It shows that biotechnology is not likely to lead to Green Revolution-style increases in agricultural productivity and output over the next 10-20 years. Biotechnology can however lead to more balanced growth, and reduced use of agrochemicals. Realizing this potential will depend on whether biotechnology research will be directed to Third World needs.
Section five contains impact studies of several agricultural commodities important to the Third World. It includes chapters on oil crops, banana and plantain, cassava, coffee and cocoa, potato and wheat. It clarifies that the success of new biotechnology depends on how well it is integrated into existing applied agricultural research practices.
The sixth section deals with socio-economic, policy and management issues. One of the tendencies identified is an increasing role of the private sector in biotechnology research. This involvement leads to the availability of large R&D and scientific resources, but also to a concentration on research and products with a high rate of return. R&D will narrowly focus on well-to-do farmers with the capacity to purchase expensive (chemical) inputs. There is a need for additional investments in biotechnology on so-called "orphan commodities", which are important as food and/or cash crops in the Third World, but which are not likely to yield high profits for private investors.
Because of the involvement of the private sector many products are subject to Intellectual Property Rights (IPRs). Although the provision of IPRs may encourage investments, the major disadvantage is that it involves proprietary protection to living organisms which some consider to be part of the common heritage of mankind.
Concerning the trade impact of biotechnology, the possibility of producing products in tissue culture and so replacing crops

currently grown in developing countries is visible. The development of an "early warning system" to identify these negative effects is highly necessary.
Although advances in biotechnology may lead to an increase in productivity, they tend to increase the productivity gap between industrialized countries and developing countries, as well as among developing countries.
The International Agricultural Research Centres (IARCs) can play an important role in adapting the tools of modern biotechnology to the needs of developing countries' agriculture. However, the IARCs are unlikely to be able to develop new basic knowledge in support of biotechnology, but rather become involved in the application of new scientific advances. Therefore, new methods for acquiring technologies from the private sector need to be considered. The IARCs could perform a role as negotiators for acquiring technologies on behalf of National Agricultural Research Systems (NARSs), particularly for the smaller countries.
The developing countries on their part need to organize their NARSs accordingly. The key issue is how to integrate biotechnology into the existing agricultural research systems. According to the author, new initiatives are needed, rather than new institutions. Furthermore, there is a need for the IARCs as well as the NARSs to engage in commercial and marketing skills, with regard to the acquisition of technology and the diffusion of the final product.
The concluding section summarizes the issues presented for International Development Agencies (IDAs). The IDAs, including the World Bank which commissioned the study preceding this book, can play an important role in making biotechnology work for the Third World.
Abstract from Biotechnology and Development Monitor.

889 91 - 5/83

Agroecology
Review, book, study, Africa, Sub-Sahara, sustainable development, long-term perspective

WORLD BANK

Sub-Saharan Africa: from a crisis to sustainable growth. A long-term perspective study.

Publ. of the International Bank for Reconstruction and Development (World Bank), Washington, D.C., ISBN 0-8213-1349-5, 1989, price £11.65

One approaches a major publication from the World Bank with the title "Sub-Saharan Africa: From Crisis to Sustainable Growth" with great expectations. Here will be a carefully considered rationale for the world's greatest development problem. The initial assessment of the crisis fuels these expectations, with a well-argued and realistic assessment of the depths of the crisis. The twin problems of soaring population and environmental degradation are rightly recognized to compromise Africa's development, and in many areas to present a nightmare scenario for the future. Soil degradation is recognized as a significant factor in environmental degradation, though not accorded the dominant importance that many soil scientists would give it. A wealth of statistical data is presented on economic indices of development, together with cautionary comments on the validity of the data.
The depressing fact that in sub-Saharan Africa per capita production of food and other products continues to fall, while in the rest of the world it increases, is well documented. A simple analysis leads to the fact that an immediate target of 4% growth in total production must be achieved, if the nightmare scenario is to be averted. One next seeks eagerly the methods which will lead to sustainable growth of this size.
The economic priorities are described in current World Bank terms- wages must fall to reflect productivity, prices must not be distorted by subsides, even to encourage fertilizer use, and policies must be established to encourage production, particularly of foodstuffs and export crops.
Agriculture is rightly recognized as having the critical role to play in development. The greatest disappointment comes when the methods by which sustainable agricultural growth might be achieved are described - or rather not described. 'Harnessing technology' for agricultural development is given five pages in a volume of 300. Those five pages describe the problem - variability of soils and microenvironments, soils readily degraded by intensified agricultural practices, lack of suitable land and water supplies for the development of irrigation, the vagaries of the climate, and so on - but provide no realistic suggestions for change. The underlying difficulty of land tenure is noted in a section on "Redefining land rights' but in terms of promoting change the authors can only say: 'judicial mechanisms for dealing with

disputes between owners claiming traditional versus modern land rights are urgently required'. Surely some lessons have been learnt from those countries which have made changes successfully, and this should be an important basis for the move from crisis to sustainable growth?
Much has also been learnt about the critical problems of sustainable soil management in different regions of Africa. Examples of the results of successful management and production policies are quoted - Rwanda, Malawi, Zimbabwe - but there is no technical description of the essentials, nor reference to the publications where such technical aspects are described. The need to strengthen agricultural research at the national level, as well as provide leadership through the international centres, is rightly stressed, as is the importance of improving education and training.
This is an important book, containing a wealth of data, and should be read by all those with an interest in African development. But it is a depressing book, not only because of the picture it presents of the nightmare scenario, but also because it reveals the considerable gap which still exists between the economists, who are concerned with development, and the scientists and technicians, who are defining the methods by which sustainable development can be achieved.
Abstract by D.J. Greenland

890 91 - 5/84

Agroecology
Review, book, Africa, ecology, climate change, population crisis, health and poverty, land-use, water resources, cash crops, food crops, irrigation, nomads, grazing, forests, fuel, energy, soil, fish, farmers, apartheid, environment, international aid, future prospects

TIMBERLAKE, L.

Africa in crisis - The causes, the cures of environmental bankruptcy.

Earthscan Publications Ltd., London, UK, 2nd edition, ISBN 1-85383-013-5, 1988, 203 p.

"Africa in Crisis" was written to show it was long-term political and economic policies that are the causes behind the problems faced today in Africa. It demonstrates how these policies have been bankrupting Africa's fragile, complex environment, and how a bankrupt environment makes development impossible in a continent in which three-quarters of the population rely directly for their livelihoods upon the environmental resources of topsoil, plants, trees, animals and water.
In some parts of Africa, such government policies continue. Northern donors have been hesitant to invest development aid in Ethiopia not only because many do not care for the regime's political ideology but because the government persists in paying small farmers less for their grain than they must spend to produce this grain. This pricing policy is at least as devasting as the government's ill-planned and under-financed efforts to move large numbers of people from the highlands to the lowlands.
And though South Africa's barbaric political system has been impoverishing the majority of the people and the entire environment of that nation and disrupting the development efforts of bordering states.
None of this means to suggest that there have been no changes for the better in Africa. The famine profoundly shocked leaders and opened minds across the continent.
African nations had agreed to tough and specific adjustment packages meant to cut fiscal deficits and improve government efficiency. Such packages are meant to produce stable economies over the long term, but over the short term they reduce spending on essential services which Africa desperately needs, such as health care and education; they cut wages, increase food prices and generally reduce spending power.
There have been other changes for the better, both inside and outside of Africa. One theme of this book is that improvements in Africa, especially in Africa's ability to feed itself, will be led by the people of Africa, especially by the farmers. The role of governments and of international agencies is to empower those people to begin that process of change.
The book is organized as follows:

- A continent on the brink
- Why famine?
- The backdrop to despair
- Misuse of land, misuse of water
- Overgrazing and the nomads
- Forests, fuel and energy
- Soil and fish: peasant farmers, peasant fishermen
- Apartheid: institutionalized bankruptcy
- Conflict, refugees and the environment
- Aid, development and the future

The first edition of this report on the problems of drought and famine across the African continent won worldwide critical acclaim. Revised and with a new introduction the authors bestselling study is invaluable reading for anyone interested in Africa.

891 91 - 5/85

Agroecology
Review, book, proceedings, conference, developing countries, sustainable agriculture, human resources, traditional techniques, self-development, appropriate technologies, ecodevelopment, agricultural research, organic farming systems, soil biology, organic fertilization, biological pest control, food quality, IFOAM

LAIRON, D. et al.

Agricultural alternatives and nutritional self-sufficiency.

Proc. of the IFOAM 7th Int. Sc., Conference, Ouagadougou, Burkina Faso, 1989, 427 pp. + annex

This book deals with the results of 7th IFOAM International Scientific Conference held at Ouagadougou, Burkina Faso, in 1989.
The book is organized in five chapters:
- I. Opening session
- II. Development work
- III. Research and experimentations
- IV. Closing session and conference recommendations
- V. Acknowledgements for financial supports

The conclusions of the 7th IFOAM International Scientific Conference open up new prospects for the development of the agro-ecological approach to agricultural production, considering the encouraging results already obtained in several countries.
The discussions brought to light a number of problems that need to be solved in the immediate future. Accordingly,the conference participants recommend that:
- In view of the diversities in the prevailing situations, in-depth scientific and practical studies should be conducted into agro-ecological systems with the view to integrating the research/development approach.
- It is absolutely necessary to intensify education and training of extension officers and farmers in the agro-ecological approach on the basis of proven traditional methods and techniques in order to ensure a meaningful participation of farmers.
- Women need to be accorded special attention in view of their major role in agriculture. In particular, appropriate training/extension programmes need to be designed and implemented for the benefit of farming women. Similarly, other relevant activities need to be embarked upon towards removing the daily constraints and difficulties facing women:
  . access to land for farming,
  . curtailment of household duties (water and fuelwood collection, kitchen duties, child education, etc.),
  . development of renewable energy resources,
  . financial support for developing income generating activities.

- Considering the inadequate flow of information regarding ongoing experiments in the field of agro-ecology and biological agriculture.

Participants strongly urge IFOAM to take every initiative to ensure the implementation of these recommendations, particularly the improvement of traditional techniques and the coordination of networks in charge of the flow of information.

892 91 - 5/86

Agroecology
Review, book, case studies, sustainable development, rural livelihoods, resource productivity, appropriate technology, planning techniques, human development, institutions, international cooperation, IIED

CONROY, C. and M. LITVINOFF

The greening of aid - sustainable livelihoods in practice.

Earthscan Publications Ltd. in association with IIED, London, ISBN 1-85383-016-X, 1988, 294 pp. + index

This book is based on the papers produced for the "Only One Earth Conference on Sustainable Development". The conference was organized by the International Institute for Environment and Development and took place 1987.
The rationale for it was that if sustainable development was to become more than a vague, abstract buzzword, it needed to be illustrated by real life projects. Only then could its implications be fully grasped, and acted upon in the development assistance process.
The people and economies of most Third World countries are heavily dependent on indigenous natural resources. Food production is a major activity for most rural people; and timber, paper, rubber and cotton textiles are but a few of the other industries based on natural resources. Thus, degradation or overexploitation of these resources directly affects economic development and human well-being.
Sustainable development is a multifaceted process, with economic, social and biophysical/technical dimensions. These factors are inextricably related, so it is meaningless to talk of the sustainability of any one on its own.
Sustainable development is a process rather than a product. A participatory approach, involving local people in decision-making and implementation, is a key factor in sustainability. It prevents inappropriate new technologies, organizations or practices from being foisted upon people by well-meaning but misguided outsiders.
This book covers a wide range of development activities, from soil conservation to cement production, from land capability assessment to upgrading squatter settlements. The lessons are numerous and diverse, but there are some key themes that recur. There are also general implications in the preceding chapters for aid agencies.
Thirty-four detailed case studies of aid projects and programmes illustrating sustainable development were commissioned for the IIED conference. Through these examples the conference aimed to assist aid agencies in identifying the types of project they could fund and the key factors in their successful implementation. The case studies were grouped into six sets, corresponding to the six parts of this book. General papers were then written, reviewing each of the six sets. These six overview papers form the bulk of this book, supplemented by summaries of each of the 34 case

studies. The full case studies can be ordered individually from IIED.
Improving the livelihoods of the poor is essential if pressures on the natural environment are to be reduced. Secure resources and adequate livelihoods lead to good husbandry and sustainable management; and by combating poverty they help to slow population growth. For these reasons, most of the projects described in the chapters are ones that have involved some of the poorest people.
The lessons and the recommendations can be considered under three headings: project aid; strengthening institutional capacity; and the national context.