

## IV CROPPING SYSTEMS

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## Cropping systems

Study, cropping systems, internal resources, sustainability, ecology, biological systems, low external inputs, rotation, conservation tillage, strip cropping, pest control  
FRANCIS, C.A. and KING, J.W.

Cropping systems based on farm-derived, renewable resources.  
Agric. Systems, 27, 1988, pp. 67-75

Crop production is a complex and integrated system. It uses a mixture of resources, some of which are farm or community derived and renewable and others which are external and purchased from outside.

This concept compares alternative sources of nitrogen, water and other growth factors needed to successfully produce a crop and maintain productivity. Internal and external resources are also used to control crop weeds and other crop pests, to provide labor and capital, and to manage the farm enterprise.

An internal or renewable resource is considered to be available on the farm or nearby. This includes rainfall, fixed nitrogen, nutrients from the soil, family labor and creative local management. Cropping systems which emphasize effective combinations of these low-cost internal elements can result in sustainable cropping systems. Such cropping patterns make use of the locally available renewable resource base and can be managed for profit as well as long-term sustainability.

In marked contrast, most production systems have been designed to use high levels of fossil fuel-derived, external resources which must be purchased or otherwise obtained from off the farm.

Examples of these components are synthetic fertilizers, chemical pesticides, irrigation water from deep wells or a distant source, hired labor and crop consultants. Since many of these resources depend on outside fuel energy, this approach is both more expensive and perhaps more tenuous in today's fragile international economic climate. With a production system based on external resources, it is possible to achieve and maintain high yields as long as those resources are available, the farmer has cash or credit to purchase these inputs, and the entire farm operation is profitable. Production systems based on external resources represent a dominance over the natural environment.

Most farming systems employ a mix of these two sources of inputs. Even the most isolated of subsistence farms has some input of new varieties or ideas from neighbors or visitors. The most externally-based, high-technology operation depends in part on soil-derived nutrients for crop growth and on rainfall for a part of crop water needs. Yet the contrast between internal and external resources is useful. More precise information about the efficient application of internal resources can be used to increase their relative importance. Use of information on crop and

pest biology and interactions among components can provide the basis for a shift in reliance from external to internal resources. It is important to design systems which include a logical balance or mix of resources. Few would question the value of increasing nitrogen fixation as a substitute for buying nitrogen fertilizer. Most farmers consider it cost effective to purchase and plant quality seed of improved hybrids or varieties rather than use home-grown seed, since this is a relatively small part of the total production cost and produces a high pay-off for the investment.

The principle remains: it is desirable to shift from heavy reliance on external purchased resources to an increased and judicious use of internal resources. With the right balance, this change can increase both the profitability of a farming operation and its long-term viability. Information on biological interactions in cropping systems can help.

Several examples are provided to show how information-intensive cropping systems can be structured to allow farmers to substitute use of internal resources for more expensive external production inputs. Carefully chosen maize or sorghum hybrids, rotation of maize with soybeans, weed control through rotations, conservation tillage, strip cropping, and pest control options illustrate some components of these systems. Cropping systems based on progressive biological sequencing and integrative farm structuring are described as broader examples of how components fit together. Building systems on renewable, farm-derived resources can lead to a more sustainable and ecologically sound agriculture.

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## Cropping systems

Asia, India, tropical climate, alfisol, experiments, energy input-output, sugarcane, crop sequences, multiple cropping systems  
SUNDARA, B. and SUBRAMANIAN, S.

Energy input-output studies of some crop sequences on short-duration sugarcane in relation to the conventional sugarcane system in tropical India.

Agriculture, Ecosystems and Environment, 20, 1987, pp. 49-57

High-intensity multiple cropping systems are necessary in the context of increasing pressure on cultivable land. Such cropping systems are usually input-intensive and thus energy-intensive. A evaluation of energy input-output relations in any new cropping systems is important. In India, short-duration sugarcane (*Saccharum officinarum* L.) varieties maturing in about 8 months as against the conventional varieties which require about 12 months are being developed. With such varieties, three crops (one plant + two ratoons) are possible in two years compared to only two crops (one plant + one ratoon) with the conventional varieties. Alternatively, after harvesting a plant and a ratoon crop of short-duration sugarcane (in 16 months), other short-duration rotational crops can be grown. Sugarcane has been considered as a renewable source of energy. In this context too, short-duration sugarcane

would be useful in producing greater amounts of biomass through multiple cropping. At the Sugarcane Breeding Institute, Coimbatore, India, some short-duration-based multiple cropping systems were evaluated for their production potential, economics and input-use efficiencies in comparison with the conventional system. In this paper the energy input-output relations of these cropping systems are discussed.

Multiple cropping systems based on short-duration sugarcane (with 3-4 crops per cropping cycle of 2 years) required about 40% more energy input than the conventional system of two sugarcane crops (one plant + one ratoon). In particular, energy inputs through fertilizers and labor were higher. Systems based on short-duration sugarcane gave a 14-27% higher energy output than the conventional system. Energy output-input ratios were slightly less in these systems than in the conventional one.

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## Cropping systems

Latin America, Colombia, experiment, acid soil, cowpea, groundnut, cassava, intercropping, plant population, spatial arrangement, dry matter, harvest index, starch productivity

FONSECA, P.D. and LEIHNER, D.E.

Efecto de poblaciones y arreglos espaciales de caupi (*Vigna unguiculata*) y mani (*Arachis hypogea*) en asociacion con yuca (*Manihot esculenta*) sobre produccion e intensidad del uso de la tierra.

(Effect of plant populations and spatial arrangements of cowpea and groundnut in association with cassava on production and land-use intensity).

Acta Agronomica, 33 (2), 1983, pp. 17-27

An experiment was carried out on an acid infertile soil in Quilichao (Cauca, Colombia) to determine optimal plant density and best spatial arrangement of 2 legumes (cowpea and groundnut) in association with cassava. Three plant densities were used for cowpea (80 000, 110 000 and 140 000 plants/ha) and 3 spatial arrangements (45/2, 70/2 and 60/3). Four plant densities were used for groundnut (150 000, 200 000, 250 000 and 300 000 plants/ha) and two spatial arrangements (70/2 and 60/3). Cassava density did not vary in either trial (9 259 plants/ha). Cassava root yield was reduced when planted with over 80 000 cowpea plants/ha; however, cowpea yields were not affected. Treatments did not affect the weight of 100 seeds nor the chemical composition of cowpea grains. Higher cassava and groundnut yields were obtained with 300 000 groundnut plants/ha in a 70/2 spatial arrangement. HI was higher in associated planting than in sole cropping.

Authors' summary

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## Cropping systems

Martinique, field trial, fodder plants, pineapple, monoculture, rotation

PINON, A. and CHAMPANET, F.

Essai d'introduction d'une rotation avec des plantes fourragères améliorantes en monoculture d'ananas. (Trial on introducing a rotation with soil-improving fodder plants into a pineapple monoculture system).

Fruits, 43, 1988, pp. 275-286

Since pineapple monoculture has been practised for a great many years and cattle fattening houses are found in the pineapple-growing areas, plans have been made to introduce crop rotations including fodder crops. The trial carried out in northeast Martinique showed that two species (*Brachiaria decumbens* and *Panicum maximum*) can meet the twofold objective, which is to produce abundant fodder and improve the soil through reduction of the number of soil parasites, deep rooting and good soil cover. For two other species, *Macroptilium atropurpureum* and *Mucuna pruriens*, the only advantages involved are that they increase the amount of organic matter produced and have deep-rooting systems.

Authors' summary

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## Cropping systems

Africa, Nigeria, rainforest zone, experiments, intercropping, sole crop, cowpea, cassava, yield, cultivar, vegetative growth, insects, fungi

WAHUA, T.A.T. and ORUBO, I.D.A.

Cowpea intercropped with cassava in a humid rainforest zone of Nigeria.

Tropical Grain Legume Bulletin (IITA), 33, 1986, pp. 1-3

Cowpea is usually planted in seasons when monthly rainfall is below 166 mm. In a heavy rainfall area like Rivers State of Nigeria, such periods fall between October and December or between February and April.

Cassava, the staple crop in this zone, is planted any time between February and October. With proper timing and early maturing varieties, solar radiation wasted between cassava rows during the first 3 months of establishment can be tapped with cowpeas. This strategy has been used to increase land productivity in different ecological zones. This study was designed to assess performances of four early-maturing cowpea cultivars intercropped with a common local early-maturing, non-branching, adapted cassava cultivar (Wocha) at Port Harcourt.

The effects of intercropping on yield characteristics of cowpeas depended on the cultivar concerned. The most affected cultivars were IT 820-889 and Ife-Brown, while IT 82 D-716 and TVX 3236 appeared to compete effectively with cassava. The average sole-crop

cowpea yields in the early seasons of 1984 and 1985 were 791 and 679 kg/ha, respectively. Corresponding mixture yields were 650 and 532 kg/ha, respectively, indicating an 18-20% reduction of cowpea by intercropping. This reduction was quite small compared with that caused by intercropping with cereals.

The yield reduction seemed to be connected with reduced early vegetative growth, which later affected number of pods per plant. Competition for soil might be responsible for that, since cassava was less than 0.5 m tall when cowpea was harvested. Even though late season yields were lower than those for the early season, only 2% of the late season grains were discolored through attacks by insects and fungi as opposed to 13.5% for early (rainy) season yields. Apart from the insects controlled with Ambush, a fungal disease caused by *Sclerotium rolfsii* killed about 1.7% of the plants in the early season and 0.8% in the late season, especially at poorly drained spots.

It seems that a good crop of cowpeas can be produced sole or in association with the common local cassava cultivar in Rivers State provided the planting is well-timed, insects are well-controlled, soil well-drained and fertilized within 3 weeks from planting, and the cowpeas harvested within 80 days. Proper planting time for cowpeas in Rivers State now needs to be investigated.

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#### Cropping systems

Papua New Guinea, field trials, fallow vegetation, secondary succession, subsistence use, selective plant use, deflected succession

LOUHMANN, B.T.M.

Subsistence use of fallow vegetation in the highlands of Papua New Guinea.

Netherlands J. of Agric. Sci., 35, 1987, pp. 546-549

The present study is an attempt to link Oldeman's model to the (traditional) practice of the Biangai people, living in villages southeast of Wau town, at approximately 7°25'S and 146°42' E, and at an altitude of 1000-1200 m. They mainly live from shifting cultivation practices, maintaining long tree fallows.

Based on information from local informants, ten study sites were selected. Two sites had been cultivated 5-8 years ago, two 8-12 years ago and two 15-20 years ago. Other sites had been subjected to frequent fires, lit for clearing purposes, of which the last ones had occurred less than one (1 field), 5 (1 field) and 20 years ago (2 fields). Sites varied in size from 100 m<sup>2</sup> to 500 m<sup>2</sup>, according to the extent of the cultivated surfaces. Climate and chemical soil fertility were approximately homogeneous over the study area. Transects were marked, profile diagrams drawn and data recorded. A reconstruction of the fallow cycle and its use by man has been attempted, combining data obtained from the profile diagrams with site histories.

The first one or two years after clearing, tuberous crops, viny crops and large herbs are cultivated, while woody seedlings of

genera such as *Macaranga* (Euphorbiaceae), *Trichospenum* (Tiliaceae) and *Lithocarpus* (Fagaceae) may be tolerated. In the second year, grasses and ferns have infiltrated the garden to such an extent that the area is left to spontaneous regrowth for 10-12 years. During the latter period the main human activity is extraction of firewood and of some medical plants (e.g. Zingiberaceae). Cutting of shrubs such as *Macaranga* sp. and *Acalypha* sp. (Euphorbiaceae) creates environments that are favorable to herbs and seedlings. Regrowth may continue beyond 12 years. In such regrowth, selective harvesting takes place of plants used for construction purposes, tool handles or weapons, e.g. *Dysoxylum* spp., *Aglaia* spp. (Meliaceae) and *Calamus* spp. (Palmae), respectively. Selective harvesting in its turn creates one-tree gaps, favoring other useful plants: encountered concentration of vines (tying purposes), grasses and Zingiberaceae (medicinal purposes), and the occurrence of fruit trees were due to these practices. It may, however, also set in motion successional processes that favor individuals of a later phase, e.g. *Elmerillia* sp. (Magnoliaceae).

Villagers consider a regrowth period of 10-12 years sufficient to restore the capacity of the site to produce crops. Often clear-cutting takes place at that time, after which the fallow cycle recommences with cultivation. Sometimes trees are left standing. Then succession is not completely interrupted and, after cultivation, regrowth occurs underneath an open canopy. Two of these latter sites were studied 15-20 years after recultivation. They had attained a tree stand with a basal area (trees with a diameter at 1.3 m of more than 10 cm) of approximately 0.4 m<sup>2</sup> per 100 m<sup>2</sup>, with densities of 4-6 trees per 100 m<sup>2</sup> (*Lithocarpus* sp., *Elmerillia* sp. and *Dysoxylum* sp.). These figures are similar to those of natural regeneration in a tropical, lower montane forest area in Papua New Guinea.

The frequent occurrence of uncontrolled fires in any phase of the cycle described above causes a deflected succession, which reduces the availability of useful plant species. This has been realized by the villagers, and regrowth on land that has been protected from fires for 20 years shows that occurring deflections were not yet irreversible.

With the exception of uncontrolled fires, the traditional practices of the Biangai people seem to enable practising a sustained management of an area with simultaneous:

- use of small areas for gardening,
- extraction of materials from the vegetation for subsistence requirements,
- growth of a considerable quantity of timber trees, and
- maintenance of a vegetation in which processes occur that resemble the local natural processes.

These traditional practices seem to support the above-mentioned model. However, insufficient sites were studied to obtain complete data on the effects of subsistence use upon the development of the fallow vegetation in the Wau area.

#### Cropping systems

Latin America, Costa Rica, experiment, intercropping, cassava, maize, spacing, minerals, fertilizers, costs, labor, economics, income

MENESES, R.R. et al.

Effecto de diferentes poblaciones de maíz al cultivarlos en asocio: 2. Aspectos económicos (Effect of different maize populations in associated cropping: 2. Economic aspects) Turrialba, 33, 1983, pp. 291-296

The economic efficiency and price sensitivity of cassava intercropped with maize at 5 different plant densities (0, 1, 3, 4 and 5 maize plants/m<sup>2</sup>; 90, 200 and 75 kg/ha of N, P and K, or 120, 200 and 150 kg/ha of N, P and K, respectively) were evaluated as part of an experiment conducted in Turrialba, Costa Rica. The economic evaluation was based on the general factor-factor and product-product models, assuming different decision-making circumstances. They included simple and combined restrictions on the availability of land, labor and cash, and the objective functions of maximizing food production and total economic efficiency. The prices used in the analysis were those available in Turrialba during May 1978 (US\$ 1 = ₡ 8.60). The prices for cassava and maize per tonne were \$ 75.50 and \$ 241.90, respectively. Results under different situations assumed for analysis indicate a lower price sensitivity and higher economic efficiency for cassava intercropped with maize at the lower fertilization treatment included in the test. The higher fertilization treatment tends to be more efficient in cassava monocrop or cassava intercropped with maize at the lowest density, particularly when cassava price tends to increase. One plant of cassava intercropped with two maize plants/m<sup>2</sup> and fertilization of 90, 200 and 75 kg/ha of N, P and K was the best evaluated option in terms of economic efficiency under all circumstances given for the analysis. The low sensitivity of this crop mixture to change in the price of maize, cassava and labor was also remarkable. Only when the cassava price decreases by 61% is it justified to intercrop 4 plants of maize/m<sup>2</sup>, provided the maize price does not decrease.

Authors' summary, revised

#### Cropping systems

Review, green manure, rice farming systems, sustainable agriculture

IRRI

The role of green manure crops in rice farming systems. Proceedings of a Symposium on Sustainable Agriculture, IRRI, Philippines, 1987, 19 pp.

Inorganic fertilizers are becoming more expensive. Another issue of great concern is the sustainability of soil productivity as

lands are called upon to produce higher yields from a single crop and higher total annual yields under intensive cropping systems. The soil organic matter and nitrogen levels vital to sustaining rice production are often limiting in East, South, and Southeast Asia soils.

Given this background, the Commission on the Application of Science to Agriculture, Forestry and Aquaculture (CASAF) and the International Rice Research Institute (IRRI) agreed to convene a series of symposia on sustainable agriculture. The first in this series was on the role of green manure crops in rice farming systems.

The objectives of the conference were:

- to review and summarize information on currently available technologies;
- to identify problem areas needing further scientific work;
- to determine the role of green manure crops in the development of integrated nutrient supply procedures for rice-based farming systems;
- to bring scientists of basic research disciplines who are working in relevant subject areas into contact with field scientists.

The symposium was attended by 92 participants and observers from 26 countries in Asia, Africa, Australia, and North and South America.

The effects of green manure on soil fertility in rice-based cropping systems were discussed after a key paper by D.R. Bouldin, Cornell University. Other participants presented research results and reviewed the literature in this area. Three papers were presented on integrated use of legumes. Deliberation on germplasm collection, testing, breeding, seed production, and management of desirable legumes for green manuring were presented. Symposium recommendations were planned by four assigned topic groups, and are presented in detail.

The symposium provided a unique opportunity to bring together most of the scientists from all over the world who are actively working on green manuring and related topics. It gave major impetus to research into using green manure to increase rice production in a sustainable agricultural system.

#### Cropping systems

Africa, Sierra Leone, study, cropping systems, smallholders, development project

ENGEL, A. et al.

Promoting smallholder cropping systems in Sierra Leone.

Schriftenreihe des Fachbereichs Internationale Agrarentwicklung, Nr. IV/86, SLE, Berlin, 1986, 226 pp. + IV-XI

The districts of Bo and Pujehun cover an area of over 8000 km<sup>2</sup> within the Southern Province of Sierra Leone. More than 80% of the 320,000 inhabitants live in rural areas and, for most of the households, farming is the major economic activity.

The annual average rainfall ranges close to 3000 mm and the average annual temperature is 26°C. The original rainforest vegetation has been replaced by a secondary forest growth derived from the bush fallow farming system. The main crops cultivated correspond with the diet. Rice, the staple food, is consumed along with palm oil and leaves from various crops (e.g. cassava). In addition, coffee, cocoa and other tree crops are grown on poorly managed plantations.

Cultivation of an upland rice farm (1 ha on average) is the dominant cropping pattern. The availability of land for upland cultivation is not seen as a problem. Farmers' knowledge on various upland rice varieties is considerably good. Insufficient seed reserves were reported, but this cannot solely explain the sub-optimal seed rates observed. The present upland rice farming makes efficient use of the limited resources, relying little on external inputs or non-renewable resources, but the possibility of increasing productivity is limited due to its low ecological potential and restricted labor resources on the farm level.

In the second year, the upland plot is often cultivated by women (63%), who keep the proceeds. The common crop is groundnut, intercropped with cassava or maize and vegetables.

Tree crop plantations, mainly coffee and cocoa, are poorly maintained due to improper brushing and the lack of adequate spacing and pruning. Individual nursing is rudimentarily developed because of a lack of inputs (polybags etc.), but there is considerable knowledge about nursing practices. Only 24% of the farmers prune their coffee (cocoa 9%). Lack of knowledge and experience are the main reasons. Tree crops, especially oil palm, fit well into the climatic and pedological conditions and, because labor input is low, they even give high gross revenues per man-day under low-yielding conditions.

In the comprehensive survey sample of 167 farmers, 53 different cropping patterns were found. Most cropping systems are a combination of food and cash crop patterns. The combination of mixed upland rice, tree crops, mostly oil palm and/or coffee, and second-year plot is most common. Swamp rice cultivation and tree crops is most common in households with limited labor resources.

Farmers who concentrate on tree crops are generally better-off and can more easily afford hired labor. The highest demand is observed for improved oil palms. There is a trend toward growing differentiation between farmers with good resource endowment (mainly labor for farm work) who can afford to concentrate on profitable tree crops, and those with poor resource endowment who have to rely on diversified subsistence production on the upland. This is of major importance for further project activities.

As a proposal for further project activities, the following key elements were worked out for a diversified production strategy:

- stabilization of the upland cultivation system,
- promotion of tree crop establishment on upland and rehabilitation of old plantations,
- support of development and cultivation of inland valley swamps,
- intensification of second-year plot cultivation on upland.

#### Cropping systems

F.R.Germany, ecophysiological studies, greenhouse, vegetation hall, Lablab purpureus, Sorghum bicolor, sole crop, mixed crop, sandy soils, greenhouse trials

SHANNAN, A.

Ökophysiologische Untersuchungen über Lablab purpureus (L.) Sweet und Sorghum bicolor (L.) Moench als Futterpflanzen in Rein- und Mischkulturen auf marginalen sandigen Böden. (Ecophysiological studies on Lablab purpureus and Sorghum bicolor for forage as sole and mixed crop on marginal sandy soils), Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen, 21, 1987, 182 pp.

Three series of trials were conducted with two lablab varieties and sorghum in the greenhouse and the vegetation hall.

#### 1st series:

This series involved studies of Lablab purpureus as sole crop under greenhouse conditions. The main results were:

- inoculation with rhizobia increased the dry weight of the shoots and the crude protein content;
- the symbiotic relationship of lablab and rhizobia depended on the lablab variety and rhizobia strain;
- with an initial fertilization of 20 kg N/ha and rhizobium inoculation, the dry weight of the shoots corresponded to the weight attained with a purely mineral fertilization with 187 kg N/ha and a crude protein content which was more than twice that of lablab plants fertilized with 250 kg N/ha;
- both lablab varieties showed the highest shoot dry weight, nutrient uptake, nodule dry weight and crude protein content at a water supply of 55-90%;
- water stress and high levels of salinity usually reduced nodule formation;
- an NaCl-soil-salinity of 0.05% increased the shoot dry weight and improved the nutrient uptake;
- 90 kg P/ha in combination with 120 kg K/ha resulted in the highest shoot dry weight, crude protein content and nutrient uptake;
- high NPK fertilization reduced the shoot dry weight and the nutrient uptake;
- soil temperatures of 20-30°C and soil pH values of 5.5 - 6.5 led to a high shoot dry weight with large differences between the lablab varieties.

#### 2nd series:

This series involved studies on Lablab purpureus and Sorghum bicolor as sole and mixed crops under vegetation hall conditions.

The following results were obtained:

- the shoot dry weight of the lablab varieties and the nutrient uptake of sorghum were improved by mixed cropping of lablab and sorghum;
- the highest shoot dry weight of mixed lablab and sorghum was found at a ratio of 1:5 (17% lablab);
- in order to reach the maximum shoot dry weight in a lablab/sorghum mixture, the proportion of lablab should be smaller than that of sorghum, because of competition for light;
- sorghum plants were more tolerant to soil salinity than lablab;
- the negative effect of soil salinity on lablab in sole stands was reduced by mixing it with sorghum;
- mixed cropping of lablab and sorghum was more effective in cases of phosphate shortage or when rock phosphate was used;
- in combination with soluble monocalciumphosphate, sorghum grew better as a sole crop, while lablab grew better in a mixture with sorghum;
- high N applications reduced shoot dry weight and P uptake of sorghum.

#### 3rd series:

This series involved studies of the effect of VA-mycorrhiza on Lablab purpureus and Sorghum bicolor as sole crops. The following results were obtained:

- inoculation with mycorrhiza improved the shoot dry weight of lablab and sorghum and increased their P uptake;
- the lablab varieties reacted differently to the various mycorrhiza strains and forms of P;
- the strongest influence of VA-mycorrhiza on sorghum was recorded in those plants given rock phosphate as source of P;
- a clear correlation between growth improvement and increasing P uptake could not always be established for lablab and sorghum.

Author's summary, amended

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#### Cropping systems

Africa, Sudan, field trials, sorghum, rice, soils, drainage, food production

STRUJF BONTKES, T.E.

Sorghum rice intercropping: a security system for the poorly drained soils of Southern Sudan.

Netherlands J. of Agric. Sci., 34, 1986, pp. 193-198

A large part of Southern Sudan lies in the Nile floodplain. Its overall topography can be characterized as flat, with small differences in elevation. Most of the soils are alfisols with poor internal drainage and little capacity to store available moisture, rendering them prone to both flooding and drought. The alfisols, which have a relatively sandy topsoil, are mostly found on the higher parts and the vertisols on the lower.

The inhabitants of the region are seminomadic subsistence farmers who grow some maize, cowpea, tobacco, okra and pumpkin on areas close to their huts, where flooding is rare. Their main crop,

however, is sorghum, which is grown on the high and intermediate areas around these fields. The farmers try to obtain 2 sorghum crops per year by ratooning the first crop or sowing a second crop at the end of the rainy season. Although differences in elevation within the field are relatively small, the intermediate areas may be flooded from time to time during the rainy season. Fortunately, sorghum is relatively insusceptible to flooding, but prolonged periods of waterlogging can nevertheless seriously reduce yields or may even kill the crop. Sorghum yields will therefore be relatively high in dry years and low in wet years. This makes food production in the floodplain unreliable.

In an attempt to obtain more reliable yields, the low areas were planted to rice. Yields were satisfactory, but because the low-lying areas constitute only a small portion of the farmers' field it was obvious that this was not a solution to the problem. This experience, however, prompted the suggestion that rice might also succeed on the intermediate areas in years of high rainfall, so that a sorghum/rice intercropping system would secure reliable food production: in dry years sorghum would grow well and in wet years rice would give good yields. To test this, a sorghum/rice intercropping experiment was set up on a field similar to those of the farmers.

The experiments were conducted in 1980 and 1981 in a field at An-yidi, a village 25 km east of Bor. Since the purpose of the experiments was to develop improvements which would be applicable by the local farmers, no action was undertaken to alter the irregularities of the soil surface.

The analysis of variance of the 1980 experiment showed that the sorghum yield varied significantly ( $P < 0.01$ ) according to the rice cultivar with which it was combined, but that the rice cultivars had no significant influence on the rice yields nor on the total yield per plot. The yield of sorghum and rice varied significantly per replication ( $P < 0.01$ ), but the combined plot yield was not influenced by the replication.

The analysis of variance of the 1981 experiment showed that the rice cultivar had no significant influence on the yield of sorghum, rice or the two combined. Here, sorghum was seriously affected by the soil moisture conditions but a combination of the two crops gave a fairly constant yield. It was also noted that the sorghum yields were higher and the rice yields lower in 1981 than in 1980, although there was not much difference in the total rainfall during the growing season. The explanation for this should probably be sought in the rainfall distribution during this period but relevant information was not available. Similarly, the fact that the rice cultivar influenced the sorghum yield in 1980 but not in 1981 may also be attributable to rainfall distribution. Intercropping of rice and sorghum is not common, as sorghum does not grow well in areas of high rainfall, while rice grows poorly in the drier areas suitable for sorghum. The results of these experiments show, however, that sorghum/rice intercropping may be useful under conditions of moderate rainfall combined with poorly drained soils. Areas which are sometimes flooded and sometimes dry produce intermediate yields for both crops. In this way, it is possible to achieve a food production system which is less depen-

dent on rainfall pattern. Other advantages are that: 1) rice suppresses weed growth on wet areas, and 2) by cultivating rice, optimum use is made of the high fertility of the low areas, which is brought about by the accumulation of fertile material from the higher areas.

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#### Cropping systems

Latin America, Peru, Andean region, evaluation, crops, intercropping, production systems

RIVERA, J.V.

Estudio sobre cultivos andios en el area del proyecto (Study on Andean crops in the project area)

Rep. Proyecto Piloto de Ecosistemas Andinos, Cajamarca, Peru, 1986

A field survey was carried out in the main area of the Andean Ecosystems Pilot Project, Cajamarca, Peru (ACP) in February 1985 to determine the distribution, area under cultivation, yield, production systems and problems that face Andean crops. Eleven local plant species were found distributed over the agroecological zone (ZA) of maize (2700-3200 m a.s.l.) and the agroecological zone of tubers and cereals (3200-3600 m). The Andean crops that occupy the largest cultivated area are: oca (*Oxalis tuberosa*), olluco (*Ullucus tuberosus*), chocho (*Lupinus mutabilis*), quinoa (*Chenopodium quinoa*) and mashua (*Tropaeolum tuberosum*), covering a total of 23.4 ha, of which 16.7 ha (71%) are devoted to oca, olluco and mashua (Andean tubers) and 6.7 ha to chocho and quinoa. Chamis has the largest area under cultivation (16.8 ha), at elevations of 3100-3200 m and 3500-3600 m, where predominantly tubers and chocho are cultivated. In the ACP area, intercropped fields are more numerous (71%) than fields sole-cropped (29%) with Andean tubers and grains.

The mixtures of Andean species frequent in the ZA of tubers and cereals are plots intercropped with oca and olluco (64%), and plots of oca, olluco and mashua; associations of oca and olluco with some quinoa are also common. In the ZA of maize, intercropped corn (65%) predominates over sole-cropped corn (35%). The most frequent mixtures are plots of corn with lines of quinoa in the higher areas within this ZA, and plots of corn with lines of bean in the lower areas. In Corisorgona, Upper and Lower Hualanga and la Shicuna, numerous parcels with intercropped and sole-cropped corn are found.

Andean tubers and grains are sown under dry-farming conditions on slopes ranging from 5 to 45%. These native plants are used mainly for home consumption; a very small quantity is sold. The peasants select the smallest tubers as seed. They do not select the Andean grains. For the consumption of chocho and quinoa grains, they use traditional methods to eliminate the bitter taste.

The germoplasma of Andean crops of the Research Center and Agricultural Promotion (CIPA-Cajamarca) and that of the peasants is large and it has several ecotypes of each species; by selecting the strongest, the most precocious and the most nutritive species,

it is possible to increase significantly the production of these species, without increasing the cultivated area. In this way, the nutrition level of the peasants, who consume mainly Andean tubers and grains, can be improved.

It is recommended to try the best ecotypes of tubers and chocho in Chamis, and the best lines of quinoa intercropped with corn in Corisorgona and Upper Hualanga. All native species must be tested with mixtures of varieties; some of them were selected for their drought resistance and others for their resistance to high moisture; these factors condition the severity of damage that plant diseases cause in Andean crops.

92

88 - 4/13

#### Cropping systems

Asia, India, field trial, banana, yam, turmeric, colocasia, intercropping, net profit

SATYANARAYANA, M.

Intercropping in banana.

J. Res. APAU, 13, 1985, pp. 28-34

Banana is interplanted with food crops, fruit trees, vegetables and condiments to produce extra food or income and to reduce the costs of plant establishment. In a number of studies banana yields were not depressed by intercropping. On the other hand, banana yields increased with green gram and black gram intercropping and decreased with cassava, groundnut, wheat and papaya intercropping. It appears that the kind of intercrop, its height and duration are instrumental for these varied results. This study was carried out at the Agricultural Research Station, Kovvur, India, to find out the effect of intercropping on the performance of banana and to evaluate the agronomic productivity and economic efficiency of intercrops in various cropping systems under banana.

Healthy suckers of poovan banana were planted during the last week of May 1980 and 1981 at 2 x 2 m (normal spacing) and 3 x 1.5 m (modified spacing for intercropping) in a randomized block design with 3 replications and with the following treatments.

Intercrops were planted immediately after banana planting, leaving 90 cm on either side of the banana plant. Fertilizer was applied separately to banana and intercrops. Each banana plant received 40 g of P<sub>2</sub>O<sub>5</sub> at planting and 200 g of N and 300 g of K<sub>2</sub>O in six equal dressings at 45-day intervals. When the intercrops were harvested, the tuber or corn or rhizome yields were noted in each plot and expressed per ha. Banana growth parameters and days to shooting were recorded.

Intercropping with yam alone or yam/elephant food yam or yam/elephant ear yam significantly reduced banana growth and yield and delayed shooting time, while turmeric and colocasia appeared to be compatible companion crops for banana. Elephant food yam alone and in association with elephant ear yam under banana produced significantly higher yield/ha/annum whereas elephant ear yam alone and in association with turmeric or yam brought lower yields.

The data on economics of intercropping in banana revealed that the yields of intercrops compensated for the extra cost involved. The net profit per ha (Rs. 50 844) was higher when banana was intercropped with elephant food yam + elephant ear yam, followed by banana + elephant foot yam (Rs. 46 137). Banana without intercrops give the lowest net profit (Rs. 10 306 to Rs. 11 313), followed by banana intercropped with elephant ear yam alone, elephant ear yam + turmeric and turmeric alone.

93

88 - 4/14

#### Cropping systems

Latin America, Mexico, highlands, experiments, germination, allelopathy, traditional agroecosystem, quelites, maize  
KAHL, H.

Allelopathic effects in the maize-quelite-agroecosystem of the Tarahumara Indians.

J. Agron. and Crop Science, 158, 1987, pp. 56-64

With reference to the maize-growing practices of the Tarahumara Indians of the northwest Mexican highland, some authors mention the occurrence of certain weeds that seem to appear naturally and by chance in maize fields and are used as wild vegetables, the so-called "quelites". These play an important role in the diet of the Tarahumara, providing them with minerals and vitamins that are usually missing in a maize-dominated diet.

The occurrence of quelites seems to be connected with maize in a still unknown way. Outside the maize fields the quelites appear scattered, but inside they are in a great abundance although not sown there. It has been hypothesized that allelopathic influences are effective in a maize-quelite agroecosystem. Little research have been done into allelopathic interactions in double-cropping systems. However, it will be impossible to integrate allelopathic influences effectively into methods of cultivation and weed management without a wide and profound understanding of the complexity of weed-crop interactions.

In this study, possible allelopathic interactions of the two quelite species, *Lepidium virginicum* (pepper grass) and *Bidens pilosa* (cobblers' pegs), and maize (*Zea mays* L.) are investigated in connection with their appearance in maize fields and their traditional use by the Tarahumara. Plants of these species were grown from seeds in the greenhouse and then transplanted to the field. Aqueous extracts were made with material of these plants and used subsequently in germination experiments.

In bio-assays with the two quelite species and different maize cultivars, it could be demonstrated that water extracts of leaves of *B. pilosa* and *L. virginicum* significantly stimulate seedling growth of maize. Different cultivars of maize showed no differences in stimulation by extracts of *B. pilosa*. This indicates an allelopathic potential of the tested quelite species. Extracts of leaves of older plants of *B. pilosa* (shortly before flowering) did not show this effect. Different water extracts of maize showed no

influence on germination and seedling growth of *B. pilosa* and *L. virginicum*.

Considering these results, the Tarahumara practice of leaving the quelites for a certain period in the maize and then harvesting them appears to stimulate maize growth. The maize-quelite double-cropping system seems to be fine-tuned and may be regarded as the result of a process of cultural learning among the Tarahumara.

94

88 - 4/15

#### Cropping systems

Africa, Cameroon, maize, soybean, intercropping, plant population, fertilization, nodulation  
SALEZ, P.

Quelques facteurs influençant le comportement du maïs et du soja cultivés en association. (Some factors influencing the behavior of maize-soybean intercrops).

Agronomie Tropicale, 41-2, 1986, pp. 101-109

In West Cameroon, preliminary studies were carried out on intercropping soybean with maize, which is widely cultivated on the farms where this legume is being popularized. First, the optimal plant populations for each species in intercrops, including two different phenotypes of maize, were determined. The most promising combination in terms of productivity, land equivalent ratio (LER) and income was selected for fertilization trials. The response of pure stands and intercrops to 2 levels of nitrogen and N-P application was tested in complex ferrallitic and andovolcanic soils. In intercropping, the LER and protein yield decreased greatly with increasing fertility of the root environment; this cropping system seems more adapted to medium and even unfavorable fertility conditions. Fertilizer application did not appear beneficial in andosols, but applications of 80 N - 100 P were profitable in intercropping on ferrallitic soils, even if the fertilizer efficiency was less than that reported for sole crops. Samplings in the fields showed that maize predominated over soybean and soybean nodulation was better in mixtures than in pure stands; this last result might direct future work.

95

88 - 4/16

#### Cropping systems

Africa, Ghana, sequence trial, maize, groundnut, productivity, residual value, succeeding crop

SCHMIDT, G. and FREY, E.

Combined intercropping crop sequence trials in the vicinity of Nyankpala.

Rep. Nyankpala Agric. Exp. Station, CRI/GTZ Joint Project, Tamale, Ghana, 1985/86, pp. 42-44

The experiments were carried out on small farms in the vicinity of Nyankpala in order to obtain additional information on the prod-

activity of maize/groundnut intercropping systems as well as on the residual value of such systems or of the respective sole crops for succeeding maize. The high productivity of a groundnut/maize succession was also to be demonstrated to the farmers.

One experiment was carried out at Dazuyili, 5.5 km SW of Nyankpala on a well-drained sandy loam. The other experiment was carried out at Kpachi, 4.5 km NE of Nyankpala on sandy loam with laterite gravel even in the topsoil. The drainage was very poor. In 1985 (test year) all plots were planted with maize variety Safita 2: at Dazuyili on 9.7.85 and at Kpachi on 11.7.85. Spacing was 70 x 30 cm on both sides; 60 kg P<sub>2</sub>O<sub>5</sub>/ha were given before planting and 40 kg N as ammonium sulphate on 12.8.85. Plot sizes were 4.20 m (6 rows) x 12 m at planting, of which 2.80 (4 rows) x 10.80 m = 21.84 m<sup>2</sup> were harvested.

Probably due to late planting, the maize did not develop well. At Dazuyili there was considerable soil variability, in particular in the vicinity of a locustbean tree (1st replication) under which maize growth was more vigorous than further away from the tree. At both sites, treatment effects as reflected in the results were already visible during the vegetation period. There was a high degree of variation and the question arises how such experiments on farmlands can be made accurate to allow definite conclusions to be drawn about treatment effects. In this case, it would have been advantageous to have had more than 4 replications.

In both experiments, sole crop groundnut was the best preceding crop for maize, followed by a 1:5 combination of maize/groundnut and N application to maize. On the other hand, sole crop maize and maize/groundnut combinations with a high proportion of maize (1 maize: 2 groundnuts) proved to be less favorable in terms of residual effects of N on maize in the next season. In spite of the high variability, the advantage of sole crop groundnut as a preceding crop for subsequent maize cultivation could be clearly demonstrated.

96

88 - 4/17

#### Cropping systems

Latin America, Colombia, experiments, cassava, cowpea, groundnut, intercropping, land use, harvest index, dry matter, leaf area, root productivity, nutrient uptake, MASON, S.C.

Land-use efficiency, canopy development, dry matter production and plant nutrition of cassava-grain legume intercropping.

Ph.D. Thesis, West Lafayette, Purdue University, 1983, 179 pp.

A 2-year field study was conducted to evaluate land use and interspecific competition effects on canopy development, dry matter (DM) production and nutrient status in cassava/cowpea and cassava/peanut intercropping systems. The influence of varying P application rates on interspecific competition in a cassava/cowpea intercropping system was also studied. Intercropping cassava with either cowpea or peanut resulted in approx. 25% greater land-use efficiency for the 11-month growing season than did sole cropped

cassava and sole cropped cowpea or peanut. The greater land-use efficiency when intercropped was associated with significantly greater leaf area and DM production during early growth than for those of sole cropped cassava, although at harvest the total leaf area and DM produced were similar for these cropping systems. Cassava yields were reduced from 0 to 35% when intercropped with cowpea or peanut. These yield reductions were associated with production of fewer storage roots/plant and lower LAI between 50-100 days after planting, when storage root initiation occurs. Intercropping with cowpea or peanut reduced cassava DM production by 200-600 g/m<sup>2</sup> in both years, which accounted for most yield differences between sole cropped and intercropped cassava. However, in 1982 when intercropped with peanut, cassava yield was further reduced, apparently due to sink size limitations caused by production of only 8.8 storage roots/plant. Nutrient concentration of intercropped cassava leaves were reduced when cowpea and peanut were growing most rapidly. Both cowpea and peanut seed yields and DM production were reduced 26-40% when these crops were intercropped with cassava, while LAI were reduced 10-30%. Increasing the P application rate from 0 to 44 kg/ha in intercropped cassava and cowpeas resulted in increased cowpea seed yield in both years, and increased cassava yield in 1981. No further cassava or cowpea yield increases occurred at P application rates greater than 44 kg/ha. Leaf area and DM production, and nutrient uptake were more responsive to P application for cowpea than cassava.

Author's summary

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88 - 4/18

#### Cropping systems

Book, review, tropics, cropping systems

PALANIAPPAN, S.P.

Cropping systems in the tropics.

J. Wiley & Sons Ltd., London, 1985, 215 pp.

This small paperback volume covers an important area of agronomy for Third World countries. Some 300 research papers are cited, mainly from India and especially from ICRISAT; but investigations conducted in other countries, particularly in Nigeria and the Philippines, are also described.

Intercropping and multiple cropping are subjects which are now attracting interest in Europe, and therefore this book should be welcomed by researchers in both temperate and tropical countries. The literature is methodically reviewed, with chapters covering principles and basic concepts, cropping systems in the tropics, management of soil fertility, and water and pest management. Also included are the vitally important aspects comprising economic and research methodology.

Despite the marked concentration on Indian work, the contents should be of great value to all students and researchers in this field. Investigation of the use of intercropping systems by small-holders could lead to major improvements in food production.

The book has considerable potential merit as a means of reawakening interest in the value of multiple cropping and the means of measuring its benefits. The need to breed cultivars adapted to conditions of stress and especially to the lower light levels prevailing in multiple cropping is recognized. Day-neutral genotypes are also becoming increasingly important, and are required despite the expensive nature of breeding programs. Such new cultivars are not likely to cost more to grow if they are adapted to the conditions of peasant farmers. The report that a yield advantage of up to 57% may be achieved by intercropping sorghum with groundnuts under a specific cropping pattern is very encouraging, as it suggests that other combinations could be equally successful. One is stimulated to ponder the impact which could be made if newer methods, such as the use of peat blocks, were introduced to enable planting to be timed to match good soil conditions. Such techniques, combined with intercropping, could reduce the field duration of crops and lessen competition.

The listing of cropping patterns for dryland situations makes the book valuable for advisors in the field. In addition, statements such as "crop intensification in dryland depends on the vagaries of rainfall" are vitally important, since they have not always been borne in mind. Such good advice abounds, and for this reason alone this book can be recommended to all tropical agriculturists.

98

88 - 4/19

#### Cropping systems

Europe, F. R. Germany, Göttingen, greenhouse experiment, plants, VA-mycorrhiza  
AHMADSAD, I.

Untersuchung der Außenmyzelbildung der VA-Mykorrhiza und deren Beziehung zur Effizienz dieser Symbiose unter verschiedenen Wachstumsbedingungen bei tropischen und subtropischen Pflanzen. (The development of extraradical mycelium of VA-mycorrhiza and its relationship to the efficiency of this symbiosis in tropical and subtropical plants influenced by various growth conditions). Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen, No. 11, 1985, 207 pp.

After developing a method for quantitative determination of the extraradical mycelium of VA-mycorrhiza, experiments were conducted in the greenhouse to ascertain the effect of different P sources, soil pH, soil salinity, soil moisture, soil temperature and light intensity on the production of extraradical mycelium of the VA-mycorrhizal fungus *Glomus macrocarpum* and to examine the relationship between the development of the extraradical mycelium and the effect of the symbiosis on P uptake and growth of *Capsicum annuum*, *Eupatorium odoratum*, *Sorghum bicolor* and *Guizotia abyssinica*.

The most important results are:

- In general, *C.annuum* and *S.bicolor* showed larger amounts of extraradical mycelium than *E.odoratum* and *G.abysinica*. An

increase of P uptake and growth after inoculation corresponding with the development of extraradical mycelium was only observed in *C.annuum*.

- The use of low-soluble phosphate favored the development of extraradical mycelium and disclosed a positive correlation to the respective increase of P uptake and growth through the inoculation.
- With all P sources, a better development of extraradical mycelium was observed at soil pH values of 6.5 and 7.5 than at pH values of 4.5 and 5.5, in most cases. As a rule no congruence could be observed between the development of the extraradical mycelium and the efficiency of the mycorrhiza at the individual pH values.
- Increased NaCl content in the soil did not exercise any direct influence on the development of the extraradical mycelium. Salinity increased the development of extraradical mycelium in the presence of adequate P supply (Marokko rock phosphate) but decreased the amount of extraradical mycelium in the low P treatments ( $\text{FePO}_4$ ). The P uptake activity of the extraradical mycelium seemed not to be reduced by NaCl.
- Low water supply (water regime 20%) favored the development of extraradical mycelium as compared to adequate and high water supply (water regimes 55% and 90%). In the treatment with Kodjari rock phosphate (trade product), the development of extraradical mycelium agreed with the decreasing mycorrhiza efficiency resulting from better water supply. In the presence of  $\text{FePO}_4$  and with adequate water supply, the extraradical mycelium was overproportionally active. In contrast to *C.annuum*, the development of extraradical mycelium of *S.bicolor* was favored by  $\text{FePO}_4$  with low as well as with high water supply. Also in the case of *S.bicolor*, the extraradical mycelium developed at adequate water supply may have influenced overproportionally the P uptake of the plants.
- Soil temperatures of 25°C, in contrast to lower and higher temperatures, favored the development of the extraradical mycelium and led to a more pronounced increase in P uptake and growth through the inoculation.
- Shading of the plants resulted in a decrease of development of extraradical mycelium, but led to an increase in the P uptake activity of the mycelium. Excellent light conditions (light intensity 100%) resulted in a higher unproductive P uptake through infection than low light levels (light intensity 30%).
- The total sugar content of the roots decreased as a result of the shading of the plants. This decrease showed a relationship to the reduction in development of extraradical mycelium and rate of infection caused by shading.
- At both levels of light intensity, 30% and 100%, inoculated plants showed a lower acid in the rhizosphere than uninoculated ones. This indicates that the improved P uptake by mycorrhizal plants supplied with low-soluble phosphate sources did not result from an increased availability of phosphate for the plant induced by acid in the soil.
- In most cases, a positive correlation between development of extraradical mycelium and rate of infection was found when dif-

ferent sources of phosphate and also various soil temperatures were compared, whereas in treatments with the other influencing factors such positive correlations were either absent or slightly indicated.

- The rate of infection did not always correlate with the extent of improvement of P uptake and growth through inoculation.
- Mycorrhizal plants generally took up more phosphate than needed for growth. The P uptake activity of the extraradical mycelium thus appeared not to be limited by absence of a P demand of the plants.

99

88 - 4/20

#### Cropping systems

Review, book, cropping systems, practices, research needs, ecological principles

FRANCIS, C.A.

Multiple cropping systems.

MacMillan Publ. Comp., 866 Third Avenue, New York, NY 10022, 1986, 383 pp., hardcover, ISBN 0-02-948610-6, US\$ 37.50

Multiple cropping, according to Francis, is the growing of two or more crops on the same field in the year. Sequential cropping is when the crops are grown in sequence; intercropping is when the crops are grown simultaneously. This book, with 15 chapters authored by 20 scientists, is devoted almost entirely to intercropping. Only the chapter dealing with cereals (Chapter 6) treats sequential cropping in any detail. The information is largely drawn from experience in the tropics, which is not surprising since that is where intercropping is most widely practised. Chapter 1 deals with the distribution and importance of multiple cropping and Chapter 2 provides a historical perspective on the subject. Chapters 3, 4 and 5 are ecologically oriented. Chapter 3 emphasizes relationships to the total agricultural ecosystem, whereas Chapter 5 discusses plant/plant interactions. Chapter 4 is one of the highlights of the book. It is an especially readable treatment of the modeling of resource use by intercrops. The author deals with the subject in general and substantive terms, wisely refraining from excessive mathematical documentation. Chapters 6 (cereals) and Chapter 7 (legumes and starchy roots) are very informative, and will be invaluable to agronomists. Chapter 8 discusses crop and soil management aspects of intercropping. Chapter 9 deals with insect, weed and plant disease management, but only weeds receive much management attention. The discussions of insect and disease are virtually confined to pest prevalence. Chapter 10 presents a concise treatment of the fundamentals of plant breeding, both in terms of methodology and genetic traits of importance for intercropped species. Chapters 11 and 12 deal with economics and the sociocultural aspects of intercropping. Research methodology and statistical procedures and design are the subjects of Chapters 13 and 14. Together, these two chapters form an important contribution to the furtherance of research in multiple

cropping systems. In Chapter 15, helpful advice on establishing research priorities is given.

100

88 - 4/21

#### Cropping systems

Africa, Nigeria, cropping systems, field trials, living mulch, alfisol, maize, legumes, nitrogen fertilizer, land management, tillage methods

IITA

Live mulch for intensive cropping.

Farming Systems Program Research Highlights 1981-84, IITA, Ibadan, Nigeria, 1985, pp. 11-13, ISBN 978-007-3

Maize can be grown in established live mulch covers of *Centrosema pubescens* and *Psophocarpus palustris* without weeding and nitrogen fertilizer. To assess crop response under intensive cropping in an alfisol, maize was grown continuously for two seasons each year during three years (1979-81) in a field subjected to several land management systems, including no-tillage, conventional tillage and live mulch. Nitrogen fertilizer levels were used as subplot treatments, plus a blanket application of 60 kg/ha of  $P_2O_5$  and  $K_2O$  in all plots.

Results of the three years of research show that maize yields averaged over five seasons of continuous cropping without nitrogen fertilizer were superior in a live mulch system (2.0 t/ha) to yields in either the no-tillage (0.8 t/ha) or conventional tillage systems (1.0 t/ha). Maize in the live mulch showed little or no response to nitrogen fertilizer. Good maize yields on a sustained basis and at low input levels could be observed only where the land management system involved the use of the legume cover crops (*Centrosema pubescens* and *Psophocarpus palustris*) as a live mulch. Maize yields in the conventional tillage system declined steadily with subsequent cropping, and this decline was not overcome by the application of nitrogen. In the no-tillage system, low maize yields were observed when no nitrogen fertilizer was applied. High maize yields were possible in the no-tillage systems with the application of 60 kg/ha or more of nitrogen. Response of maize to nitrogen was conspicuous in this land management.

The pattern of moisture depletion in the soil surface layers (0-30 cm) in the land management systems showed that the depletion rate was generally faster in the presence of the live mulches but that these mulches contributed to higher moisture retention in the soil following rainfall than either conventional or no-tillage. This is evidently due to protection of the soil surface against raindrop impact, maintenance of better soil structure, and better infiltration rate. Moisture retention was highest in *Psophocarpus palustris*, and, in general, a slightly higher moisture regime prevailed in weed-free compared with the unweeded plots.