The Role of Green Manures in Rainfed Farming Systems in the Humid Tropics

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Cover crops have been used for a long time by small farmers in the tropics in their crop rotations, mostly as a cheap source of biologically fixed nitrogen, for the recycling of leached nutrients, for protection against erosion, for the build-up and maintenance of soil organic matter and for the suppression of weeds. Unfortunately, these benefits have only recently begun to receive attention by scientists or development agencies, after a long period of neglect.

The use of cover crops is particularly relevant in the humid tropics, as high rainfall generally has depleted the soil of nutrients, especially nitrogen, which leaches easily. Levels of soil-organic matter are generally low, and there is a rapid and persisting weed growth, which is one of the main reasons why farmers have to abandon their plots (Nye and Greenland, 1960). Under these conditions, sustainable semi-permanent agriculture has to not only compensate for the nutrients removed by the harvesting of products, but also recycle the nutrients that have leached to deeper layers in the soil profile and suppress weed growth. Last but not least, the prevailing socio-economic conditions require that these measures be cheap, locally feasible and not labour-intensive.

Leguminous green manure crops (Anon., 1979) can be grown successfully if their growing period or plant geometry does not negatively affect the performance or the labour requirement of the associated food crop(s). Therefore, twining cover crops are usually grown in relay cropping with a food crop, if rainfall in the following months will allow the crop to produce sufficient biomass. However, in drier conditions the establishment of the legume as a companion crop to the (cereal) food crop may be required (Aggarwal and Garrity, 1989).

Since many green manures cannot be used for human consumption, other benefits should become obvious to the farmer after one or two cropping cycles. Grain legumes, although providing immediate economic benefit, tend to accumulate nutrients in the grain which is harvested, so that their effect on the performance of the following crop is usually low (Van der Heide et al., 1985). Nitrogen-fixing cover crops can be an excellent way to supply a substantial quantity of nitrogen and recycled nutrients to the annual crop rotation, by returning the total biomass produced to the soil, just before planting one, or a combination of food crops in the following season. Leguminous forage crops to provide feed for cattle can have a double function.

Nitrogen supply to food crops

In terms of nitrogen supply, green manures may contribute 30 – 60 kg N per ha annually (Greenland, 1985) or even over 100 kg N per ha (Bouldin, 1988) to the following crop. A substantial fraction of N in leguminous green manures mineralizes rapidly. The quantity and timing of N supply by decomposing residue should be adapted as well as possible to the demands of the succeeding food crop, taking into account the reutilization of residues from other crops in the rotation. The residual long-term effect of only one green manure crop is relatively small. The cumulative effects of continued use of such crops are important, not only in terms of N-supply but also in regard to soil organic matter and soil productivity.

These observations may be illustrated by experimental results from the high-rainfall zone of Nigeria (Van der Heide et al., 1985) where the residual effects of 4 years of continuous cropping and annual fertilizer applications of 0, 45, 90, 135 and 190 kg N per ha on soil productivity were assessed, using the following annual crop rotations:

- Intercropping maize (first season) and cassava (whole year)
- Monocropped maize (first season) followed by cowpea (second season)

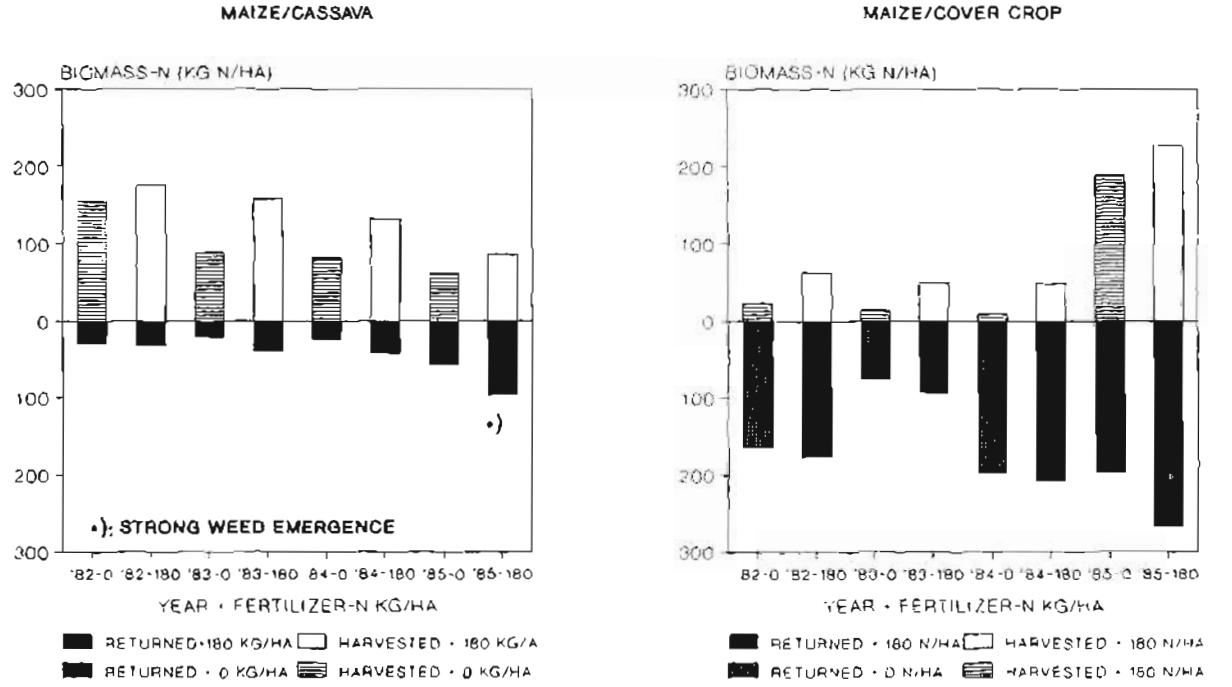

Figure 1. Nitrogen in plant residues harvested and returned to the soil in two crop rotations in S.E. Nigeria.

- Maize (first season) followed by green manure *Stylosanthes guianensis* (second season, 1982) and *Mucuna utilis* (second season 1983-1985)
- Intercropping maize (first season), cassava and tree type Pigeonpea (*Cajanus cajan*) (whole year).

Considerable differences among these cropping systems exist in the ration of N removed from the field and N returned through plant residues (Van der Heide, 1988) (fig. 1). As a result, significant differences in residual effects occur, as measured in the 5th cropping year in unfertilized monocropped maize used as test crop (fig. 2). This experiment demonstrated that incorporation of a leguminous green manure in the cropping system led to a better soil productivity than the other cropping systems, whereas no significant residual effect from previous N-fertilizer applications was observed. Similar observations have been reported from the humid lowlands of Mexico (Gliessman, 1982)

Soil organic matter

Generally, soils in the humid tropics are highly weathered and leached, with most of the available nutrients present in the organic topsoil (Sanchez, 1976). Because organic matter supplies most of the cation exchange capacity, the rapid decrease in organic matter content that usually occurs when primary forest is converted to agricultural land, results in a marked reduction in nutrient holding capacity of the soil (Von Uexkull, 1986). An adequate level of organic matter in the topsoil is therefore vital to the sustainability of cropping systems where no or only a limited fallow period is included.

Slowly decomposing residues may have an important effect on the organic matter content of the soil (Bouldin, 1988), but this effect will occur only after a period of several years (Van Faassen and Smilde, 1985).

As an example, in an experiment in Indonesia we found that the estimated N-input (biomass multiplied by N-content) to the soil was higher for *Crotalaria juncea* than for *Mucuna utilis* (198 and 71 kg ha respectively), but maize production was higher after Mucuna, as Mucuna residue decomposes more quickly than Crotalaria. The extra N-uptake by maize (uptake following cover crop minus uptake by control) was 121 and 147 kg/ha respectively (Hairiah and Van Noordwijk, 1989). The extra N-uptake by maize following Mucuna was even higher than the estimated N-input, possibly due to decomposition of dead Mucuna leaves during growth of this cover crop. In a similar experiment, which is still going on, we anticipate that Crotalaria will have a stronger impact on soil organic matter build-up in the long run, as compared to Mucuna. The evaluation of the effect of the incorporation of a green manure into a crop rotation system should take a prolonged period into account, and not be limited to a cropping cycle of one year.

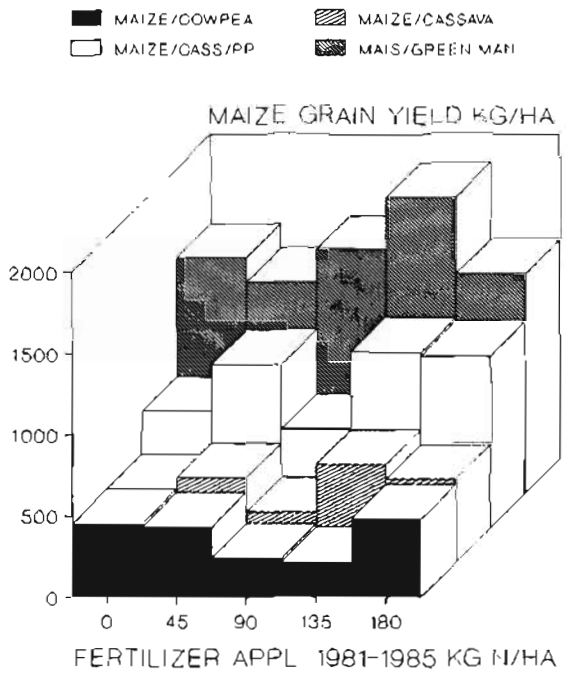

Figure 2. Residual effects of 5 years continuous growing of 4 cropping systems, and applications of 5 levels of N-fertilizer in S.E. Nigeria.

Recycling of nutrients

Deep-rooted crops in a rotation system may help to recover nutrients leached to the subsoil. How deep roots have to go in order to contribute to the recycling of nutrients depends on the amount and distribution of the rainfall, the buffer capacity of the soil for the nutrient in question (biological or chemical) and the duration of the process of leaching (Van Noordwijk, 1989). Under high rainfall conditions, especially at the start of the rainy season, permanent deep root systems, as some trees have, are required for recycling. Most food crops have a shallow root system due to the adverse soil conditions and their root system may develop too slow to intercept the mineralization flush which occurs when the soil is rewetted. As far as we know, the leguminous cover crops *Centrosema*, *Pueraria* and *Crotalaria* can develop deep root systems on acid soils in the humid tropics. The fast growing Mucuna is shallow-rooted and is not drought-tolerant on acid soils. The deep-rooted cover crops however, usually establish themselves relatively slowly, and are therefore unable to control weeds effectively (Hairiah and Van Noordwijk, 1987).
Normally shallow-rooted crops can develop deep roots by following old root channels left in the soil by crops or trees. In deeper layers of the soil they can recover nutrients from leachates, which are mostly transported through the same channels (Van Noordwijk, 1989).

Weed Control

„There is no doubt that the increasing effort of keeping the land free of weeds as the cropping period proceeds is often the primary reason for a patch of land being abandoned" (Nye and Greenland, 1960). Particularly if land resources are becoming scarce, and fallow periods have to be shortened, persistent weeds such as *Imperata spp* proliferate, ultimately resulting in the establishment of anthropogenic grasslands that are extremely difficult to recover for agricultural purposes (Srivastava, 1986).
It is remarkable that the potential of cover crops to control weeds has hardly been investigated. However, on several occasions where shifting cultivators have been obliged to shorten or abandon the fallow period, they have resorted to the use of cover crops to suppress weed emergence, such as *Mucuna (Stizolobium) deeringiana* (Bort.) in Northern Colombia (Van Eijk-Bos, 1986), Yam beans (*Pachyrhizus erosus*) in S.E. Asia, or *Mucuna sloanei* (Anon., 1979) and *Mucuna utilis* (Akobundu, 1983) in W. Africa.

A rapid establishment is crucial to the seed suppressing potential of a cover crop. Akobundu and Poku (1984 and 1985) observed that *Mucuna utilis* was able to completely cover plots infested with *Imperata cylindrica* (density before treatment 100 stands/m2) in a period of 19 weeks, and continued to suppress the weed throughout the year. This is due to the vigorous growth in the first weeks after planting, as demonstrated by observations of light interception by

6 cover crops in Nigeria (figure 3, Hairiah and Van Noordwijk, 1986).

When introducing a cover crop in an existing crop rotation system, a good potential for weed suppression is the key to farmers acceptance, as beneficial effects from weed control may be observed right after establishment of the cover crop, while effects of improved nutrient supply may occur only in the longer run.

Kretschmer (1989) discussed the growth habit, suitability as fodder, tolerance to soil acidity and water requirements in the growing season of 50 tropical legumes. Root characteristics are known for only a few species. Within each species, considerable variation in important characteristics occurs. The task of collecting and comparing tropical germplasm has only recently been taken seriously.

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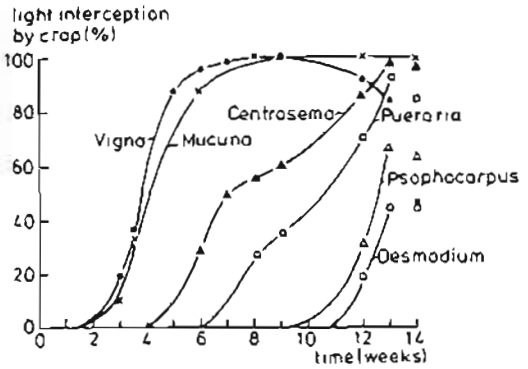

Figure 3. Light interception by six cover crops comparing light intensities inside and outside plots.

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Further reading:
Green Manuring with Fast-Growing Shrub Fallow in the Tropical Highland of Rwanda. Kurt Raquet. In: **Ecofarming Practices for Tropical Smallholdings, Research and Development inTechnical Cooperation.** Johannes Kotschi (ed), Working Papers for Rural Development Nr. 14, 1989. GTZ, P.O. Box 5180, D-6236 Eschborn 1, R.F. Germany
The „Projet Agro-Pastoral" of Nyabisindu, Rwanda (altitude: 1600-1850 m, rainfall: 950-1400 mm) has positive results with *Mucuna utilis* in single-season fallow. Promising results were also obtained in multiple-season fallow with a mixture of shrubs, *Cajanus cajan, Crotalaria lachnophora, Tephrosia vogelii*, and the soil coverers *Desmodium intortum and Desmodium uncinatum* which were occasionally supplemented by the shrubs *Crotalaria pallida* and/or *Sesbania macrantha*. With regard to the soil-desinfecting effects of some compositae, notably *Tagetes*, deliberately tolerated weed growth in the first year is highly effective with the multiple-season fallow.
In the same publication **Conservation of soil fertility by peasant farmers in Atlantic Province, Benin** Anne Floquet. Besides farmers' innovations in soil fertility conservation, successful project experiences with *Cajanus cajan* as green manure are described.