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Improvement of soil fertility and weed suppression through legume-based technologies

Collaborative Group on Maize-Based Systems Research (COMBS)

Research Guide
Guide de recherche
Guia de Pesquisa

48

IITA Research Guide 48

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April 1995

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Collaborative Group on Maize-Based Systems Research (COMBS). 1995. Improvement of soil fertility and weed suppression through legume-based technologies. IITA Research Guide 48. Training Program, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 52 p. Second edition.

Improvement of soil fertility and weed suppression through legume-based technologies

Objectives. This guide is intended to enable you to:

- analyse the role of legumes in farming systems;
- determine criteria for characterization of target zones and technologies;
- characterize target zones;
- characterize legume-based technologies;
- match target zones and technologies;
- analyse gender implications for on-farm testing.

Study materials

- Color slides showing problems in different farming systems, as described in Section 1.
- Samples of leguminous plants.
- Farmers' fields.

Practicals

- Select a farming system in your area. Determine the most relevant criteria for characterizing the target zone. Characterize promising legume options and select the most appropriate ones. Describe how the legume options may fit into the target zone, considering gender implications.

Questions

1 Why are farmers in West and Central Africa confronted with intensification of land use?
2 With what problems do farmers have to cope because of land pressure?
3 Why do legumes currently present the best potential to maintain soil qualities?
4 How can legumes be integrated into existing cropping systems?
5 What is presently the most important task with respect to legume technologies?
6 Why did technologies developed on-station often fail to fit farmers' needs?
7 What steps are required to match promising technologies with diverse farming systems?
8 What factors have a major influence on the appropriateness of legume technologies?
9 Where are labor-intensive legume systems likely to be rejected?
10 What benefits can legumes contribute to the farm?
11 How can you characterize climatic zones based on rainfall?
12 How can you characterize market access?
13 How can you acquire the necessary information for a complete characterization of target zones?
14 Where can you obtain information on legume species?
15 At what stages should you integrate gender considerations into the procedure?

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Abstract. Increasing populations in West and Central Africa leads to intensification of land use and reduced fallow periods. Agricultural intensification in turn, results in degradation of soil fertility, erosion, spread of diseases, pests and weeds. Leguminous plants, integrated into existing cropping systems, currently offer the best potential to overcome constraints. The Collaborative group on Maize-Based Systems Research (COMBS), through on-farm research, tries to match available technologies with a diversity of farming systems. This document is based on present experiences.

1 Role of legumes in farming systems

Farmers in West and Central Africa are confronted with intensification of land use and reduced fallow periods, because of increasing population. This phenomenon however, varies from country to country, between zones within the same countries, and even from farmer to farmer.

Farmers in the derived savannas of southern Benin Republic, for example, have to cope with land scarcity, degrading soil fertility, spread of weeds and inaccessible inputs, like fertilizer or herbicides. In the northern guinea savanna of Nigeria, farmers are confronted with the degradation of soil, physical and chemical properties in intensified cereal-based cropping systems, using subsidized fertilizer and abandoning the fallow period totally. In the mid-altitudes of Cameroon, crops are planted on originally rich, volcanic soils that are degrading because of acute land pressure, erosion and lack of practices for soil fertility maintenance.

Additionally, cereal-specific pest species within the parasitic weed complex of *Striga*, or cereal nematodes can increase to major constraints.

Farmers experience similar basic problems of soil fertility maintenance and decreasing land productivity under diverse ecological and economic conditions. They need technologies which can help to ameliorate problems. Researchers who have appreciated these problems as major constraints to sustainable crop production, have developed a range of technological options and are making increased efforts to take the long term maintenance of crop productivity into consideration.

Leguminous plants currently present the best potential to contribute significantly to the maintenance of nitrogen levels, organic matter content and physical properties of soils in intensified cereal-based cropping systems. Legumes like cowpea and groundnut play important roles in many areas of West and Central Africa as sources of food and feed.

Other species like pigeon-pea or *Dolichos lablab* that give food grain and fodder are less widely spread. The use of legumes like *Mucuna* spp., *Crotolaria spp.* or *Aeschynomene* spp. is hardly known to farmers, although extensive research activities on-station show contributions of these legumes to the productivity of cereal-based systems.

Legumes can be integrated into existing cropping systems as cover crops, live-mulch, fodder, or food crops, and the integration may be achieved through alley farming, planted fallow, or multiple cropping systems. The most important task at present is to identify the most relevant legume technology for each target zone and to encourage farmers to test and eventually adopt them.

COMBS developed the outlined approach to technology targeting in order to support farming systems researchers in their efforts to identify the most appropriate legume-based technologies for soil fertility improvement and weed suppression in their mandate areas. Too often, the technologies developed on-station failed to fit farmers' needs because of improper targeting. The synchronized characterization and targeting as presented here contribute considerably to the definition of recommendation domains for testing legume-based technologies on-farm.

COMBS is at present developing a database on the most promising legumes, which is a prerequisite for the selection of the most appropriate technologies out of all available options. At the same time, farmer-participative field work is ongoing in order to test and further develop our concept of the decision process and match it with the farmers' perceptions.

On-farm research tries to match the diversity of promising available technologies with the diversity of farming systems in a mandate area in order to identify the most appropriate technologies for each target zone. Recommendation domains are defined on the basis of such efforts. For this process, four steps are required.

The **first step** requires the definition of criteria which are most relevant for characterizing target zones and technologies (Section 2). The criteria should be relevant and easy to use for the differentiation of zones and technologies.

The **second step** involves ecological and socioeconomic characterization of target zones and farming systems (Section 3). Diagnostic methodologies for the description of target zones and farming systems have been described extensively. Multi-disciplinary teams identify and divide the area into zones, stratify farms into homogenous groups and prioritize the major cropping/farming systems. However, data are rarely used for progressively defining research and recommendation domains according to the prevalent constraints and the most promising technologies. The technique described in Section 3 guides researchers in using information from diagnostic surveys for the definition of recommendation domains for legume-based technologies.

The **third step** requires the agronomic and economic characterization of technologies (Section 4). Methods for analysis of cropping systems and on-farm experimentation have been adequately described by agronomists and are being used for practical on-farm work. The conceptualization of the on-farm experiments into a framework of technology characterization according to its major constraints to acceptability and its major contributions needs further efforts. Section 4 describes such an approach for leguminous crops.

The **fourth step** which is the identification of the most appropriate legume cropping system for the improvement of soil fertility and weed suppression, requires a synchronized characterization of target zones/farming systems and technologies (Section 5). Both have to be matched together to identify the most appropriate species in a target zone.

2 Criteria for characterization

The biophysical (soils, climate, topography, vegetation, etc.) and socioeconomic (land, labor, capital, human) factors in the geographical mandate area have to be identified and characterized, as these factors have a major influence on the appropriateness of the different technologies. For example, legume species have specific adaptations to climate and soil, and labor-intensive legume cropping systems are likely to be rejected where labor is scarce.

Factors in the overall farming system that might be significantly influenced by the introduction of legume options should be identified and characterized. Legume options can contribute food, nitrogen, organic matter, fodder, firewood or soil cover to the farm. Farmers respond to these contributions differently, based on specific needs and constraints experienced on their farm. For example, palatable legumes can be used for fodder, if livestock is an important component of the farming system; food legumes like soybean may be attractive in areas close to major markets.

In the overall analysis, the characteristics of a target zone i.e. the biophysical, and socioeconomic constraints and opportunities have to be matched with the necessary information about technologies. COMBS is using this approach in its work on leguminous crops. It selected parameters according to the present state of knowledge from on-farm work in the West and Central African sub-region. New criteria will be added as on-farm experimentation progresses.

The following description refers to Table 1, which lists a definition of criteria for target zone characterization and their relevance to technology characterization for the integration of legumes into farming systems.

Ecological conditions and adaptation of species. Parameters 1 and 2 (climatic zone and altitude) are general biophysical characteristics of target sites. Only legume species that are adapted to these conditions should be selected for these sites. The following 6 parameters (3-8) characterize soil related constraints of acidity, fertility degradation, water logging, erosion and compaction.

The occurrence of bush-fires and residue burning has been included here as a soil management factor. Characteristics mentioned above may be related to parent material, topography, land scarcity and lack of fertilizers resulting in wide-spread problems of soil acidity, erosion or degradation. However, they may be field specific as well, relating to crop and individual farm management or micro habitat differences.

The same target site is therefore often heterogeneous for these characteristics, and it is in such cases more appropriate to develop on-farm testing on the basis of recommendation domains with target sites that are representative of such characteristics rather than for geographically defined areas. The legumes to be selected for each of them should not only be adapted to the constraints of the sites as for example soil acidity or soil compaction, but should also contribute to reducing or overcoming these constraints.

Requirements of a site and potential contributions of species. Parameters 9-13 characterize sites in their agricultural produce requirements and their major biotic constraints. Legumes can contribute directly through food grains, (cowpea, soybean, pigeon pea, ...), fodder, (*Aeschynomene* spp.,*Centrosema* spp., *Dolichos* spp., ...) or wood, (*Gliricidia* spp., *Cassia* spp., ...) to the availability of scarce and marketable farm products. They may also contribute indirectly to the productivity of other crops by reducing biotic constraints like cover crops for weed control or trap crops for parasites. Any legume introduced into a system should not be an additional host of already existing soil-related pests.

System description and integration. The last eight parameters (14-21) describe the socioeconomic environment of the sites and agronomic niches in the present cropping system. These characteristics are related more to the system of legume integration, for example through planted fallow rotation or relay planting of a food legume, than to the legume species.

System description and integration allows for identification of the most promising ways of how the legume species selected through parameters 1-13 could be integrated into the prevailing farming system. The most promising species and method of integration should then be tested in the recommendation domain. Farmers' participation is an essential requirement during the on-farm experimentation phase.

Table 1. Target zoning and technology characterization: Parameters

Characteristic	Definition	Relevance
Ecological conditions and adaptation of species		
1 Climatic zone and rainfall	Length of growing period = number of days when precipitation is above 1/2 potential evapotranspiration: 210 days Humid forest and forest-savanna transition zone 180-209 days Southern guinea savannas 150-179 days Northern guinea savannas 120-149 days Sudan savannas	Legume species differ in their adaptation to the climatic zones; *Pueraria* is better for the forest zone and *Stylosanthes* is better for the savannas.
2 Altitude	Meters above the sea-level in tropical latitudes < 800 Lowlands 800 -1600 Mid - altitudes >1600 High - altitudes	Legume species differ in their adaptation to temperatures in different altitudes; beans *(Phaseolus)* are better adapted to mid-altitudes and cowpea to lowlands.

3 Soil acidity	Soil pH (in water) <5.0 acid 5.0-6.0 moderate 6.0-7.0 neutral >7.0 alkaline	Some species are tolerant to soil acidity (e.g. cowpea, *Pueraria)*, others are tolerant to alkalinity *(Rhynchosia, Lens)*.
4 Fire	Frequency of bushfires and residue burning: frequent moderate rare	Most species are susceptible to fire but some species are highly tolerant *(Stylosanthes guianensis)*. Others can quickly recover from the root stock or seeds.
5 Soil fertility	Soil organic carbon content (%) or visual evaluation of the weed vegetation can be used for the characterization of the status of soil degradation. < 0.3 very low 0.3-0.8 low >0.8 moderate The contribution of a species as a monocrop to the change of nitrogen in the soil over one season can be defined as: >60 kgN/ha = high increase + 20 to + 60 kgN/ha = moderate increase - 20 to + 20 kg N/ha = neutral - 60 to - 20 kg N/ha = decreasing	Some species like *Acacia auriculiformis* or *Flemingia* can grow in and restore highly degraded soils, whereas others require a minimum level of soil fertility for establishment. The contributions of legumes to soil fertility also vary widely; *Centrosomes* contributes more to short-term N-flush in the soil, whereas semi perennial *Stylosanthes* contributes more to the build-up of soil organic matter.

6	Water logging	The frequency of water logging conditions in the field during the growing season. frequent temporary rare	Sites with frequent or temporary water logging require species like *Aeschynomene* or *Sesbania*, that are tolerant to such conditions.
7	Soil erosion	Soil erosion depends on slope, soil type, crop and soil management and climatic factors. The severity can be estimated as: severe gully erosion severe sheet erosion moderate light	Species with a slow early growth and superficial root development are less suitable for erosion control than deep rooting, perennial species that grow quickly.
8	Soil compaction	The degree of soil compaction depends on soil type, soil management, crop species grown and climatic factors. It can be measured through the analysis of soil bulk-density: >1.5 severe compaction 1.3-1.5 moderate compaction <1.3 low compaction	The rooting pattern of the legumes, the surface cover during the season and the contribution to soil-organic matter are important criteria to be taken into account. Pigeonpea has a deep tap root and covers the ground well as a semi-perennial whereas groundnuts can even increase soil compaction.

Requirements of a site and potential contributions of species

9 Food	The need for food exists everywhere, but the interest in food from legumes increases as farmers get through their total yields more competitive prices against the other food crops. Farmers interest in a food legume can at present only be estimated: high interest, as other food crops have comparatively low productivity, moderate interest, low interest as other food crops are very competitive.	Traditional legumes like cowpea or bambara contribute grain for home consumption, others like *Psophocarpus or Pachyrrhizus* produce edible tuberous roots.
10 Fodder	The value of legume-derived fodder depends on the husbandry system in the area, the availability and prices of alternative fodder items. Further research is necessary to define the parameters. well established fodder markets, dry season fodder markets occasionally, no fodder requirements.	Some legumes are unpalatable hence they are adequately protected against roaming cattle, whereas other legumes can be harvested as hay and sold in the market.

11 Wood	Wood may be needed for fire, construction or staking and its value in the farm depends on the prices for alternative materials. Further research is necessary to develop criteria for the parameters: no wood scarcity, fire wood scarcity, construction wood scarcity, staking material scarcity.	Yams or climbing beans require stakes that can be produced from certain alley-trees.
12 Weeds	A high incidence of noxious weeds increases weeding efforts and can reduce crop yield. The major weed species to be suppressed should be indicated: perennial grasses like *Imperata* annual grasses like *Rottboellia* perennial sedges like *Cyperus* *rotundus* annual sedges like *Kyllinga* perennial broad-leaf weeds like *Eupatorium* annual broad-leaf weeds like *Commelina* parasitic weeds like *Striga*	Legumes contribute best to weed suppression if they have a vigorous early growth, and cover the soil quickly. Climbing legumes like *Mucuna* are more likely to suppress erect and tall growing grasses than bush-type legumes. Parasitic weeds like *Striga* are best reduced through legumes that have a trap crop effect (stimulate *Striga* germination without being a host).

13 Pests	Certain soil-borne pests can accumulate in cereal-based cropping systems: nematodes like *Pratylenchus* pathogens like *Fusarium moniliforme* soil millipedes soil white grubs or in legume based cropping systems: nematodes like *Meloidogyne* pathogens like *Sclerotium rolfsii* millipede insects The knowledge about the major soil-borne pest that causes considerable yield reduction is desirable.	The introduced legumes should not be hosts of existing pests in the system, they should rather contribute to reduce the pest constraint. *Mucuna* and *Crotolaria* have been used to reduce soil nematode populations, whereas *Gliricidia* can host the adults of white grubs.

System description and integration

14 Land	Percentage of arable land being cropped every year (land use intensity ratio R). >66 land scarcity 66-20 moderate scarcity <20 abundant	Different systems of legume integration have different land requirements; multiple food crop systems can reduce land requirement for a unit of output, whereas planted fallows increase it.

15 Land tenure	Land tenure systems vary widely. The length of the period of secured land ownership is considered: permanent long-term 3-8 seasons moderate 1-2 seasons short-term	Long term investments in soil improvements or fertility maintenance require not only a high value of land but also security of land ownership. Alley cropping systems and fallow systems require moderate to long-term land ownership.
16 Labor	Price ratio of labor cost per 1 man-day and cereal product price of 1 kg at the farm-gate during period of the major labor demand. <10 abundant 10-20 moderately scarce >20 scarce	Alley cropping systems need additional labor for pruning. Groundnuts are labor demanding at harvest whereas planted fallow systems require labor for planting and slashing.
17 Market access	The access to markets allows the purchase of inputs and the sale of produce. It depends on the road network, the distance to the next market town, transport costs and purchasing power in the market (including industrial use). The parameters need further research for better definition. poor access moderate access good access	Legumes like soybean have a good market for industrial use whereas traditional legumes depend less on market availability as they are used for home consumption.

18 Material input	Price ratio of the input price (including transportation to the farm) and the farm product price is calculated. For nitrogen fertilization, the ratio of 1 kg N fertilizer to the maize price can be defined as follows: >8 difficult access 3-8 moderate access <3 good access for farmers	Fertilizers are a major input for soil fertility maintenance. Some legumes can contribute up to 150 kg N/ha per year, whereas an early soybean variety may even reduce N in the soil because of seed export.
19 Cash	The time lag that farmers can accept for an investment is used as a criteria. < one season scarce 1-2 seasons moderately scarce > 2 seasons less scarce	Fertilizers are purchased with cash and the return is expected at harvest. Some legume technologies require an investment at planting, and the cash return comes only after 2 - 3 seasons. The availability of family labor against hired labor is relevant here.
20 Extension and rural institutions	The level of training of the farm community and the access to extension services depend on the rural infrastructure and the existence of a functional extension system. good new technologies can easily be transferred to the farm community moderate - poor access and training levels are poor	The introduction of new components into existing farming systems requires transfer of the necessary management skills. Some legume technologies like alley cropping or soybean utilization require the transfer of specific skills to the farmers.

21 Cropping system	A comparison of the growth period in the target zone against the phenology of the different predominant cropping systems helps to identify agronomic niches in the cropping patterns, where physical resources (precipitation, light, soil nutrients) are not fully used. The present role of legumes in the system should be taken into account. no niche any introduction of a new crop requires the replace- ment of an existing component. early season the present system does not fully utilize the early season resources. late season the present system does not fully utilize the late season resources.	The higher the value of land, the more relevant the efficient use of available resources. Different legume systems (e.g. planted fallow against relay multiple cropping) and species (shade tolerant cowpea against shade susceptible soybean) fit into different available niches.

The criteria specified in Table 1 give a framework for the subsequent characterization of a specific target zone. The necessary information for a complete characterization of target zones may come from secondary sources, (e.g. climate, altitude, soil characteristics ...), from previous work (e.g. fodder needs, pests, weeds, labor ...), or may require some additional diagnostic work on site.

The selection of villages that are representative for a sufficiently large target zone is a crucial step during this process. Heterogeneity in farming systems or between fields have to be taken into account and may require the definition of target farming systems along recommendation domains.

In Table 2, four sites have been listed as examples, according to the presently available information. The sites are examples of target zone characterization for defining constraints and opportunities in the integration of legumes into the farming system. Sites 1 and 2 are both located in similar ecological conditions, although soils are more degraded in Site 2.

The major difference between the two sites is in the socioeconomic environment: land and labor are valued higher in Site 1 than in Site 2; and material inputs, cash and new skills are more difficult to access in Site 2.

There is no niche available in the sorghum/groundnut system, but the maize/sorghum system gives a late season niche in Site 1 and the sorghum/cowpea system gives an early season niche in Site 2.

Sites 3 and 4 are both located in the forest savanna transition zone. However, land use intensity is much higher in Site 3 than in Site 4, because of differences in population density and market access between the sites. As material inputs are scarce in Site 3 and moderately accessible in Site 4, soils are more degraded in Site 3. The reduced productivity of the major food crop maize, makes it possible to introduce legumes into the system.

Even labor-intensive technologies may be acceptable in Site 3, as labor is moderately available.

Table 2. The characterization process: Examples

Characteristic	Site 1	Site 2	Site 3	Site 4
Name of site	Kaya, Kaduna State Nigeria	Yamrat, Bauchi State Nigeria	Adja Plateau, Benin Republic	Transition zone, Ghana
Ecological conditions				
1 Climatic zone and rainfall	Northern Guinea Savanna 160 days	Northern Guinea Savanna 155 days	Transition between forest and savanna zone Bimodal: 120 + 80 days	Bimodal: 140 + 90 days
2 Altitude	700 m - lowlands	400 m - lowlands	100 m - lowlands	232 m
3 Soil acidity	Depends on fields, 80 % neutral 20 % moderately acidic	Depends on fields, 20 % neutral 80 % moderately acidic	Depends on fields, > 95 % neutral, < 5 % moderately acidic	pH 5.3-6.8, 70 % neutral 30 % slightly acidic

4	Fire	Frequent on most fields	Frequent on most fields	Rare	-
5	Soil fertility	Most fields have % OC at 0.3 - 0.8 low	Most fields have low % OC, except fields around compound low to very low	Most fields have low % OC (0.3 - 1.0 %). An estimate: very low (10 %) low (40 %) moderate (35 %) good (15 %)	% OC range from 0.8-1.3 at 0-20 cm depth. Moderate to low.
6	Water logging	Depends on fields, an estimate 90 % rare 10 % temporary	Rare	Rare	Rare to moderate
7	Soil erosion	Most fields have some slope; moderate erosion	Rare	Rare in 10-15 % of fields; moderate sheet erosion occurs after heavy rain	Low to moderate
8	Soil compaction	No reliable data available. Estimate: moderate.	No reliable data available. Estimate: moderate to compacted.	No reliable data, but soils seem compacted in fields with very low O.C.	Low to moderate.

9 Food	Maize/sorghum very competitive Low to moderate interest in food legume	Sorghum/millet with low productivity Moderate to high interest	Maize with low to moderate productivity Moderate to high interest	Maize moderately competitive. Moderate interest
10 Fodder	Farmers indicate fodder shortage for March-May; dry season fodder markets good	Farmers indicate no severe fodder shortage except in May; dry season fodder shortage moderate	Shortage during cropping seasons (tethered animals: labor constraint)	Dry season fodder shortage
11 Wood	No reliable data available, but wood export from village No wood scarcity	No reliable data available No wood scarcity	Shortage of quality firewood and construction wood	Estimate No wood scarcity
12 Weeds	Major weed: *Striga* on cereals	Major weed: *Striga* on cereals	Major weed: *Imperata*	Major weeds: *Imperata* *Cyperus* *Rottboelia*

13 Pests	Major soil pests: nematodes on cereals fusarium on cereals white grubs	Major soil pests: nematodes on cereals millipedes	Pest problems: severe pest complex on cowpea and cotton, moderate borer problem during second season maize	Major soil pests: nematodes on cereals

System description

14 Land	R ~ 90 Scarce	R ~ 75 Scarce	R ~ 75-80 (if land under oil palm fallow is regarded as "fallow") Very scarce	No reliable data: estimate R > 30 Moderately scarce
15 Land tenure	De facto land ownership Moderate to permanent	Communal land ownership Moderate	Variable. 30-70 % of cultivated land is owned by the farmers themselves. Moderate to permanent	De facto land ownership 40 %, rented land renewable every cropping season 55 %, share cropping 5 % Moderate to permanent

16 Labor	Labor/maize price = 12 - 15 Moderately scarce	Labor/maize price = 10 - 12 Moderately scarce	Labor/maize price = 12 - 15 Mainly family labor. Moderately available	Labor/maize price = 10 - 12 Moderately scarce
17 Market access	Paved road Good	25 km from paved road Poor access	Fairly good infrastructure Good	Paved road in poor condition Fairly good
18 Material input	Nitrogen/maize price = 1.5 - 2.0 Accessible	Nitrogen/maize price = 3.0 - 4.0 Moderately accessi-ble	Nitrogen/maize price = 5 - 5 Scarce	Nitrogen/maize price = 3 - 6 Moderately accessible
19 Cash	No reliable data Scarce to moderatly scarce	No good market connections Scarce	Scarce	Farmers tend to invest in short season crops. Scarce

20 Extension and rural institutions	Farm supply center and extension agent in village Good	Extension agent at 8 km distance Moderate	One extension agent per 4 villages. Poorly trained and not very much interested in crops other than cotton. Poor - moderate	Extension services lack logistics, agent lacks knowledge in agro chemicals. Moderate
21 Cropping system	Depends on farmer's choice: for sorghum/ groundnut No niche for maize/ sorghum Late season niche	Depends on farmer's choice: for sorghum/ groundnut No niche for sorghum/cowpea Early season niche	Basis: oil palm fallow system with annual cropping in association with young oil palms during cropping period. Main crops (mono and mixed crop): maize, cotton, cassava, groundnut, cowpea. No real niche available. Oil palm fallow niche	Continuous maize, maize + cowpea or + groundnut intercrops. To be determined

4 Characterizing legume-based technologies

Information is available from the literature on the characterization of the more common legume species. The establishment of databanks to compile this information is in progress and will indicate the most urgent gaps of knowledge. Any field trial on these species should attempt to contribute to the completion and confirmation of the data banks. The susceptibility of the species to specific pests or vice versa, their contribution to reducing soil-borne constraints need more research.

Six species were characterized in Table 3 according to available information. Only criteria 1-13 were taken into account, as these are most related to the morphology and physiology of the species. *Mucuna pruriens* for example is adapted to the humid and subhumid tropical lowlands. It performs well on neutral to slightly acid soils, which can be of low fertility, but should not be water logging.

Pueraria mucunoides prefers a more humid environment in the tropical lowlands, but it can grow on acid soils of very low fertility even under temporary water logging conditions.

Cajanus cajan and *Glycine max* are the only two species in Table 3 that contribute grain for human consumption, while *Mucuna* and*Desmodium* produce fodder for livestock.

Criteria 14-21 are determined more by the system of legume integration than by the species. Table 4 gives examples for this last step of characterization. Different planted fallow systems are compared to a rotation of multiple food crops. Land and labor requirements vary widely between these systems.

Land-demanding systems like a planted fallow rotation are likely to be rejected in land-scarce areas, whereas labor-intensive systems like alley cropping will probably not be accepted in areas of low population density and high labor prices.

Table 3. Legume species: Examples

Characteristic	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6
Legume species	*Mucuna pruriens*	*Pueraria mucunoides*	*Cajanus cajan*	*Desmodium distortum*	*Crotolaria caricia*	*Glycine max*
Common name	velvet bean, mucuna	puero mucuna	pigeon pea pois d'Angole	-	-	soybean, soya
Variety	*utilis*	-	-	-	-	medium maturity
1 Climatic zone and rainfall	>150 days	>180 days	>150 days	>150 days	>150 days	>150 days
2 Altitude	< 800 m	< 800 m	< 1600 m	< 1600 m	< 1600 m	< 800 m
3 Soil acidity	5.5 - 7.0	4.5 - 7.0	4.5 - 7.0	5.5 - 7.0	5.5 - 7.0	5.5 - 7.0
4 Fire	susceptible	susceptible	-	tolerant	-	susceptible

5	Soil fertility:						
	requirements of minimum % OC	low	very low	low	low	low	moderate
	contribution of N to soil in a monocrop	high	high	moderate	moderate	moderate	low
6	Water logging	susceptible	moderate	susceptible	susceptible	susceptible	susceptible
7	Soil erosion:						
	contribution to sheet erosion control	high	high	low	moderate	moderate	moderate
8	Soil compaction:						
	contribution to reduce soil compaction	moderate	moderate	high	-	moderate	low

9 Food						
food contributions	none	none	moderate	none	none	moderate
other products	none	none	none	none	fiber	oil
10 Fodder						
contributions to dry hay	moderate	none	low	moderate	none	low
contributions to green fodder	low	none	low	low	none	none
11 Wood						
for firewood	none	none	low	none	low	none
for construction	none	none	none	none	none	none
for staking	none	none	low	none	none	none

12 Weeds						
contribution to control:						
perennial grasses	high	high	low	-	-	low
annual grasses	high	high	moderate	-	-	moderate
perennial sedges	high	high	-	-	-	high
annual sedges	high	high	-	-	-	high
perennial broadleaf						
annual broadleaf	moderate	high	-	-	-	low
Striga on cereals	-	high	-	-	-	low
Striga on legumes	low	low	low	-	moderate	moderate
	-	-	low	increase	-	-
13 Pests						
reductions	cereal nematodes	-	-	-	-	-
increase	-	-	thrips	-	-	pod bugs

Table 4. Legume integration into maize systems.

Characteristic	System 1	System 2	System 3	System 4	System 5
System of integration	planted fallow	planted fallow	planted fallow	multiple food crops	planted fallow
Mode of integration	rotation	relay	multiple cropping	rotation	alley cropping
14 Land requirement	one season pure crop	none, but end of season pure crop	none, but replacement in inter crop	one season inter crop	none, but re-placement in in-ter crop (10-20%)
15 Land tenure requirements	long-term	short-term	short-term	moderate-term	long-term
16 Labor requirements at maize planting	moderate (land preparation and planting)	none	low (planting)	high (land preparation and planting)	high (copicing)
requirements at maize weeding	none	moderate (planting)	low	moderate (weeding)	high (2nd copic-ing)
requirements at maize harvest	none	low	low	moderate-high	none

17 Market access requirements	low	low	low	low-high (depending on produce for home consumption or market)	low
18 Material input	none	none	none	moderate (depending on species, fertilizer, pesticides, seeds,...)	none
19 Cash time lag for return on investment	two seasons (effect on subsequent crop)	0.5-1.5 seasons (effect on main crop or subsequent crop)	one-two seasons (effect on other intercrop or subsequent crop)	one-two seasons (direct return from food value or from subsequent crop)	2-3 years during establishment phase, then 0.5 - 1 season
20 Extension special skills required	none	none	weed management (selective weeding)	crop management (fertilization, harvest, utilization ...)	alley management (planting, copicing)
21 Cropping system niche required	full season	late season	full season	full season	year-round

5 Matching zones and technologies

COMBS is presently working on developing a concept for selecting the most promising legume technology. A computerized program is under development to guide the decision making process. The program has information on over 100 species stored in a database similar to Table 3.

First, the ecologically most adapted species are selected. Characteristics 1-8 in Table 1 are used to select the ecologically most adapted species according to the target site which is characterized according to these criteria as shown in Table 2. The more restrictive the conditions, the less the number of species available, whereas a wide choice of species is available in favorable ecological conditions.

The selection of the most contributing species comes next. Characteristics 9-13 (Table 1) specify the criteria for selecting species that contribute most to the farming system according to the requirements of the target site as shown in Table 2. The lower the resource endowment of the farming system, and the higher the complexity of weed and pest constraints, the more difficult it will be to find a legume species which meets the multiple needs and constraints of the farmers.

Then, the selection of the most appropriate system of legume integration has to be made. Characteristics 14-21 (Table 1) indicate socioeconomic and agronomic niches, opportunities and limitations for the integration of legumes into the farming system. Target sites have to be characterized again according to these criteria as shown in Table 2. There may be different options according to the socioeconomic strata of farmers selected or the time frame of our projections. This is a complex step which still requires considerable research and insight into the target area.

In the last step, selected species/systems have to be integrated into a design of a legume technology most appropriate for the recommendation domain. Any species that has been selected in Step 1 as being ecologically adapted, as well as in Step 2 as contributing most to the farming system, is potentially useful.

The agronomic design for the integration of these species into the farming system should be done according to the systems selected in Step 3. The information given in characteristic 21 (niches in the cropping system) guides this process. Farmers' perceptions about crops and crop associations are an important element for the adoption. Diagnostic trials, where farmers are exposed to different options increase farmers' participation in the decision process.

6 Gender implications for on-farm testing

Researchers on farming systems are becoming increasingly aware of the differences which exist in many areas between the role women and men play in agricultural production and the overall household activities. Access to the resources for and benefits from production is not the same for all members of a household. Activities in crop and livestock production, especially the sharing of time and labor between the different household members should be looked into.

Labor profiles for men and women are available for many areas, although they have not often been used for on-farm research planning. The access and control of resources like land, animal and machine power, inputs or hired labor may be different between household members. Control and access to benefits are important incentives for an individual to adopt a certain technology. Although some household members may contribute considerably to the production of a crop, they may have little control over the benefits. Such differences may lead to differences in perception about an improved technology or may have unpredictable effects on some members of the household.

Gender analysis has become the commonly accepted term for determining gender roles and intra- and inter-household dynamics within farming systems and applying that analysis to decisions about agricultural research and development activities. Though households can be disaggregated in several ways, gender has proved to be a particularly useful method.

As different legume-based technologies have been characterized for their requirements and their contributions according to Table 1, the most promising options should be tested for their implications for the different members of the household. Table 5 gives examples of the relevance of gender variables in each step of the characterization and selection procedure. It should be integrated into the early stages of the procedure and the most promising options tested for differential effects on household members.

Table 5. Relevance of gender variables.

Characteristic	Gender variables	Relevance
Ecological conditions and adaptation of species		
1 Climatic zone	Not applicable	Not applicable
2 Altitude 3 Soil acidity 4 Fire 5 Soil fertility 6 Water logging 7 Soil erosion	Researchers should observe whether there is any gender related pattern to field heterogeneity within a specific zone, e.g. if women's fields are generally of poorer quality (greater acidity, more water logging, etc.) than men's.	There may be significant variation in ecological conditions constituting a subzone and requiring a different portfolio of legume species for these fields and the explicit selection of collaborators from these zones.
8 Soil compaction	Gender neutral	Gender neutral

Requirements of a site and potential contributions of species

9 Food 10 Fodder 11 Wood 12 Weeds	The desirability of food, fodder, wood, or weed suppression as contributions of legume species may differ by gender depending on men's and women's respective responsibilities within the farming system. Both men and women should be interviewed to determine preferences.	If gender disaggregated preferences differ (e.g. women wanting wood for cooking, men, fodder for animals), then both sets of desirable contributions should be taken into account in: selection of species for on-farm experiments, placement of species, understanding 'ownership' of species.
9 Food	Women are more likely than men to have specific knowledge about food preferences and about the desirable characteristics of specific products (grains, roots).	Desirable criteria for specific products should be incorporated into the selection and evaluation of trial species.
10 Fodder	Where fodder is desirable, it should be determined who is responsible for gathering fodder and what features in terms of accessibility (placement, height, seasonality, etc.) are important.	Such characteristics should be taken into account in on-farm trials, monitoring their accessibility for desired purposes.

11 Wood	Where wood is desirable, it should be determined who uses wood and for what purposes, e.g. stakes and firewood, etc. If only men are interviewed, they may underestimate the amount of time required (or potentially saved) for gathering firewood because it is a woman's responsibility.	A list of wood uses should be included in the species selected for trials. Where women need more available firewood, placement and/or species selection and possibly treatment (such as pruning) may be important, to insure that species are not used for alternative purposes.
12 Weeds	The person most knowledgeable about noxious weeds and current practices which appear to encourage or inhibit weed growth should be identified.	Persons most knowledgeable about weeds should be included in assessing the usefulness of different species in weed suppression.
13 Pests	The person most knowledgeable about pest problems and their history should be identified.	Legume species should be selected so that they do not aggravate existing pest problems. If possible, species should help reduce problems.

14 Land	There may be differences in abundance or scarcity of land for cropping between men and women, or the allocation of fields may be part of a larger pattern of land use. Researchers should notice whether there is a difference in cropping and fallow conditions or in the pattern of use between men's and women's fields.	This may be a clue to a subzone related to the different patterns of use and fallow for men's and women's fields.
15 Land tenure	Land tenure or duration of tenancy rights may differ between men and women by seniority. The tenancy rights may be part of a larger pattern or not.	The requirement of moderate to long-term land ownership/tenancy rights for introduction of some legume species may not fit women farmers. Nevertheless, some contributions such as cuttings for mulch or use of wood as firewood may be compatible with planting legumes not in women's fields, but in communal fields or other 'communal' niches to which women have access. Species selection may also be important in that case.
16 Labor	Researchers should determine whether labor is gender specific for particular operations or enterprises, especially where family labor is used. Seasonal peaks may differ between men and women. A gender disaggregated seasonal calendar would help identify availability of labor for specific tasks at particular times.	Price ratio of labor/maize may give rough indication of labor availability or not. Monitoring 'who does what' during trials will help determine actual labor availability as well as the competing demands for labor. Further research on effect of increased labor availability on the system might be done.

17 Market access 18 Material input	Access to inputs or to opportunities for sale may be different between men and women and should be noted.	Where there are constraints to women's access to markets for inputs or sales, their interest in introducing legumes may be limited.
19 Cash	Availability of cash or credit as well as the time lag tolerance may differ between men and women.	Availability of cash or credit and time lag tolerance will affect the acceptability of legumes with longer maturity to harvest.
20 Extension and rural institutions	The availability of extension services often differs sharply between men and women. Research indicates that advice given to men do not trickle down to women if men are the ones responsible for specific tasks or are also growing same crops under the same or different resource conditions.	Where the introduction of new components requires the extension of management messages or new skills, the availability of extension services directly to women as well as men is an issue which needs to be openly recognized and addressed.
21 Cropping system	If men and women have different cropping systems, the agronomic niches may differ. Men and women may have different cropping systems which are totally separate or which are part of a larger pattern. See also No. 14 and 15.	The agronomic niches may differ between men and women in association with differences in resource availability, labor, and desirable contributions (No. 9-12) and thus affect the choice of experimental legumes species for on-farm trials.

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8 Suggestions for trainers

If you use this Research Guide in training ...

Generally:

- Distribute handouts (including this Research Guide) to trainees one or several days before your presentation, or distribute them at the end of the presentation.

- Do not distribute handouts at the beginning of a presentation, otherwise trainees will read instead of listen to you.

- Ask trainees not to take notes, but to pay full attention to the training activity. Assure them that your handouts (and this Research Guide) contain all relevant information.

- Keep your training activities practical. Reduce theory to the minimum that is necessary to understand the practical exercises.

- Use the questions on page 4 (or a selection of questions) for examinations (quizzes, periodical tests, etc.). Allow consultation of handouts and books during examinations.

- Promote interaction of trainees. Allow questions, but do not deviate from the subject.

- Respect the time allotted.

Specifically:

- Ask trainees about their experiences with regard to the content of this Research Guide as listed on page 5 (10 minutes).

- Present the content of this Research Guide, using slides and samples of leguminous plants (1 1/2 hours). Discuss the tables included in the document with the help of overhead transparencies (copy the tables transparencies with a photocopier).

- Conduct the practical suggested on page 3 in groups (1 day). You may refer to methods of surveying before going to the field (see section 7: Bibliography).

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The International Institute of Tropical Agriculture (IITA) is an international agricultural research center in the Consultative Group on International Agricultural Research (CGIAR), which is an association of about 50 countries, international and regional organizations, and private foundations. IITA seeks to increase agricultural production in a sustainable way, in order to improve the nutritional status and well-being of people in tropical sub-Saharan Africa. To achieve this goal, IITA conducts research and training, provides information, collects and exchanges germplasm, and encourages transfer of technology, in partnership with African national agricultural research and development programs.

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