# Final report

# Development of low input systems such as organic farming by optimising the use of legumes in a dry region of Nicaragua to strengthen soil fertility, yield, human nutrition and farm income

## Use of legumes in low input systems

# ULLIS

**Glenda Bonilla (MIS/UNA)**
**Emilio Perez (UNA)**
**Carlos Ruiz (UNA)**
**Rein van der Hoek (CIAT)**
**Diana Kurzweg (BOKU)**
**Bernhard Freyer (BOKU)**

**University of Natural Resources and Applied Life Sciences (BOKU)**
**Universidad Nacional Agraria (MIS/UNA)**
**Centro Internacional de Agricultura Tropical (CIAT)**

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**Abstract**

Organic farming is for many farmers a feasible alternative to increase productivity, reduce costs and improve the natural resource base. Legumes are of major importance in agriculture worldwide and they usually have the ability to fix atmospheric nitrogen allowing high protein contents of the plant and increasing nitrogen availability for other crops. Their high biomass provides soil cover maintaining humidity and green manure, and produces feed.

This research focuses at the use of drought tolerant forage legumes as green manure and as animal feed in mixed smallholder farming-systems (based on maize, beans, livestock) in Central America, where soil nutrient depletion is common, leading to degraded soils, low agricultural productivity, food insecurity and poverty.

The objectives were to develop legume based cropping systems in five experiments where legumes are used as green manure and animal feed. Main emphasis of the study was to investigate the effect on agronomic characteristics, nitrogen fixation and subsequent maize production, in combination with diagnostic studies and implementing support strategies to farmer training / knowledge transfer and experience exchange.

The project was jointly carried out by UNA students and staff (Nicaragua), BOKU University and students from BOKU and the University of Copenhagen with support from CIAT. The work took place at several sites, including UNA research farms and local communities, and consisted of:

- screening experiments at two distinctive sites in which agronomic characteristics of different forage legumes were compared, including biomass production, effect on subsequent maize yield and potential for animal production: some promising materials *Canavalia brasiliensis*, *Lablab purpureus* and some accessions of *Vigna unguiculata* (e.g., 9611, IITA 284/2) doubled maize yield in comparison to the local check.
- determination of nitrogen-fixing ability of forage legumes: $N_2$-fixation rate of legumes varied between 52 and 81%.
- experiments with shrub legumes (alley cropping in combination with maize), evaluating their effect on soil fertility and maize production and *Leucaena leucocephala* showing most promising results regarding agronomic characteristics (plant height, biomass production).
- evaluation of the agronomic behaviour of both indigenous and introduced legumes and their effect on maize during the growing period and after mulching: It was found that the introduced legumes *Canavalia brasiliensis* and *Vigna unguiculata* performed better than the local species, establishing better in drought conditions and showing higher robustness against pests.
- on-farm and community research, including a Participatory Rapid Appraisal and training workshop on use of both introduced and local herbaceous forage legumes and leguminous shrubs for improvement of soil fertility and animal feed. Additionally, students did (1) a potential adoption analysis of organic farming methods and (2) a community analysis on development project activities, their effectiveness, lessons learned and the identification of success factors. Especially adverse ecological conditions, lack of communication and community feel and lack of adaptability of new technologies turned out to be important causes of project failure.

Research results and developed capacities in the form of six graduated students, three staff (UNA) and various farmers at the project sites are direct and sustainable outcomes of the project. Furthermore, two students from universities from the North based their MSc. on fieldwork within the project and one thesis was published as a book. Further impact can be expected from research results translated into extension messages for farmers and used as inputs for further research and contributions teaching materials.

**Zusammenfassung**

Bernds job

## 1. Introduction

### Organic farming

Organic farming is for many farmers more and more an alternative to manage successfully their farm. Advantages are: reduced costs for agricultural inputs, reduction of soil erosion, development of soil fertility, higher yields and in some cases better income by linking to international organic markets. In tropical countries like Nicaragua where traditional agriculture is predominant, organic farming practises are less common, but gain an increasing interest among the farmer communities. Often, the economic situation of the farmers doesn't allow for agricultural inputs, except the most important ones like seeds, and sometimes fertilizer and pesticides. Optimal use of natural resources is therefore key to maintain or increase soil fertility.

Specific research for organic farming cropping systems in tropical environments is very rare. There is a need to invest more in the development of especially legume based systems to sustainably increase crop yields. Effects of such systems in Nicaragua (e.g. Schmidt & Orozco, 2003) and in Kenya (e.g. Lelei, 2004; Lelei et al., 2004) had shown convincing results.

### Legumes

Legumes are of major importance in agriculture worldwide. Many of them (*Fabacaea*) have root nodules being evidence of symbiosis with nitrogen-fixing bacteria (*Rhizobium*) allowing a crude protein content of the plant up to 35% and even increasing nitrogen availability for other non-nitrogen fixing crops like cereals. Furthermore, biomass yields of many legumes are high, making them suitable as cover crops maintaining soil humidity and providing green manure, reducing erosion, suppressing weeds and strengthening of the antiphytopathogenic potential of the soil. The high protein content in combination with an often regular or even good palatability makes legumes also an important source of protein for livestock.

### Use of legumes in mixed crop-livestock systems

The use of drought tolerant forage legumes as animal feed is an effective strategy to reduce production decrease in the dry season. This research focuses on the introduction and evaluation of new forage germplasm. Species and accessions having shown reasonable yields and a decrease of less than 48% in biomass production in the dry season are considered for further evaluation. In pastures, addition of forage legumes enhances animal production twofold: through higher biomass production and through increasing the overall nutritive value.

Small farms based on maize and beans and often including cattle characterize the dominant farming system in Central America. Soil nutrient depletion is a common problem leading to degraded soils, a decline in agricultural productivity, and, eventually, to food insecurity and poverty. Legumes can decrease soil erosion, optimise farm-energy balance, and increase soil fertility and soil waterholding capacity.

### Former research findings

Preceding activities in the research region (CIAT, Universidad National Agraria (UNA), local partners) consisted of workshops with local farmers in which current problems were articulated identifying causes and interactions between crop management and soil resources. Main focus was the evolution of the production systems over time and reasons for change. These workshops were the first step in a learning alliance process with farmers in San Dionisio (Orozco & Franco, 2001).

A survey on the use of organic matter in San Dionisio (Dohmeyer, 2003) showed that, although local and national organizations have been working on cover crops/green manures

(CCGM) in San Dionisio in the last decade, there were only 36 farmers who knew about the benefits of CCGM, and only 30% of them can be considered of having integrated CCGMs into their production system.
Studies on the nutrient flows at farm levels revealed crop residue management as a main cause for decreasing soil fertility. As above ground residues are burnt, and in the case of beans below ground residues are pulled out (and subsequently burnt), soil organic matter decreases and nutrient balances are negative. Decreasing crop yields are the consequences, which can not be made up for through increased chemical fertilizer application.
In order to complete the process of learning about soil resources in San Dionisio we conducted a characterization survey ("feria de suelo" (Trejo et al, 1999)), where farmer matched local soil quality indicators with scientific ones, including physical (texture, colour, infiltration, consistency), chemical (pH, SOM), and biological parameters such as rhizobia presence and soil fauna. Farmer groups then conducted maize experiments with different N-P-K fertilizer levels to identify the most important nutrient on their fields. Nitrogen resulted as the most important nutrient throughout the watershed, while the application of P only resulted in a marginal effect on maize yield. Potassium had no effect.

**Conclusions and outlook**

From the above described activities and results it was concluded that traditional fertilization can be substituted through a single legume crop prior to maize crops. There are options to enhance farmer production systems in the dry hillsides of Nicaragua and reverse the current tendency of these soils to degrade leaving farmers with higher yields and lower production costs.
This report presents an overview of the project results of the experiments during both project periods, the first from February 2005 to October 2007 and the second from November 2007 to April 2010.

## 2. Objectives

The objective of this project jointly carried out by the University of Natural Resources and Applied Life Sciences (BOKU), Vienna, Austria, the Universidad Nacional Agraria (UNA), Managua, Nicaragua and CIAT is to develop options based on legumes as green manure and animal feed. More specifically, the original targets of the project as mentioned in the project document were as follows:

**(a) On-station trials:**

1. To find out the impact of different legume species / varieties, planted in the dry season, on soil organic matter after a four year rotation (see 2.1).
2. To study the performance of different legume species / varieties about root biomass, above ground biomass, nitrogen fixation and the effects on subsequent maize performance (see 2.1).

**(b) On-Farm trials:**

3. To investigate the impact of cover crops/green manure (CCGM) improved residue grazing in the dry season on subsequent maize performance in comparison with non-grazed cover crops/green manure (CCGM) rotations, as well as their labour and economic impacts (see 3.1).
4. To analyse the impact of cover crops/green manure (CCGM) species / varieties on subsequent maize performance, as well as their labour and economic impacts (see 2.1).
5. To implement support strategies for farmer/researcher to farmer training / knowledge transfer, experience exchange - combining on station trial knowledge with farmer specific

knowledge (site specific techniques) accompanied by B.Sc. / M.Sc. students and local farmer organizations (see 3.2).

## 3. Activities February 2005 – September 2007

This chapter consists of two parts:

- An experiment carried out by the *Universidad Nacional Agraria* to evaluate the adaptability of 16 genotypes of forage legumes.
- A research carried out by a Danish student (Signe Borgen, University of Copenhagen) together with the *Universidad Nacional Agraria* to evaluate (1) (potential) N-contribution (N-fixation, mineralization) of four cover legumes (as green manure) to the soil and subsequent crops and (2) research the adoption (potential) of green manure and other organic production methods by farmers.

This part reflects the outcomes and conclusions as presented in technical reports of UNA and the thesis by Mrs. Borgen (Borgen, 2007).

### 3.1 Evaluation of the adaptability of 16 genotypes of forage legumes in the sub-humid zone of San Dionisio, Matagalpa

**General objective**: Assess the adaptability of 16 genotypes of forage legumes
**Specific objectives:**

1. Assess the drought tolerance of forage legume germplasm
2. Determine feed quality of the forage biomass

**Hypothesis**
$H_O$: None of the assessed genotypes adapts at the dry zone of San Dionisio-Matagalpa
$H_a$: At least some assessed genotypes adapt at the dry zone of San Dionisio-Matagalpa

**Material and methods**
The experiment was established in San Dionisio, Matagalpa, situated at 165 km from Managua. The geographical coordinates are 12 $^o$ 45´ 45´´ latitude North and 85 $^o$ 51´ 10´´ longitude East.
The zone is semi-arid and characterized by extensive livestock keeping. The population is poor and depends mainly on agriculture based on maize and beans. Annual rainfall varies usually between 800 and 1100 mm with peaks up to 1600 mm but distribution is unequal with a rainy season of maximally seven months. Average temperature varies between 22.5 and 25 $^o$C (ITLAPLAN, 1996 cited by Barreto et al., 1997).
Four soil types can be distinguished: alluvial soils, latosols, meteorized soils and forest soils. In this region mollisols, inceptisols, entisols and alfisols predominate; soil depths vary from shallow to deep.

**Description of the experiment**
A complete randomised block was established with 16 treatments and three replicates, the total experiment area was 975 $m^2$. The area of each plot was 3m* 4m = 12$m^2$ (useful area: 4.5 $m^2$. The treatments were:

- *Vigna umbellata* CIAT 24466, CIAT 4279, CIAT 24469, CIAT 466, CIAT 522, CIAT 24360, and a local variety (“Testigo”):
- *Vigna unguiculata* INTA 1, INTA 2, IITA 715, IITA 573-5
- *Lablab purpureus* CIAT 52535, Highworth, CIAT 21603
- *Canavalia brasiliensis* CIAT 17009
- *Canavalia ensiformis*

**Variables measured**

- Germination rate: measured up to 15 days, hereafter the proportion of surviving plants per furrow and per plot.
- Cover height: to be assessed every 15 days in the three central furrows of each experimental plot.
- Biomass (kg): in each parcel three square metres, at the onset of the flowering stage.
- Cover %: every 15 days till the end of the biological cycle of the crops

**Experimental results**

After the establishment of the experiment on 08/10/05 assessments were done every 15 days of the following variables: germination rate, survival rate, cover % and cover height. We found that some treatments showed low germination rates. This might be due to the seed quality. In subsequent assessments germination rates of some accessions increased slightly. In addition, rabbits ate the few plants that survived.

On 26/11/05 the penultimate assessment was done and the survival rates varied between 13% and 60%. Based on these results it was decided to replant, but results were disappointing, leading to our conclusion that the seed germination quality was low. A next assessment on 10/12/05 showed that rabbits had eaten the few remaining plants.

- The *Lablab purpureus* accessions and *Canavalia brasiliensis* showed relatively better germination rates
- Germination rates of *Vigna unguiculata* were very low
- Only *Vigna umbellata* "testigo" showed a germination rate of over 50%
- *Canavalia ensiformis* did not germinate at all
- There was no significant difference between blocks

**Conclusions**

- There were no significant differences between blocks and between species ($p<0.05$), however it was possible to identify the robustness of the different germplasm.
- Survival rates show the same tendency as germination rates, the *Lablab purpureus* accessions performing relatively well, as well as *Vigna umbellata* "testigo"
- Survival rates of *Vigna unguiculata* are low

**General recommendations**

- Although not mentioned in the original report, another factor leading to this disappointing outcome was a prolonged drought period (personal communication by involved UNA personnel). It is therefore recommended to do a next trial in the *primera* (from May to August) instead of the *postrera* (from September to December) growing season.
- It is highly recommended to do germination tests with seed intended for an experiment. However,the heterogeneity of seed material has always to be taken into account.
- It is recommended to protect plots against rabbits and other animals (chicken wire might be too expensive, but there are also other options).
- Low seed quality and other natural limiting factors can extensively affect yields, even of improved germplasm.

### 3.2 Biophysical adaptation of legume green manures and social adoption analysis in sub-humid Nicaraguan hillsides of San Dionisio

(based on the MSc. thesis by Signe Borgen)

Adaptation of four legume species was evaluated in the sub-humid hillsides of Nicaragua for its i) N fertilizer potential and ii) social adoption potential.

The first component tested the biophysical niche of the legumes at the end of the rainy season, represented by the following hypothesis:

**Hypothesis 1:**
*Canavalia brasiliensis*, *Lablab purpureus*, *Vigna unguiculata* and *Vigna umbellata* are drought resistant and biophysically well-adapted to conditions in San Dionisio and similar environments as green manures established at the end of the rainy season.

The social analysis evaluated the human, social and physical capitals in relation to green manure use and three other organic production methods as well as farmers' adoption behaviour and is embodied by the following hypothesis:

**Hypothesis 2**:
Factors related to social, human and physical capital hinder farmers' adoption of green manure and organic production methods in general.

### 3.2.1 Field trial

The legume trial had a randomised block design consisting of four legumes (*Canavalia brasiliensis*, *Lablab purpureus*, *Vigna unguiculata* and *Vigna umbellata*) with and without compost application in three replicates, resulting in 24 plots of 4x6 m with an actual sample size of 5x3m.
Only *Canavalia brasiliensis* persisted, while the three other legumes performed poorly. Germination rates were low (estimated at 40%, probably caused by chickens eating the seed). *Vigna umbellata* disappeared within 45 days after planting, and only few plants of *Lablab purpureus* and *Vigna unguiculata* survived till maturity.
The trial was further impaired by pests (mainly beetles and ants), which affected *Canavalia brasiliensis* less than the other legumes. Canavalia yields were estimated at 900 kg/ha DM (2500 kg/ha fresh weight) for the control plot and at 1000 kg/ha with compost application (2600 kg/ha fresh weight). In comparison to literature and local data from CIAT experiments (with yields up to 5300 kg/ha fresh weight) these yields were low. The positive effect of compost on biomass production is likely caused by higher water retention in the early stages and a possibly higher nutrient availability later on.
$N_2$ fixation rates (measured using the Natural Abundance Method) were high, though the poor biomass production indicated that the plants were not performing well. Total N contributions from fixation were calculated, and compared for the compost and control treatment. The pot experiment verified that nodules were present and actively fixing $N_2$ in the local soil. Compatible rhizobia were present for both *Lablab purpureus* and *Vigna unguiculata,* and symbiosis could therefore be expected, even without inoculation. Due to lack of seeds, *Canavalia brasiliensis* was not included in the pot experiment, but nodules were present and active in plants in the field. *Vigna unguiculata* and *Lablab purpureus* did not associate with the same *Rhizobium* genus: the first with the slow-growing *Bradyrhizobium* Rhizobium strains and the latter with a fast-growing strain of the *Rhizobium* genus. Average nodule numbers per plant were 8.8 and 7.7 for *Vigna unguiculata* and *Lablab purpureus* respectively.
$N_2$ fixation was 81 and 52 %Ndfa for *Lablab purpureus* and *Vigna unguiculata* respectively, and nodules were actively fixing without inoculation. *Canavalia brasiliensis* was found more suitable than the other legumes as a late rainy season green manure, resisting pest and drought stress. This plant showed the highest N contribution (estimated at 13.5 kg N/ha after 180 days with an $N_2$ fixation of 64% Ndfa). Compost application had a negative effect on $N_2$ fixation but increased biomass production, resulting in a similar net N contribution. Further experiments including on compost quality are needed to determine if compost should be recommended to increase N contribution from dry season green manures.

**Incubation experiments**

Two incubation experiments were done, one to determine inorganic N content of the compost during four weeks with weekly measurements and a second to determined mineralization patterns of *Vigna unguiculata*, *Canavalia brasiliensis* and *Lablab purpureus* during four weeks with measurements every 14 days. Water content of all soils was 50% of their water holding capacity. Compost and plant material were added in a quantity of 11% and 1% of soil weight respectively. Incubation took place at 25ºC under aerobic conditions. Samples were mixed with 1 M KCl for 45 min, filtered and analysed for nitrate and ammonium by flow injection analysis (FIA).

The net N mineralization of *Vigna unguiculata*, *Lablab purpureus* and *Canavalia brasiliensis* varied according to material quality and the soil used for incubation. The trial residues immobilized between 0 and 65 mg N/ha after four weeks incubation with an N content of the plant residues close to 2% of DM. Experimental conditions like residue particle size and incubation period may have led to a higher immobilization compared to field conditions. In conclusion, *Canavalia brasiliensis* is not considered an immediate N source, but contributes to long-term soil fertility build-up, with potential for remineralization after one month.

### 3.2.2 Social survey

Together with three UNA students an evaluation of human, social, and physical resources influencing green manure adoption was conducted. The survey was conducted with 182 representative farmers selected by a stratified sampling procedure using the following criteria: farm size, farm type and membership of an organization. The themes covered were live barriers, composting, green manure and biological pest control. Some farmers mentioned lack of information as the most important constraint for all themes, in spite of high awareness of (in descending order) live barriers, composting, and green manure. Awareness and know-how was very high for live barriers (95% and 80%), composting (86% and 59%) and green manure (72% and 48%) but lower for biological pest control (72% and 48%), which might be due to the less precise description of this method.

Adoption rates found were 57, 37, 33 and 17% for live barriers, composting, green manure, and biological pest control, respectively, and were higher for farmers with higher education and belonging to an organization. Adoption of green manure was especially limited by lack of access to seed. Land tenure influenced adoption live barriers more than the other factors.

Lack of information was mentioned most often (28% of the farmers) as the main constraint to use organic production methods. Almost half of the respondents claimed to know how to use green manure and a third had actually practiced this.

A positive correlation was found between organization membership and knowledge level. Knowledge level tended to increase with farm size, but no differences were found in adoption rates of organic production methods of small (70%), medium (78%) and large (65%) farmers. Hence, knowledge of methods does therefore do not automatically lead to their application, possibly because from the point of view of these farmers they are not suitable for larger farmers who are more mechanized.

There is generally a high awareness and knowledge on organic production methods in San Dionisio, but this has generally not been translated into their concrete application at farm level limiting farmers' experience.. Human capital seems therefore not the most limiting factor for adoption of organic production methods. Social capital is more important: a positive relation exists between organization membership and adoption. The institutional presence in San Dionisio is quite large, which is reflected in relatively high adoption rates of especially live barriers.

Approximately 40% of farmers in San Dionisio are farming under insecure tenure conditions. This influences adoption of long term organic farming methods, reducing the use of live barriers with 24% and using of green manure with 10%. These results comply with general findings indicating that tenure and especially lack of access to land restricts adoption of green manure and other organic production methods.

Physical capital, primarily in terms of availability of seeds and land, was the main limiting factor for 61% of the respondents in the adoption of green manure, lack of seeds accounting for more than 60%. Labour availability could also be a constraining factor if short-duration legumes are planted at the end of the rainy season and incorporation would coincide with harvesting coffee and *postrera* beans in December/January. Incorporation in March/April of long-duration green manures such as *Canavalia brasiliensis* would not be likely to compete with other farming activities.

**Conclusions and recommendations**

It could be argued that the poor agricultural production in areas such as San Dionisio could be increased by facilitation of credit schemes enabling purchase of chemical inputs. However, whereas mineral fertilizers - especially phosphorus - increase production, organic soil improving methods are much more effective, especially at the long-term. For instance, the post-Mitch situation (after the hurricane Mitch in October 1998, which devastated large parts of Honduras and Nicaragua) emphasized once more the importance of increasing agro-ecosystem resilience. Additionally, organic fertilizers require less monetary inputs and green manures could play an important role by providing nitrogen and organic matter to increase soil fertility.

This research showed that *Canavalia brasiliensis* can be used as a green manure in the late rainy season, with potential N remineralized and available for the following crop. Further trials are necessary to determine the biomass potential of *Vigna unguiculata*, *Lablab purpureus* and *Canavalia brasiliensis* planted at the end of the rainy season. Biological pest control could probably reduce pest attacks, however to identify strategies, an elaborate research design is to be established.

Use of green manures is not widespread in San Dionisio. However, biophysically adapted species are available. Limiting factors are lack of physical resources, such as seed availability. This constraint can be lifted in various ways, most requiring intervention from government or development agencies.

A seed system also offering access by the poorest farmers should be established. Lending schemes show potential, but are not accessible to everybody. Distribution and access to land is another barrier, where political action is needed.

**Perspectives for organic farming in San Dionisio**

Sustainable and/or organic farming practices are being already implemented in San Dionisio and awareness and use of live barriers is widespread. However, one practice alone clearly cannot sustain an organic production system and it is arguable whether the present soil fertility levels and fragility of agro-ecosystems can allow sufficient production with immediate effect without the application of agrochemicals. On the other hand, results suggest that integrating organic components like legumes and compost offer better long-term solutions and it is therefore recommended to embark on a gradual conversion to organic production. The presence of agricultural organizations in San Dionisio promoting organic methods is a first step. Appropriate and adaptable, innovations could spread spontaneously. Farmer involvement in project formulation, implementation and identification of objectives is also a positive step. Dissemination of the concept of sustainability of environmental as well as social aspects might create an innovative spirit amongst farmers, enabling adaptation of farming methods according to individual needs. The land tenure issue is not likely to hinder adoption of organic production methods if yields increase while labour and financial inputs remain equal or decrease. Institutional support from development organizations and the

Nicaraguan government, focusing on seed availability of cover legumes and distributing information on organic farming, may provide a solid starting point.

## 4. Activities October 2007 – April 2010

Since the project activities had only been partially fulfilled, it was decided to restart in October 2007. Representatives of the implementing institution UNA (*Universidad Nacional Agraria*), as well as research sites and students were identified and experiments were designed.

The targets of the project as mentioned in the revised project document are as follows:
(a) On-station trials:
1. To find out the impact of different legume species / varieties, planted in the dry season, on soil organic matter after a four year rotation.
2. To study the performance of different legume species / varieties about root biomass, above ground biomass, nitrogen fixation and the effects on subsequent maize performance.

(b) On-Farm trials:
3. To investigate the impact of cover crops/green manure (CCGM) improved residue grazing in the dry season on subsequent maize performance in comparison with non-grazed cover crops/green manure (CCGM) rotations, as well as their labour and economic impacts.
4. To analyse the impact of cover crops/green manure (CCGM) species / varieties on subsequent maize performance, as well as their labour and economic impacts.
5. To implement support strategies for farmer/researcher to farmer training / knowledge transfer, experience exchange - combining on station trial knowledge with farmer specific knowledge (site specific techniques) accompanied by B.Sc. / M.Sc. students and local farmer organizations

The following four main activities were carried out:

1. Evaluate 16 genotypes of forage legumes in trial plots at two experiment sites in the Pacific region of Nicaragua and their effect on maize production (project target 1, 2, 4). These experiments took place at the Ranch Ebenezer and the Finca Santa Rosa. A complete randomised block was established with 16 treatments and three replicates (see Annex 2 for details).
2. Evaluate the effect of four genotypes of leguminous shrubs/trees at one experiment site (El Plantel, research farm of UNA) on soil fertility and maize production (alley cropping) (project target 2, 4) (see Annex 3 for details).
3. Evaluate the agronomic and production characteristics of five forage legumes in semi-arid conditions (project target 3, 4)
4. On-farm and community research. This part includes a Participatory Rapid Appraisal (PRA) and training workshop on use of both introduced and local herbaceous forage legumes and leguminous shrubs for improvement of soil fertility and animal feed in Pacora, San Francisco Libre, Managua (project target 5). Additionally a student from the University of Potsdam - BOKU did research on (1) the behaviour of both indigenous and introduced legumes and their effect on maize during the growing period and after mulching and (2) a community analysis on development project activities, their effectiveness, lessons learned and success factors.

UNA Personnel and students involved in the project:

Faculty of Natural Resources (FARENA)
Dr. Emilio Pérez Castellón

Ing. M.Sc. Glenda Bonilla
4 students: Luis Manuel Martínez, Aurelio Núñez, Ronny Tinoco, Carlos Valle

Faculty of Animal Science (FACA)
Ing. M.Sc. Carlos Ruíz
2 students: Fabio Leonel Valle Solís, Magdiel Gabriel Murcia Aguilar

University of Potsdam - BOKU University
1 student: Diana Kurzweg

For a complete timetable of the project see Annex 4.

### 4.1 Evaluation of 16 herbaceous legumes and their effect on maize production

#### 4.1.1 Site characteristics

The Ranch "Agropecológico en Especies Menores" Ebenezer (RAEME), is situated in the municipality of Niquinohomo, Masaya Department at an altitude of 400 masl, an average rainfall of 1,200 mm most of which falls in the rainy season from July to November. Soils are clay loam with an effective depth of 40 cm. Main purpose is breeding of small livestock goats (Nubia), sheep (Pelibuey), rabbits, pigs and poultry. Around 7 ha are used as pasture and small household gardens.
The "Finca Santa Rosa" of the Universidad Nacional Agraria is situated just outside Managua, with an area of approx. 140 ha. Soils are volcanic, deep with a good permeability. In 2005 and 2006 average rainfall varied between 1400 y 1900 mm. The farm is characterized by various production systems used for research activities; the largest part consists of mainly *Brachiaria* and *Panicum* pastures.
The experiment was established at the beginning of the first growing season (*Primera*) in May 2008 with the planting of the maize. The legumes were planted at the beginning of the second growing season (*Postrera*) in September of the same year. Harvest of both maize and legumes took place during the first months of 2009.
Seven species (16 accessions) of herbaceous legumes were associated with *Zea mays*, variety NB6. Measures variables were germination, plant height, stem diameter, cover, presence of leaf damage by insects, presence of weeds, dry matter percentage, yield, number of nodules, root weight and nitrogen percentage in legume biomass. The experimental test design consisted of three randomised blocks, perpendicular to one another, and each block was divided into 17 plots.
The soil characteristics of both sites are presented in Table 1 (for more details see Annex 4).

**Table 1: Soil characteristics of Santa Rosa and Niquinohomo**

| | depth | pH | OM | N | P | K | Ca | Mg | clay | loam | sand | texture |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cm | | % | | ppm | me / 100 g soil | | | % | | | class |
| Niqui-nohomo | 0-15 | 6.28 | 4.4 | 0.22 | 0.01 | 2.10 | 16.05 | 4.38 | 34 | 30 | 36 | clay-loam |
| | 0-30 | 6.31 | 4.2 | 0.21 | 0.99 | 1.70 | 13.91 | 3.85 | 32 | 26 | 42 | |
| Santa Rosa | 0-15 | 6.83 | 4.70 | 0.24 | 74 | 4.48 | 29.26 | 9.21 | 38 | 48 | 14 | clay-loam |
| | 0-30 | 6.94 | 3.21 | 0.16 | 61.7 | 3.99 | 29.82 | 9.67 | 38 | 48 | 14 | |

#### 4.1.2 Legumes

**Agronomic characteristics**

Plant development differed considerably per site. Though at both sites legumes performed quite well, at Niquinohomo the maize harvest failed due to drought.
An important agronomic characteristic is tolerance to pests, and therefore pest incidence was evaluated (Table 2). At both sites, *Centrosema plumieri* was most resistant. The *Vigna* and

*Lablab* accessions were in general quite heavily affected however, with *Canavalia brasiliensis* in an intermediate position. Damage was defined as the percentage of affected plants.

**Table 2: Pest incidence of legumes in Santa Rosa and Niquinohomo**

| | Santa Rosa | | Niquinohomo | |
|---|---|---|---|---|
| Treatment | % damage | Duncan* | % damage | Duncan* |
| *Canavalia brasiliensis* CIAT 17009 | 62 | bc | 49 | d |
| *Centrosema plumieri* | 21 | d | 7 | e |
| *Lablab purpureus* 2 | 73 | abc | 66 | bc |
| *Lablab purpureus* CIAT 21603 | 78 | ab | 80 | a |
| *Lablab purpureus* CPI106471 | 77 | ab | 49 | d |
| *Lablab purpureus* CPI-676 | 66 | abc | 66 | bc |
| *Lablab purpureus* CQ- 2975 | 79 | a | 82 | a |
| *Vigna umbellata* CIAT 24360 | 80 | a | 83 | a |
| *Vigna umbellata* CIAT 26469 | 64 | abc | 60 | cd |
| *Vigna unguiculata* IITA 131-2 | 70 | abc | 80 | a |
| *Vigna unguiculata* IITA 284/2 | 64 | abc | 63 | bc |
| *Vigna unguiculata* IITA 390/2 | 67 | abc | 74 | ab |
| *Vigna unguiculata* 9611 | 59 | c | 53 | cd |
| *Vigna unguiculata* Verde Brasil | 70 | abc | 55 | cd |
| *Vigna unguiculata* FHIA | 59 | c | 49 | d |

*different letters denote significant differences ($p < 0.05$, Duncan's multiple range test)

Because of their high palatability, legumes are usually quite heavily affected by pests and reduction of damage is difficult to achieve. However, even in cases of substantial pest damage, legumes often still reach acceptable production levels (biomass, grains).

**Biomass production**

Table 3 presents the legume biomass production. *Lablab purpureus* 2 (Dl) showed highest yields in Santa Rosa, whereas performance of *Vigna umbellata* 26469 (vum1) was lowest.
In Niquinohomo *Vigna unguiculata* Verde Brasil (vun1) showed the highest average, this in contrast to *Vigna unguiculata* 390/2 (Vun 6). *Canavalia brasiliensis* did quite well at both sites, as well as the cowpea accessions *Vigna unguiculata* Verde Brasil and *Vigna unguiculata* 284/2.

**Table 3: Legume biomass production (DM, in kg/ha) at Santa Rosa and Niquinohomo**

| Treatment | Santa Rosa | Niquinohomo |
|---|---|---|
| *Canavalia brasiliensis* CIAT 17009 | 2017 | 950 |
| *Centrosema plumieri* | 554 | 79 |
| *Clitoria ternatea* | 439 | 8 |
| *Lablab purpureus* 2 | 3140 | 962 |
| *Lablab purpureus* CIAT 21603 | 2454 | 693 |
| *Lablab purpureus* CPI106471 | 1656 | 399 |
| *Lablab purpureus* CPI-676 | 1866 | 622 |
| *Lablab purpureus* CQ- 2975 | 1865 | 269 |
| *Vigna umbellata* CIAT 24360 | 1746 | 290 |
| *Vigna umbellata* CIAT 26469 | 91 | 4 |
| *Vigna unguiculata* IITA 131-2 | 1931 | 635 |
| *Vigna unguiculata* IITA 284/2 | 1446 | 1124 |
| *Vigna unguiculata* IITA 390/2 | 131 | 197 |
| *Vigna unguiculata* 9611 | 846 | 177 |
| *Vigna unguiculata* Verde Brasil | 1772 | 1486 |
| *Vigna unguiculata* FHIA | 386 | 214 |

**Nodulation**

*Lablab purpureus* 2 (Dl), *Vigna unguiculata* FHIA (vun4) and *Vigna unguiculata* Verde Brasil (vun1) showed highest numbers of nodules and highest root biomass, this in contrast to *Clitoria ternatea* (Cl) and *Centrosema plumieri* (Cp).

**Legume N-content**

N-content of varied considerably between the different legumes (Table 4). The *Vigna umbellata* accessions showed relatively low contents (under 2%), whereas *Lablab purpureus* accessions contained up to 3% of nitrogen, with *Canavalia brasiliensis* and *Clitoria ternatea* also in the upper ranges. Cowpea accessions showed intermediate results.

### 4.1.3 Effect of forage legumes on agronomic maize parameters

The main objective of this experiment is the evaluation of the effect on maize of intercropping with legumes. The following production indicators were evaluated: plant height (Table 5), stem diameter, germination rate and incidence of pests and diseases.

**Table 4: Legume N-content**

| Treatment | N content (%) | Duncan* |
|---|---|---|
| *Canavalia brasiliensis* CIAT 17009 | 2.94 | a b |
| *Centrosema plumieri* | 2.07 | c d |
| *Clitoria ternatea* | 2.70 | a b c |
| *Lablab purpureus* 2 | 2.74 | a b c |
| *Lablab purpureus* CIAT 21603 | 2.81 | a b c |
| *Lablab purpureus* CPI106471 | 2.34 | a b c d |
| *Lablab purpureus* CPI-676 | 3.00 | a |
| *Lablab purpureus* CQ- 2975 | 2.77 | a b c |
| *Vigna umbellata* CIAT 24360 | 1.97 | c d |
| *Vigna umbellata* CIAT 26469 | 1.63 | d |
| *Vigna unguiculata* IITA 131-2 | 1.80 | d |
| *Vigna unguiculata* IITA 284/2 | 1.81 | d |
| *Vigna unguiculata* IITA 390/2 | 2.14 | b c |
| *Vigna unguiculata* 9611 | 2.19 | a b c d |
| *Vigna unguiculata* Verde Brasil | 2.34 | a b c d |
| *Vigna unguiculata* FHIA | 2.02 | c d |
| *different letters denote significant differences (p< 0.05, Duncan's multiple range test) | | |

**Table 5: Maize height at Santa Rosa and Niquinohomo**

| | Santa Rosa | | Niquinohomo | |
|---|---|---|---|---|
| Treatment | height (cm) | Duncan* | height (cm) | Duncan* |
| *Canavalia brasiliensis* CIAT 17009 | 138.53 | c d e | 61.74 | e f g |
| *Centrosema plumieri* | 125.54 | f e g | 70.03 | b c d e |
| *Clitoria ternatea* | 159.2 | a b | 74.92 | b c |
| *Lablab purpureus* 2 | 139.21 | c d e | 86.73 | a |
| *Lablab purpureus* CIAT 21603 | 144.07 | c | 66.43 | d e f |
| *Lablab purpureus* CPI106471 | 150.6 | b c | 71.31 | b c d |
| *Lablab purpureus* CPI-676 | 151.46 | b c | 72.85 | bc |
| *Lablab purpureus* CQ- 2975 | 148.84 | b c | 67.8 | c d e f |
| *Vigna umbellata* CIAT 24360 | 117.18 | f g | 64.47 | d e f |
| *Vigna umbellata* CIAT 26469 | 128.87 | d e f | 64.71 | d e f |
| *Vigna unguiculata* IITA 131-2 | 160.23 | a b | 65.35 | d e f |
| *Vigna unguiculata* IITA 284/2 | 167.98 | a b | 77.08 | b |
| *Vigna unguiculata* IITA 390/2 | 142.52 | d c d | 61.23 | f g |
| *Vigna unguiculata* 9611 | 137.46 | c d e | 59.78 | f g |
| *Vigna unguiculata* Verde Brasil | 139.9 | c d e | 71.41 | b c d |
| *Vigna unguiculata* FHIA | 113.73 | g | 65.65 | d e f |
| no intercrop (local check) | 120.03 | f g | 55.54 | g |
| *different letters denote significant differences (p< 0.05, Duncan's multiple range test) | | | | |

In Santa Rosa, intercropping with *Vigna unguiculata* 284/2 provided best results, in contrast to the combination with *Vigna unguiculata* FHIA and *Vigna umbellata* 24360. At the Niquinohomo site *Lablab purpureus* 2 (Dl) and *Vigna unguiculata* 131-2 were most

promising, whereas intercropping with *Vigna umbellata* 26469 and *Centrosema plumieri* appeared to be least beneficial.
A striking general result was that at both sites the local check (maize without intercropping) showed poorer results in comparison to intercropping with any legume.

**Effect on yields**
Maize yield was measured at both sites, but due to drought in Niquinohomo the maize yields were very low, not representative and therefore not taken into consideration.

**Table 6: Maize yield (kg/ha) at Santa Rosa**

| Treatment | Santa Rosa |
|---|---|
| *Canavalia brasiliensis* CIAT 17009 | 3690 |
| *Centrosema plumieri* | 1789 |
| *Clitoria ternatea* | 2561 |
| *Lablab purpureus* 2 | 3286 |
| *Lablab purpureus* CIAT 21603 | 3633 |
| *Lablab purpureus* CPI106471 | 3543 |
| *Lablab purpureus* CPI-676 | 2424 |
| *Lablab purpureus* CQ- 2975 | 3580 |
| *Vigna umbellata* CIAT 24360 | 3118 |
| *Vigna umbellata* CIAT 26469 | 2284 |
| *Vigna unguiculata* IITA 131-2 | 4127 |
| *Vigna unguiculata* IITA 284/2 | 2434 |
| *Vigna unguiculata* IITA 390/2 | 2675 |
| *Vigna unguiculata* 9611 | 2620 |
| *Vigna unguiculata* Verde Brasil | 2787 |
| *Vigna unguiculata* FHIA | 3137 |
| no intercrop (local check) | 1832 |

Differences between the treatments were not statistically significant ($p>0.05$), due to the high variability. Highest yields were obtained when intercropping with *Vigna unguiculata* 131-2, *Lablab purpureus* accessions 21603, CPI –106471 and "2", as well as with *Canavalia brasiliensis*. As with plant height, results of the local check and *Centrosema plumieri* were poorest, indicating that there is indeed an effect of the legumes on maize yield.

**4.1.4 Some general conclusions and observations**

- The Santa Rosa site presented better results than Niquinohomo (drought).
- *Vigna unguiculata* Verde Brasil and *Lablab purpureus* 2 showed in general best results (agronomic characteristics, production, nodulation and biomass N-content).
- Least performing legumes were *Vigna unguiculata* 390/2, *Vigna unguiculata* FHIA and *Vigna umbellata* 26469.
- In general, maize performed best when intercropped with *Lablab purpureus*, especially the accessions CQ- 2975 and CIAT 21603. Maize without intercropping showed poorest results.
- These results are still preliminary. Additional analysis (including soil) will provide more insight in for instance nutrient fluxes.

### 4.2 Evaluation of four leguminous shrubs intercropped with annual species under conditions of drought

The trial was established in June 2008 at the UNA "El Plantel" farm. The climate is characterized by an annual rainfall of 1100 mm with a rainy season of six months (May to November) within which a relatively dry period during August and September. Average temperature is 26 degrees C. Soils are Mollisols of volcanic origin, with intermediate soil depth and well drained (Table 7, for more details see Annex 4).

**Table 7: Soil characteristics of "El Plantel"**

| | depth | pH | OM | N | P | K | Ca | Mg | clay | loam | sand | texture |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cm | | % | | ppm | me / 100 soil | | | % | | | class |
| El Plantel | 0-15 | 6.77 | 2.4 | 0.12 | 12.1 | 1.09 | 25.03 | 11.25 | 34 | 34 | 32 | clay-loam |
| | 0-30 | 6.88 | 1.8 | 0.09 | 2.5 | 0.90 | 25.73 | 11.28 | 34 | 34 | 23 | |

Four leguminous shrubs were planted as alley crops with maize: *Gliricidia sepium*, *Leucaena leucocephala*, *Caesalpinia velutina* and *Erythrina poeppigiana*. *Canavalia brasiliensis* was planted between the alleys. *Calopogonium* sp. was also evaluated. Soil samples were taken and analysed.

The experimental test design consisted of three randomised blocks, each block was divided into 5 experimental plots of 300 m2 each. The measured variables were: survival rate, plant height, plant diameter, maize height, biomass production of Canavalia and *Calopogonium* sp., the soil was analysed for pH, organic matter, nitrogen, available phosphorus and potassium, calcium, magnesium and electric conductivity.

Results:

- Highest plants: *Leucaena leucocephala*
- Largest plant diameter: *Gliricidia sepium*, *Leucaena leucocephala*, and *Erythrina poeppigiana*
- Highest *Canavalia brasiliensis* plants were measured in the plots associated with *Caesalpinia velutina*, lowest with *Gliricidia sepium*.
- Biomass of *Canavalia brasiliensis* was highest in plots associated with *Leucaena leucocephala*
- Biomass of *Calopogonium sp* was highest in plots associated with *Gliricidia sepium*, lowest with *Caesalpinia velutina*.

Conclusions:

- *Leucaena leucocephala* and *Gliricidia sepium* show best agronomic results
- *Leucaena leucocephala* is suitable as an intercrop (alley) with the most productive legume *Canavalia brasiliensis*.

### 4.3 Agronomic and production characteristics of five forage legumes in semi-arid conditions

The experiment took place at the Finca "Santa Rosa" of UNA, altitude 80 masl, characterized by sandy loamy soils, with a pH from 6-7, with Organic Matter content of approx. 4% but low fertility (see Table 1 and Annex 4 for more details). The climate is sub-humid, with annual rainfall between 800 and 1200 mm, and a relative humidity between 60 and 90%. Treatments consisted of five forage legumes: three accessions of *Vigna unguiculata* (Verde Brasil, 9611 and IITA 284/2), *Vigna radiata* and *Pueraria phaseoloides*.

Objectives

General: assess the agronomic and production characteristics of five forage legumes in semi-arid conditions

Specific:

- determine the agronomic behaviour of five forage legumes
- determine biomass production (fresh and dry), as well as production of seed
- select the best performing species/accessions

Material and methods

The experimental area (512 $m^2$) consisted of five plots, each of them was planted with a different forage legume in eight rows, with a distance of 0.4 m between rows and 0.3 m between plants. The agronomic variables were germination, growth, plant height, cover, pest and disease incidence. Production variables were biomass weight (fresh and dry) and seed production (number of pods per plant, number of seeds per pod)

Results

*Vigna unguiculata* 9611 and IITA 284/2 showed both highest biomass and seed production, and a sustained growth even during the first part of the dry season. Biomass and seed production of *Vigna unguiculata* Verde Brasil was lowest. *Pueraria phaseoloides* established well but was attacked by pests (insects) leading to loss of the plot (Table 8).

**Table 8 : Biomass and seed production of five forage legumes**

| Accession | Biomass production (DM kg/ha) | Seed production (kg/ha) |
|---|---|---|
| *Vigna unguiculata* Verde Brasil | 250 | 0 |
| *Vigna unguiculata* 9611 | 1300 | 480 |
| *Vigna unguiculata* IITA 284/2 | 1150 | 465 |
| *Vigna radiata* | 650 | 200 |
| *Pueraria phaseoloides* | n/a (pests) | n/a (pests) |

Conclusions

- The *Vigna unguiculata* accessions 9611 and IITA 284/2 are suitable materials for semi-arid conditions, showing reasonable biomass and seed production and good pest resistance.

## 4.4 On-farm and community research

### 4.4.1 The behaviour of local and introduced legumes and their effect on maize during the growing period and after mulching

This research was done by the MSc. student Diana Kurzweg in collaboration with UNA and took place in Pacora, a community of the municipality of San Francisco Libre situated approx. 30 km. north of Managua, close to lake Managua, with approximately 250 habitants in 50 families. The region is relatively dry, with an annual rainfall from 1000 - 1200 mm (mainly during the wet season between May and October), usually with long dry spells. The soils are loamy and poor (N = 0.9 g/kg, P = 0.00 ppm).

Objective

The objective was to investigate the behaviour of *Canavalia brasiliensis* (CIAT 17009) and *Vigna unguiculata* (9611) and their effect on maize production, in comparison to maize as a monocrop without and with fertilizer.

Methods

Both legumes were intercropped in rows between maize to observe their growth characteristics and their effect on the maize plants, when sown ten days after the maize and used as mulch at flowering. These treatments were compared to fertilized and unfertilised plots without legumes. The treatments are presented in Table 9.

**Table 9: Treatments of intercropping experiment in Pacora**

| Treatment | No. of replicates |
|---|---|
| Maize without legumes | 4 |
| Maize without legumes + N-fertilizer (25kg N / ha) | 4 |
| Maize with *Canavalia* (early cut) | 4 |
| Maize with *Vigna* (early cut) | 4 |
| **Total** | **16** |

Expected outcomes included a dense plant cover to protect against erosion, to keep soil temperature low reducing evaporation, and to decrease growth of weeds.
An additional treatment included cutting the legumes before flowering and using them as a mulch, in order to increase the amount of plant available nitrogen in the soil for the subsequent (maize) crop. Legume biomass and total N content were measured at the onset of the flowering stage for a first estimate of the potential N release.

Results
Average biomass production was 599 kg DM/ha for *C. brasiliensis* and 308 kg DM/ha for *V. unguiculata*. Although – because of unusual drought - these values are far lower than usual, the plants stayed green and vital throughout the experiment. No differences were found in maize yields between fertilized and unfertilized plots, even though the maize plants in the fertilized plots were higher and showed more resistance to wind.

Additionally, a field trial was carried out comparing the performance of *Canavalia brasiliensis* CIAT 17009 with the three indigenous legume species *Teramnus uncinatum*, *Macroptilium atropurpureum*, *Centrosema macrocarpum* under local conditions.
The three tested indigenous species showed good drought resistance and little vulnerability against pests and diseases once they were established. They performed however poorly in comparison with *C. brasiliensis*. Germination rates were low, as well as the survival rate during the initial stage and biomass production. Reasons were probably strong weed pressure (especially from *Cyperus* spp.), heavy pest attacks during the initial growth, low rainfall and poor soils.

Conclusions:

- The legumes *Canavalia brasiliensis* CIAT 17009 and *Vigna unguiculata* 9611 showed resistance against drought but did not directly affect maize production under unusual conditions of drought. Additional experiments would be needed to elaborate further on these results.
- When compared to indigenous legumes, *C. brasiliensis* showed better resistance against weeds, pests and drought.

### 4.4.2 Community analysis on development project activities, their effectiveness, lessons learned and success factors

Additionally to the field trials, the MSc. student Diana Kurzweg carried out a community analysis during her four months' fieldwork.
General objective:

To identify how and why local farmers participate in activities of research and development agencies at community-farm level.

Methods:
Qualitative formal and informal interviews were held with members of 14 families in Pacora on development project activities, their effectiveness, lessons learned and success factors.
The research evaluates former rural development projects and influence of research that have been done in that village, including their impact on poverty reduction and contribution to protect natural resources.
The focus was on transfer of knowledge, but also on donations and external influences in general. Reasons for success of projects as well as for failure are explained and recommendations for further work are given. Different types of projects are compared regarding their success. These types include top-down approaches, participatory research, farmer trainings, farmer-to-farmer programs, offered possibilities for farmer to do research on their own, implementation of local businesses, and on-site trials.

Results:
It was assumed that ecological obstacles for new crops were a reason for failure of transfer knowledge to the people. That means that people did not adopt new practices that aid agents tried to introduce, because in their case the practices just did not work convincingly.
Adverse ecological conditions is one reason why people rarely implement new crops or cropping practices, such as use of legumes or planting of fruit trees and vegetables. However, various other obstacles have been detected leading to failure of projects, including:

- difficulties in spread of knowledge due to lack of communication and community feeling
- difficulties to implement knowledge into daily life, for instance because big changes of routine are unusual - new methods are often perceived as too labour intensive, effects are usually not directly visible or only provide long-term benefits
- techniques not adapted to the local situation
- lack of (financial) resources implement new practices

Livelihoods have not improved much due to lack of self-initiative from the community members, to lack of input of knowledge and ideas, a bias towards prestige and western values rather than basic principles for survival and a healthy life and external influences causing unwanted side-effects.
The effect of the variety of different project approaches and research activities has generally been small. However, some contributions and knowledge have been accepted well by the people, and could partly contribute to protect natural resources, mainly because they fitted well in local practice and did not require much extra labour.

### 4.4.3 Participatory Rapid Appraisal (PRA) and training workshop on use of both introduced and local herbaceous forage legumes and leguminous shrubs for improvement of soil fertility and animal feed in Pacora, San Francisco Libre, Managua

Objective:
The objective of the appraisal and workshop was to obtain and share information on native and introduces forage legumes, to improve farm management applying a combination of local knowledge and introduced technologies on use of forage legumes in dry conditions.

Methods:
The appraisal included the use of participatory tools like group meetings, semi-structured interviews and field visits and involved 5 students. The workshop consisted of a training on

use of forage legumes. The activities were facilitated by the university teachers who participate in the project.

Plant species and parts used as animal feed by the different farm animals were identified. Apart from this, 21 community members received a training on use and management of legumes. The PRA consisted of collecting, identifying and determining the use of the forage species, using the following elements as mentioned in Table 10:

**Table 10: Elements of PRA on use of forage legumes for animal feed**

| Plant type: Shrub, Shrub | | | | | | |
|---|---|---|---|---|---|---|
| Type of animal | Leaves | Branches | Flowers | Fruits | Season | Observations |
| Cattle | | | | | | |
| Horse | | | | | | |
| Goat | | | | | | |
| Sheep | | | | | | |
| Pig | | | | | | |
| Rabbit | | | | | | |
| Poultry | | | | | | |

The results were analysed statistically and presented to the community to share, discuss and confirm the findings

Results:

- A total of 16 shrub and 16 tree species were identified
- Shrubs and trees are part of the diet of most livestock species, especially cattle and small ruminants
- Most consumed shrubs are Palo Grande, Chagüite, Flor Amarilla, Zorrillo Blanco, Malva, Guacimito and Chililllo de Gallina
- Most consumed trees are Leucaena (*Leucaena leucocephala*), Marango (*Moringa oleifera*), Guácimo de ternero (*Guazuma ulmifolia*), Brasil y Tamarindo (*Tamarindus indica*), of the fruits Marango (*Moringa oleifera*), Guácimo de ternero (*Guazuma ulmifolia*), Brasil, Tamarindo (*Tamarindus indica*) and Carbón (*Acacia pennatula*)
- The components most consumed of shrubs are leaves (70%. The other parts (branches, flowers, fruits account each for approx. 10%).
- The components most consumed of trees are leaves (55%) and fruits (45%).

Conclusions:

Leaves of shrubs and trees are mainly eaten by cattle, followed by horses, goats and sheep. Branches (of shrubs) are predominantly consumed by cattle and goats, followed by horses and sheep.

## 5. General observations and conclusions

Table 11 provides an overview of the different sites and participants of the project.

**Table 11: Sites and participants of research components**

| | Nr. of students | San Dionisio | Sta Rosa (farm UNA) | El Rancho (Niquinohomo) | Pacora (San Francisco Libre) | El Plantel (farm UNA) |
|---|---|---|---|---|---|---|
| herbaceous legumes / adaptability + N-fixing potential | 1 (Univ. of Copenhagen), + 3 (Fac. of Agronomy) | X | | | | |
| adoption potential of organic farming | 1 (Univ. of Copenhagen), + 3 (Fac. of Agronomy) | X | | | | |
| herbaceous legumes / maize | 2 (Fac. of Natural Resources) | | X | X | | |
| leguminous shrubs / maize | 2 (Fac. of Natural Resources) | | | | | X |
| herbaceous legumes / animal production | 2 (Fac. of Animal Sciences) | | X | | | |
| intercropping maize with *Vigna* and *Canavalia* | 1 (University of Potsdam – BOKU) | | | | X | |
| diagnosis, workshops etc. with farmer groups | several (Fac. of Natural Resources) | | | | X | |

Farming systems research:
Some data are still being analysed or need some further work and final results will become available by the end of 2010. However, it can already be concluded that this project has contributed significantly to increasing the understanding of the (potential) role of herbaceous legumes in mixed crop-livestock farming systems in Nicaragua, especially regarding their adaptability in conditions of drought and poor soils, and as intercrop with cereals (maize) and shrubs/trees.

Capacity building:
The project has contributed substantially to institutional and individual capacity development within the partner UNA (Universidad Nacional Agraria), in the form of graduated students (10) and involved staff members (3). Furthermore, two students from universities from the North (BOKU in collaboration with University of Potsdam, Germany, and University of Copenhagen) did their fieldwork as a basis of their MSc. graduation.
As pointed out in the introduction, the project built on preceding activities in the research region (CIAT, UNA, local partners) based on farmers' issues on causes and interactions between crop management and soil resources. The involvement of BOKU (in the form of

Prof. Freyer and participating MSc. students) has led to a strengthening of North-South cooperation between universities (BOKU-UNA) and research centers (BOKU-CIAT).
Research results (thesis, other publications) and developed capacities in the form of graduated students (UNA, BOKU, University of Potsdam, University of Copenhagen), staff (UNA) and farmers in the research areas are direct sustainable outcomes of the project.

Dissemination of results:
The project has a direct impact on over 20 farmers in the community of Pacora, participating in experiments, surveys and receiving training. Indirect impact can be expected from disseminated research results translated into extension messages for farmers, but above all use of these results as inputs for further research, contributions to content of curricula and other teaching materials, and project proposals. For instance, recently a new project partly based on ULLIS and named "*Eco-efficient crop and livestock production for the poor farmers in the sub-humid hillside areas of Nicaragua* ", was started. The activity leans heavily on on-farm work, is funded by ADA and implemented by CIAT in collaboration with BOKU, UNA and the Nicaraguan Agricultural Research Institute - INTA.

**List of theses**

Borgen, S. 2007. Biophysical adaptation of legume green manures in semi-arid Nicaraguan hillsides of San Dionisio, and social adoption analysis. Master Thesis. Faculty of Life Sciences, University of Copenhagen, Denmark.

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**Books**

Kurzweg, D. 2010: Ecological and social limits for rural development in developing nations. The example of Pacora, Nicaragua. VDM Verlag Dr. Müller e.K. ISBN 978-3-639-25598-0, paperback, 180 Pages.

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**List of acronyms**

| | |
|---|---|
| ADA | Austrian Development Agency |
| BOKU | University of Natural Resources and Applied Life Sciences |
| CGIAR | Consultative Group on International Agricultural Research |
| CIAT | Centro Internacional de Agricultura Tropical |
| CCGM | cover crops/green manures |
| ha | hectare |
| masl | meters above sea level |
| MIS Consortium | Consorcio para el Manejo Integrado de Suelos en Centro América |
| PRA | Participatory Rural Appraisal |
| ULLIS | Use of legumes in low input systems |
| UNA | Universidad Nacional Agraria, Nicaragua |

**Annex 1: Trial design herbaceous legumes: Rancho Ebenezer in Masaya and Finca Santa Rosa (UNA)**

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dl | Maiz | Vun5 | Vum1 | Vun6 | Vun4 | Can1 | Lab3 | Cl | Vum2 | Lab2 | Vun2 | Vun3 | Vun1 | Lab4 | Cp | Lab1 |
| Vun6 | Vun2 | Can1 | Lab2 | Cp | Vun4 | Maiz | Lab3 | Cl | Vun5 | Vum1 | Lab1 | Lab4 | Vun3 | Vum2 | Vum1 | Dl |
| Vun2 | Vun1 | Maiz | Vum1 | Vun6 | Lab3 | Cl | Can1 | Vun5 | Vun3 | Lab4 | Vum | Vun4 | Lab1 | Cp | Lab2 | Dl |

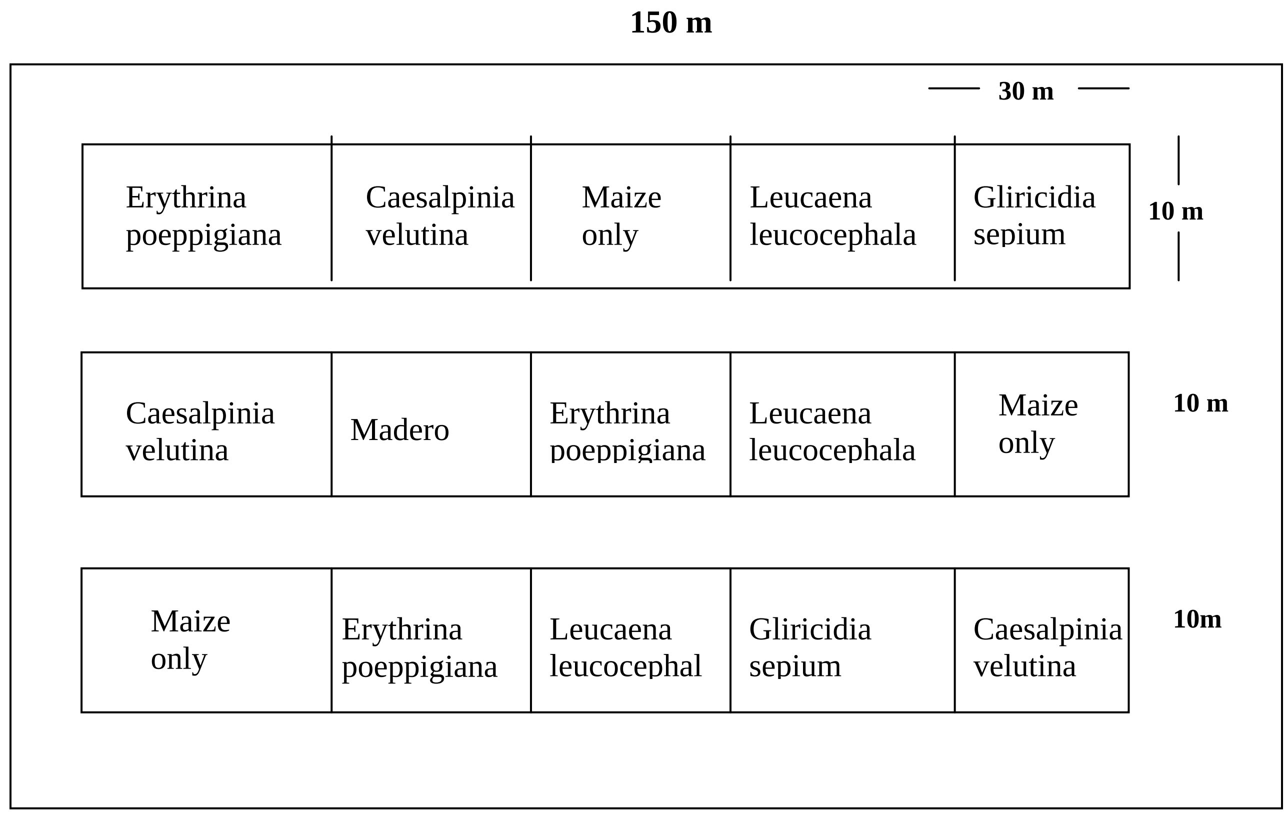
Key (treatments):

Can1: *Canavalia brasiliensis* CIAT 17009
Dl: *Lablab purpureus* "2"
Cl: *Clitoria ternatea*
Cp: *Centrosema plumieri*
Lab1: *Lablab purpureus* CPI-106471
Lab2: *Lablab purpureus* CPI-676
Lab3: *Lablab purpureus* CQ-2975
Lab4: *Lablab purpureus* CIAT 21603
Maiz: *Zea mays* (NB 6): control

Vum1: *Vigna umbellata* CIAT 26469
Vum2: *Vigna umbellata* CIAT 24360
Vun1: *Vigna unguiculata* Verde Brasil
Vun2: *Vigna unguiculata* 9611
Vun3: *Vigna unguiculata* IITA 284/2
Vun4: *Vigna unguiculata* FHIA
Vun5: *Vigna unguiculata* IITA 131-2
Vun6: *Vigna unguiculata* IITA 390/2

each plot measures 4 x 3 m.

**Annex 2: Trial design leguminous shrubs and trees: El Plantel (UNA)**




Chocuabo: *Caesalpinea violacea*
Guanacaste: *Enterolobium cyclocarpum*
Leucaena: *Leucaena leucocephala*
Madero: *Gliricidia sepium*

## Annex 3: Timetable October 2007 – April 2010

| ***Activities*** | ***2007*** | ***2008*** | | | | | | ***2009*** | | | | | | ***2010*** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *N-D*[1] | *J-F* | *M-A* | *M-J* | *J-A* | *S-O* | *N-D* | *J-F* | *M-A* | *M-J* | *J-A* | *S-O* | *N-D* | *J-F* | *M-A* |
| *1,2. All legume trials* | | | | | | | | | | | | | | | |
| Contacts for establishment trials | 1-4[2] | | | | | | | | | | | | | | |
| Demarcation of trial plots | 5-8 | | | | | | | | | | | | | | |
| Collection of soil samples | 5-6 | | | | | | 5-6 | | | | | | | | |
| Clearing of trial plots | | 1-8 | | | | | | | | | | | | | |
| Planting of trials (except goat trials) | | | | 1-8 | | 1-8 | | | | | | | | | |
| Data collection[3] | | | | 6-8 | 1-8 | 1-8 | 1-8 | 1-8 | 1-8 | 1-8 | | | | | |
| Replanting (if necessary) | | | | 5-6 | | 5-6 | | | | | | | | | |
| Collection of plant samples | | | | | 1-8 | | | | | | | | | | |
| Maintenance | | | | 5-8 | 1-8 | 1-8 | 1-8 | 1-8 | 1-8 | | | | | | |
| Data analysis | | | | | 1-8 | 1-8 | 1-8 | 1-8 | 1-8 | | | | | | |
| Thesis writing | | | | | | | | | | 1-8 | | | | | |
| Presentation of thesis | | | | | | | | | | | 1-8 | | | | |
| *3. Legume trials animal production* | | | | | | | | | | | | | | | |
| Selection and preparation of plots | | | | | | | | | | 1-8 | | | | | |
| Planting of trials | | | | | | | | | | | 1-4 | 1-4 | | | |
| Data collection[3] | | | | | | | | | | | | 1-8 | 1-8 | 1-8 | |
| *3. PRA* | | | | | | | | | | | | | | | |
| Training workshop | | | | | | | | | | | 1-8 | | | | |
| Fielddays | | | | | | | | | | | 1-8 | | | | |
| Writing final reports | | | | | | | | | | | | | | 1-8 | |
| Handing in final reports | | | | | | | | | | | | | | | 1-8 |

Note:
[1] months
[2] weeks during the 2-month period
[3] including germination rates, cover, biomass, diseases, survival rates, feed intake, milk production, milk quality, live weight gain, inventory of microfauna (soil)

**Annex 4: Results of soil analyses at the different experiment sites**