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Promoting Sustainable Development in the Traditional Banana Growing Areas of Southern Belize and Alleviating Poverty

Expertise in Environmental Assessment and Management

Final Report
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FRAMEWORK CONTRACT BENEF – Lot N°6: Environment
Letter of Contract N° 2008/160516 – Version 1
To promote sustainable development in the traditional banana growing areas of Southern Belize and to alleviate poverty
Expertise in environmental assessment and management
August - September 2008

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Abstract

The mission took place from August 18th, 2008 to October 4th, 2008 and was composed of one agronomist, team leader, and a laboratory specialist. Each expert stayed five weeks in Belize.

The objectives of the mission were to review and provide a comprehensive assessment of the actual environmental monitoring activities performed by the Banana Growers Association and by each farm and to appraise the local capacities to test and analyze the related parameters with respect to international standards and agricultural practices; to make recommendations to improve them. The mission included a list of practical related laboratory equipment to be proposed in order to monitor the industry’s environmental impact (for a maximum of €150,000.00).

AGRO-ENVIRONMENTAL ASSESSMENT

Agronomical matters having an impact on the use of chemicals

- The system of production in Belize is perennial, meaning that bananas are grown non-stop on the same plots, sometimes for the last thirty years or more.
- The prevalence of *Mycosphaerella fijiensis* Morelet (Black Sigatoka Fungus) affecting the leaves of the plants and of *Radopholus Similis*, which is an endo-parasitic nematode affecting the roots, is extremely high.
- Until now, the only methods used to control these pests and diseases have relied on the use of chemical pesticides, placing Belize among the nations (producing bananas) using the highest quantities of pesticides: 60 to 70 kg of active ingredients per hectare and per year (Fungicides + nematicides/insecticides + herbicides).
- It is now very difficult to reduce these quantities. For instance, the fungus (*Mycosphaerella*) has developed a resistance to systemic fungicides and more contact fungicides must now be spread, more often. The use of environmental friendly fungicides is presently tested with the hope that they could constitute 15% of the solutions.
- To control *R. Similis*, only two options exist:
  - The biological option: A twelve month fallow before replanting, or crop rotation, possibly coupled with the use of cover crop in order to improve the biological activity of the soil and get a better equilibrium between nematode species. This option also includes any possible means to increase the soil organic matter.
  - The Chemic option: Three nematicide treatments per year.

Soil fertility and biology

- The comparative study of the soils analyses performed in 2008 versus those implemented eight to ten years ago is showing a dramatic fall of the soil organic matter (SOM), except on one or two farms were new alternative techniques have been introduced.
The amendments brought to the soils are generally poor (liming amendments and organic amendments). Fertilizing practices rely mostly on the use of mineral fertilizers.

Soil profiles are showing soil compaction, leading to a decrease in the biological activity of the soil and preventing the fair development of the roots. **Compaction is the number one soil problem quoted by the farmers.**

This compaction is due to the cultivation itself, but it has been favoured by the cropping system: Farmers have done some land rehabilitation with the support of the European project, but the replanting never included any fallow or crop rotation, when these techniques are the only ones having a long term effect on soil compaction.

To resume the situation of the cropping system today, two images can be used:

1. Considering the four components of a soil system described by Norman Uphoff and al (2006) - minerals, air, water, organic content - only two components have been taken care of during the last thirty years: The minerals (with the fertilizers and liming amendments) and the water (with irrigation and drainage systems). **Two major soil components have been totally neglected: The organic matter and the air.**

   Presently, the soils are functioning like cars without tyre at their wheels and with no oil in the engine.

2. One might have forgotten also in Belize that a plant starts to grow from the roots and not from the leaves: Leaves are receiving all the attention, chemicals like rain, to which mineral fertilizers may be added. Roots are just entitled to receive mineral fertilizers, and nematicide/insecticide treatments mainly with molecules that are now forbidden in Europe for environmental reasons. **Only a few farms are now starting to adopt biological approaches to soil management.**

**Environmental monitoring activities**

- All farms are GlobalGAP certified, meaning that they are functioning under a Quality Management System and that they comply with all the requirements of GlobalGAP, Fyffes (+ Dole sometimes) and the supermarkets in the UK.

- This certification gives a lot of credit to human safety matters, and more especially for the safe use of chemicals. The certification also deals with some environmental matters, and the farms usually comply with these requirements, at the exception of one however: The disposal of solid plastic waste, often wildly done ‘in the jungle’ (as said by a farmer).

- **But, to be GlobalGAP certified does not necessarily imply that one does not pollute the environment,** since no restriction is given on the quantity of chemicals spread per hectare and no analysis of pesticide residues from soil or drains or rivers is demanded by GlobalGAP.

- Therefore, **It belongs to the government to perform these monitoring activities**, which will involve various competencies (agronomy, geology, hydrology, laboratory, sociology, environment, human health, etc) working over a long period of time.
PROPOSALS FOR A SUSTAINABLE BANANA PLAN

Proposals are made on more environmental friendly practices that are necessary not only for the purposes of the environment but also on an economical point of view. Yields are presently too low and no increase will be reached if no alternative cropping system is used.

The choice is particularly clear and a decision has to be taken: It is either to continue a high use of chemicals (with the bad results that we have seen) or to implement alternative techniques, more friendly to the environment and more sustainable.

Alternative Cropping Systems

Objective 1: To Restore Soil Biological Activity and Fertility.
   Sub-Objective 1: To decrease soil compaction, and to plant banana in a clean soil, free of Radopholus Similis:
   Action 1: Lying fallow for at least twelve months,
   Action 2: Crop rotation.

Sub-Objective 2: To Restore the Soil Organic Matter (SOM) Content:
   Action 1: Making of compost from various sources, internal and external to the farms,
   Action 2: To install analytical tools to monitor integrated fertilizing plans (Soil analysis interpretation norms and a computerized system).

Objective 2: To reinforce Integrated Pest Management (IPM), and to improve the management of chemicals residues from empty cans.
   Action 1: Trials on practices allowing a significant reduction in the use of chemical herbicides,
   Action 2: Trials on Bio-beds.

ACTIONS AT BGA LEVEL

Objective: To reinforce the technical capacities of the Banana Growers Association in order to improve its agro-environmental monitoring activities,
   - Action 1: To bring a regular scientific support to the team of the BGA in charge of the Sigatoka Control,
   - Action 2: To strengthen the Agronomic Department,
   - Action 3: To bring a support to the Environment Department,
     - The department could acquire and install three small incinerators (one per region of production) in order to deal properly with the management of waste,
We can also conceive that the department provides full waste management services including the collection and treatment of this waste, or disposal at a proper place. A service that farmers would pay for.

- Action 4: Testing of the biobed (which could be carried out by the BGA).

ENVIRONMENTAL MONITORING AT NATIONAL LEVEL

Several studies have been made in Belize on the use of pesticides and their impact on the environment, some of them in the Banana Belt.

None of these studies has really highlighted any sign of levels of pollution that would have a demonstrated impact on the environment. However, these studies were limited in their objectives as well as in their means and they all recommended to banana industry to limit contamination.

One study in particular (Evaluation of pesticide and fertilizer usage in bananas & potential risks to the environment, 1994) estimated that approximately 32 T of Mancozeb (Dithane 60 SC used against the black sigatoka) accumulates in the environment annually, and that caution should be exercised in using the water draining the banana areas, and more especially in the Swasey River.

Other studies (not necessarily made in Belize) are showing that pesticides may have negative impacts on useful insects or fungi, meaning that when biological means are used in IPM, one must pay a lot of attention to the side effects of the pesticides spread against another pest or disease.

Considering the huge amounts of chemicals used by the banana industry in Belize (60 to 70 kg/ha/year), we propose a study to estimate pesticide contamination levels in the area, a study that would involve various competencies and the Belize Agricultural Health Authority (BAHA).

BAHA and CIL

BAHA is the legally established statutory body and the internationally recognized competent authority in Belize for animal health, plant health, food safety and quarantine services.

The Central Investigation Laboratory (CIL) is under the umbrella of the food safety department. It is committed in providing high quality, cost effective and accurate product testing services in partnership with the food and agricultural industries and other regulatory bodies of Belize.

The laboratory is equipped with sophisticated analytical equipments able to analyze a large spectrum of organic residues but the current analytical demand is not important enough to maintain a good level of experienced analysts.
Furthermore, following flooding and water damages caused by a hurricane in 2007, the activity has been drastically limited to microbiology, with only two technicians on duty.

**The Central Investigation Laboratory needs to be boosted by new ambitious** projects that could fit the constant increase in environmental and agronomic concerns in Belize.

According to the conclusions ending our environmental assessment in the banana industry, several projects of equipment could be envisaged to face different priorities of funding:

A proposal for 150 000 € analytical equipments, including new techniques like ICP spectrometer and elemental analyzer, was eventually set up to provide the laboratory with the material means to meet the whole future Belizean demand (estimated to about 2000 samples) for soil and plant testing.

These new techniques that confer the capacity to carry out agronomic analyses with short delay and good productivity will also enlarge the analytical competence of the BAHA to cope with new environmental monitoring strategies and food safety analyses programs. The corresponding specifications for tenders were written up to be billed on October 20th.

This task has been necessarily preceded by many preliminary contacts with analytical equipment suppliers in order to seek and rank the best potential manufacturers.

**But, first of all, the BAHA Laboratory has to overcome several impediments:**

- To refurbish or the re-build new functional premises,
- To choice a future definitive location as Belize City is too prone to hurricane,
- To quickly hire qualified analysts and maintain a good level of skills with few personnel,
- To look after technician training through intensive practical training courses,
- To set up the guidelines of a quality system scheme leading to a next certification.

**Each of these commitments is necessary.** The certification will bring to the laboratory an international credibility and will strengthen its authority. It’s a main condition for a durable activity. **But all these challenges will require additional financial aid.**

It is also essential that BAHA catches a very large share of the analytical demand in Belize to cover the most important proportion of its cost by services incomes. These analyses include pesticides residues, veterinary drugs, microbiology, soil and plant testing, fertilizer, compost, food and feed analysis, etc … and will not only involve the banana industry but all agricultural sectors and fisheries.

Several options are proposed concerning a sustainable commercial agreement between the BAHA laboratory and the various agricultural sectors, including the banana industry.
1 Introduction

1.1 Background

Banana is Belize’s main export industry and contributes an average BZ$50 m per year to the country’s foreign trade. It accounts for over 10% of employment in the Stann Creek District. Most of the workers are immigrants from neighbouring countries and speak Spanish, not English.

The Belize banana industry is a compact sector of 21 farms operated by 9 organized growers using modern technology on 6000 acres of drained and irrigated land. All farms are Eurepgap compliant since 2002 and fruit quality has consistently been reliable to a high standard. However, the country’s average yield is only 28 t/ha (650 boxes / acre).

An important contributing factor is the lack of an industry-wide production technology package adapted to the region and its conditions. A systematic, science-based approach to plant and plantation management can have a broad and positive impact on the entire industry.

In the areas of environmental assessment and monitoring, an improved monitoring of the environmental parameters could significantly contribute to environmental friendly agricultural practices satisfying both the market ethical requirements and the reduction of costs.

1.2 Objectives of the Assignment – Experts Profiles

(See ANNEX 1: Detailed TOR)

Global and specific objectives:

The global objective is to promote sustainable development in the traditional banana growing areas of Southern Belize and to alleviate poverty.

Specific objectives are:

1. Sustainable and environmental friendly development of the banana industry in Belize,
2. Sustainable strengthening of local laboratory capacities, particularly in the area of agronomic and environmental testing capabilities

Results to be achieved:

1. An updated and detailed assessment of the actual environmental monitoring activities performed by the BGA and by each farm, and the local capacities (equipment, procedures and competences) to test and analyze the related parameters with respect to the international standards and agricultural practices.
2. A detailed practical plan to alleviate the impact of the banana industry on the environment, including for each farm: recommendations, feasibility, related costs and impact indicators.
3. A list of practical related equipment to be bought before the end of the year 2008 under the Banana Support Programme (maxi 150,000 euro) to monitor the industry’s impact on the environment, enhance local testing lab capacities and sustainable synergies with agro industry.

4. Drafting of a sustainable commercial agreement between the banana industry and the BAHA laboratory about an environmental monitoring work programme.

Experts Profiles

Expert 1: Team leader - Environmental Expert Cat I specialized in environmental management of production.

Expert 2: Environmental Expert Cat II specialized in lab management.

1.3 Dates and Main Facts of the Assignment

(See Annex 2: Daily Activities)

The assignment of the environmental expert took place (in Belize) from August 19th until September 22nd, 2008. The mission of the lab expert took place (in Belize) from August 31st to October 4th, 2008.

The tasks accomplished by the environmental expert have consisted in:

- Elaboration of a questionnaire adapted to the regional characteristics,
- Environmental Assessment made on 15 farms (representing all farms), including:
  - Soil and climate characteristics of the farm,
  - Crop management,
  - Labour,
  - Environmental policies and procedures,
  - Record keeping system.
- Assessment of the actual environmental monitoring activities performed by the BGA

At the end of his assignment in Belize, a debriefing presentation was made to the PIU and BGA on the main results of his mission at farm level and at the level of the BGA. An outline of a Sustainable Banana Plan, including actions at both levels, was presented. This meeting took place on Friday 19th September at the Big Creek office of the Banana Growers Association. It was following a previous meeting held during the morning at the Ministry of Agriculture in Belmopan with Mrs. Francine MAGLOIRE, another debriefing meeting held the day before with M. Rodrigo BLANCO (Manager Sigatoka Programme at BGA), and various meetings with individual farmers.

The tasks accomplished by the lab specialist were as follows:
• Participating in the assessment on environment issues on some farms and in meetings with those in charge to give their opinions on the subject.
• Meeting with people in charge of BAHA,
• Assessment of the BAHA laboratory facilities,
• Contacts with several providers and manufacturers of laboratory equipment for specification data and price and pre-negotiation,
• Writing technical specifications for the tenders,

At the end of his assessment, a debriefing meeting was held at the Ministry of Agriculture in Belmopan on October 2nd, 2008. No representative from the Banana Growers Association attended this last meeting.
2 System of Production and Organization of the Banana Sector in Belize: Main Facts

2.1 Location of the Farms, Management at Farm Level

Environmental risks: Rivers and coastal areas

The banana farms of Belize are located in the Stann Creek and Toledo District. Due to the soil and climatic conditions and the water requirements of the banana production, all farms are located along two rivers crossing these districts: The Swasey River and the South Stann Creek River. Environmental risks will therefore concern these watershed areas and especially the river and coastal areas, including the shrimp farms located downstream and using draining water of the banana areas.

The farms are divided into three groups according to this situation (see Annex 3: Map, and Banana Farms of Belize):

- South Stann Creek farms (SSC River): Farms n° 7-8-15-16-5-25-26
- Swasey farms (Swasey River): Farms n° 9-10-12-13-14-18-21&22
- Cowpen farms (Swasey River): Farms n° 1-2-3-4
- Bladen river farms Farms n°6-11-17

Management systems

These twenty one farms are operated by nine Ltd Companies. Most of them are technically managed by managers who are not the owners. These managers generally hold a diploma in agricultural sciences. Only a few growers run their own farm.

Thus, there is a second division into 9 groups, concerning ownership and management:

<table>
<thead>
<tr>
<th>Farms (by ownership)</th>
<th>Acres</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2-3-6-9-10-11-12</td>
<td>2560</td>
<td>41 %</td>
</tr>
<tr>
<td>4-15-16</td>
<td>1156</td>
<td>19 %</td>
</tr>
<tr>
<td>7</td>
<td>751</td>
<td>12 %</td>
</tr>
<tr>
<td>5-25-26</td>
<td>582</td>
<td>9 %</td>
</tr>
<tr>
<td>8</td>
<td>408</td>
<td>7 %</td>
</tr>
<tr>
<td>14</td>
<td>306</td>
<td>5 %</td>
</tr>
<tr>
<td>21-22</td>
<td>274</td>
<td>4 %</td>
</tr>
<tr>
<td>13</td>
<td>140</td>
<td>2 %</td>
</tr>
<tr>
<td>17-18</td>
<td>70</td>
<td>1 %</td>
</tr>
<tr>
<td>Total area</td>
<td>6200</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Distribution of land by ownership

It is obvious that these natural and ownership characteristics affect by themselves soil management and environmental monitoring, which may differ from region to region, owner to owner, and manager to manager, consequently having an effect on management and yields.
We were able to observe some of these effects during our assignment, but certainly not all (See Following chapters and ANNEX 4: Assessment per farm).

2.2 Cropping System: Historical Facts

Bananas have been produced in Belize for a long time. The present farms have usually existed since the 1970s or the 1980s. The cropping system is a perennial or ‘none-stop’ system, which means that plantations have been producing bananas for the last twenty to thirty years without any fallow or crop rotation. However, since the existence of the European project, and following the 2001 hurricane, some rehabilitation of land and replanting has been done (see § European aid); which means that soils have been ripped, drained, irrigation systems installed, and have been replanted with vitro-plants (however with no cleansing of the soils done).

It is also recognized that the Belizean banana plantations have historically received high doses of chemicals. The high level of chemical use is mainly due to the prevalence of the Black Sigatoka (Mycosphaerella foliar disease).

2.3 Compliance with Eurepgap (GlobalGAP) Standards

The bananas from Belize are put onto the European market, which means that every stakeholder of the industry (from suppliers to buyers) must comply with the requirements of the European Union. These requirements are part of a ‘package’ called EurepGAP (GAP as Good Agricultural Practices), now becoming GlobalGAP (as Global world).

All farms are EurepGAP (GlobalGAP) certified, and they must also answer to possible additional requirements from the buyers and supermarkets (Fyffes and Dole, TESCO).

To be certified means that the farm is functioning under a Quality Management System. Certifiers from the European Union control the system once a year with a checklist containing hundreds of control points that embrace the following matters for a banana farm:

- Site History and Management,
- Record keeping and Internal self-assessment/internal inspection,
- Workers Health, Safety, Welfare,
- Propagation material,
- Soil management,
- Fertilizer use,
- Irrigation and ferti-irrigation,
- Integrated Pest Management (including diseases and weeds),
- Harvesting,
• Produce handling,
• Waste and pollution management, recycling and re-use,
• Environment and conservation,
• Complaints,
• Produce traceability,

As a matter of fact, EurepGAP requirements are directly managed by Fyffes in Belize (see § Fyffes below)

During our mission in Belize we saw the very high level of control to which farmers are bound: At the time of our assignment, three controller teams (totalizing more than ten persons) were present in the area:

- Dole Controller
- Fyffes Controllers
- EurepGAP controllers
- To whom we can add two controllers of the SSD-PIU Project, plus ourselves.

Considering all these controls and the various recommendations given by these controllers, we considered that our mission should rather be complementary and deal more directly with the actual agricultural practices, their impact on the environment, and possible actions to implement in order to improve them and to increase yields. One farmer also complained about all these ‘advisors who should rather tell the BGA what to do (rather than complaining about us)’.

2.4 FYFFES (and GLOBALGAP)

Fyffes (registered in Ireland), was the sole buyer of bananas in Belize until the beginning of the year 2008. It is still the most important one with 80% of the market shares. The local office is in Big Creek, and is directly involved in many environmental matters of the production.

Fyffes has its own Code of Conduct that farmers must comply with. This code includes EurepGAP requirements plus other requirements on either social matters (workers welfare) or demands from the supermarkets. By complying to Fyffes Code of Conduct, farmers are complying to GlobalGAP.

Practically, Fyffes manages a Produce Marketing Organization (PMO), which includes all banana farmers of Belize. This system reduces the number of audits from EurepGAP: Fyffes audits every farm at least once a year, while EurepGAP will audit only a sample of them (3 to 5 per year).

Concerning Fyffes, commercial activities and relationships with the BGA can be summarized as follows:
• Quality Control: Fyffes has five inspectors who visit each farm every day during packaging, and another check is made in the evening at the port on samples chosen at random. Each palette has a label and is scanned, using a bar-coding system for ensuring traceability.

• Payments: Fyffes buys the bananas FOB, and also pays for the storage of the bananas at the port, done in containers. At the end of the day, the farmer gets a delivery note that he gives to the BGA, which can then send an invoice to Fyffes.

2.5 Banana Growers Association

2.5.1 Legal Framework and Roles

The Banana Growers Association is the statutory body representing the banana growers in Belize. Its board of directors is constituted of 9 elected members. Decisions are normally taken by consensus, but legally by a majority vote. The Vote is not based on the person or the company but on the average production of the last three years, meaning that the majority of the votes can be reached by a minority of growers (today, three growers have the majority). Meetings are held once a month, and an AGM once a year. The roles of the association are as follows:

- Coordinates the production and the sale of bananas,
- Ensures marketing and accounts management with buyers (Fyffes and Dole).
- BGA Is the legal Authority to implement the disease control (Sigatoka),
- Recommends quality production standards and gives agronomic advice to farmers,
- The BGA also runs the distribution of small inputs (Bacterol, Glue, Bankit 25 SC) related to post harvesting and packaging matters.

2.5.2 Organization Chart

Thirty persons make up the personnel of the BGA, as shown in the Organization Chart below, dispatched in various services as follows:

- Administrative and quality departments, at the Big-Creek office,
- Sigatoka, Agronomy and Environment departments at the Savannah Airport office (This office is called the Mixing Station).
2.5.3 Internal Functionning (Sigatoka, Agronomy, Environment)

The **Sigatoka department** is in charge of the *Mycosphaerella* foliar disease on all farms. It is the most important service, **employing approximately 50% of BGA personnel**: Three pilots (for three planes), four field supervisors, one GPS person, six staff at the mixing station and one manager. **The total cost of the Sigatoka programme amounts to 2 B$ per box, or 1400 US$ per ha** (as compared with 1300 US$ in Costa Rica). However, farmers are charged only 900 US$ per ha, plus 50 US$ when minor nutrients are added to the solution.

The **Nutrition and Nematodes department** employs three staff dealing with soil and leaf samplings, their preparation and mailing to laboratories (one in Costa Rica and one in Honduras). The interpretation of this analysis and advice to farmers is done by a plant nutritionist who comes from Central America twice a year. This department is also in charge of the nematodes analysis, done by its technician.

The **environment department** consists of one person in charge of training and supervising at farm level in the following areas: Health (Food handling), Safety (Personal Protective Equipment) and Environmental Protection.
Environmental protection concerns four main areas:

- Waste Management: Fuel and Oil (lubricants), Plastic bags, Containers.
- Water protection: Drains (the technician makes sure that no weeding is done in order to avoid erosion), sedimentation tanks (for treatment of fungicide-alum effluent at the packing station), used waste water that must go to another septic tank, and analysis of the river and well waters.
- Soil protection,
- Wildlife protection.

The environment officer is in charge of the water samplings that are then analyzed at the BAHA Laboratory or at the National Brewery laboratory (see § Assessment)

### 2.5.4 Financial Situation of the BGA

The financial resources of the BGA come from fees taken on the sale of bananas (0.69 B$/box). The total amounts to approximately 2.5 Million B$ per year. The fee corresponds to 4.4% of the banana price (15.68 B$/ 18kg box in 2008).

**BGA costs** break down as follows:

- **Port fees and fuel surcharge fees**: 34%
- **Sigatoka control**: 55%
- **Agronomy/Environment /Quality**: 3%
- **Administrative costs**: 8%

The fuel surcharge fees are related to the bananas sold to Dole, which are transported to Honduras or Guatemala by truck.

According to the manager, the actual fees are not sufficient to pay the current expenses of the BGA, neither the interests of its liabilities that amount to 12 Million B$:

- **Social security**: 7 000 000.00
- **Banks**: 2 800 000.00
- **Fyffes**: 1 000 000.00
- **A. Zabaneh**: 1 100 000.00
- **Small creditors**

In order to solve this financial problem, the members of the board just agreed (in September 2008) to change the system as follows:
Each grower will pay directly the charges for the control of Sigatoka, port fees and fuel surcharge related to his own production.

Negociations will be opened with the banks and social security in order to consolidate the debt and find an agreement, so that the BGA will no longer bear for these debts.

The BGA will therefore assume its administrative costs plus agronomic and quality services.

Whatever solution is effectively reached, the manager of the BGA assess that running costs of the BGA amount to 4 B$ per box off-debt, instead of the 0.69$ fees that growers pay today. We arrived at the same figure with data communicated by M. Rodriguo Blanco (Manager Sigatoka).

That is to say that the Banana Growers Association has no means to increase its agro-environmental monitoring activities, and that farmers will be reluctant to increase their fees at a level that would allow it.

2.6 Other Stakeholders

Inputs suppliers (fertilizers, chemicals, etc) are private and generally deal directly with the farmers (except for Sigatoka Control). They must also comply with the GlobalGAP requirements for suppliers and may provide training to farmers on environmental, hygiene or security matters, as we could personally witness it on farm 4.

Bananas are sold to two buyers: Fyffes (80% of the production), and Dole (on 9 farms) since the beginning of the year 2008. It must be said that Dole did not come by itself, but was called by the farmers who say that Fyffes was rejecting too much of their bananas. The bananas that Dole buys are transported to ports in Guatemala by trucks (The Fuel Surcharge is paid by the BGA).

Other private stakeholders of the banana industry are the contractors (farms roads, drainage and irrigation systems, land preparation, etc), and the various professions that may intervene on the farms (builders, electricians, computers and services companies, etc).

The Government is directly involved in the Banana Industry mainly through the Pesticides Control Board that also comprises farmer organizations. The Government is the partner of the European Commission and part of the Project Implementation Unit, but no representative is physically present at the PIU office in Independence.

Pesticides Control Board
In 1985, the Government of Belize passed the “Pesticide Control Act” to promote the production and availability of wholesome food through rational pest and pesticide management.

The Pesticide Control Board was created in 1987: “The role of the PCB is crucial in the proper use and management of pesticides to ensure the wholesomeness of products sold in the local and foreign markets” Hon. Rene Montero, Minister of Agriculture, Fisheries and Cooperatives, 2008.

The board is composed of representatives from the various stakeholders of this sector, and in particular the government: Ministry of Health, Ministry of Agriculture, Ministry of Environment, Ministry of Labour, CARDI, University of Belize, Belize Center for Environmental Studies, Banana Growers Association, Citrus Growers Association, Cane Farmers Association, Grain Growers, Belize Livestock producers Association, and smaller cooperatives and NGO’s.

Main roles and actions of the pesticides Control Board are (or have been):

- To establish a pesticide scheme for the country,
- To establish all regulations required to fully implement the Act, regarding safe use of chemicals, transport, storage, disposal, advertisement, repacking and reformulation,
- To establish regulations to control the labeling and registration of pesticides,
- To regularly review pesticides registration procedures, and to allow for registration of formulations (instead of active ingredients),
- To review tariff regulations on pesticides,
- To establish and implement the National Pesticides Certification program (NPCP),
- To license persons to import or manufacture pesticides, and to authorize persons to sell restricted pesticides,
- To ensure by means of information and training the certification of Farmers in the safe handling of restricted chemicals,
- To deliver The **Certified Pesticide Applicator license** (CPA),
- To ensure awareness and cooperation with the medical sector and education in schools.

**Main roles and actions in the banana industry**

Every year, the PCB edits a list of Pesticides that can be used in agriculture (Register of pesticides), and a list of “Chemicals approved for use in Belize Banana Industry” *(See the list revised in August 2008 in Annex 5).*

The board issues the “Certified Pesticides Application License” that is compulsory for people who purchase or use chemicals that are on the “Restricted Pesticides List”. This list contains approximately twenty five chemicals that may be hazardous for persons or for environment. **However, the license is compulsory for the use of all chemicals in the Banana Industry.**
From 2002 to 2006, the PCB delivered 3000 licenses in the Stann Creek and Toledo districts, mainly for the banana and citrus industries.

A technical assistant is appointed to fulfill the various duties of the PCB at farm level in the Toledo and Lower Stann Creek District:
- Training in pest management, pesticides application and safety, storage, etc
- Monitoring and inspections of pesticide application,
- Health and environment matters.

A training session is organized every three months on every banana farm. According to M. Orticio Tuch, technical assistant of the PCB, twelve to fifteen persons attend the class on average (which means that approximately 50 people per year may be trained on each farm).

This high level of training given on the farms, which we saw for ourselves, is also due to the relatively high turn-over of workers.

In order to face this problem, the Pesticides Control Board set up a Master Trainer’s course for the training of trainers (technicians, field supervisors) who are habilitated to deliver classes to other workers of the farm.

![Picture 1: Training session on the safe use of chemicals, Farm 4 – August 2008](image)

### 2.7 European Aid, Project Implementation Unit, Programmes

The European Aid for rural development in the Stann Creek District in Belize (SSD) started in 1999. Since 2006, the programmes have been implemented by an office in Independence village that is called PIU (Project Implementation Unit). In 2008, the unit is under the umbrella of the Ministry of Economic Development, Commerce and Consumer Protection, and the Ministry of
Agriculture. However, no representative of these Ministries is present at the PIU office in Independence, and PIU officers have to go to Belmopan or Belize City whenever it is necessary.

We must say that the programmes implemented since 1999 and until 2008 appear to be an addition of well-targeted projects on various subjects rather than actions being part of a comprehensive strategy with well-defined goals and objectives. The holding of annual conventions to finance these projects is not helping a comprehensive approach, either. A summary of implemented actions is presented below:

1. Direct actions towards the banana production (cropping systems):

   • Investment programmes at farm level: Drainage and irrigation systems have been installed and/or upgraded on 70% of the area. This has been a very important component of the project, if not the most important, which is continuing today.

   • Rehabilitation of 56% of the area since 2001 (hurricane Iris), with the planting of vitroplants, however with no previous cleansing of the soil until 2008. Since 2007 a more comprehensive programme has been implemented on 475 acres including tillage, leveling, drainage, irrigation, and planting of vitroplants. Continuation of the project, driven by a new integrated approach including fallowing, is scheduled for the years 2008 (239 acres), 2009 (575 acres), 2010 (275 acres), totalizing more than a 1000 acres.

   • Support to the Banana Growers Association: This support has mainly dealt with the control of the black sigatoka (including studies and financial support for the purchase of chemicals), a niche-market study, and another study on the control of nematodes. The more recent actions are still being carried out: Our mission on environment and laboratory matters, a mission on plant nutrition, plus some investments (vehicles). Some fertilizers (worth more than 1 Million B$) and nematicides will also be provided to the farmers. It is expected to link some environmental conditions to the procurement of these inputs to the farmers.

   • The PIU office, and more especially its drainage and irrigation engineer, is also providing a direct support to the farmers for the running and management of their irrigation system. The BGA has received equipments and several people have been trained to do the job, but nobody is doing it.

2. Rural and social development activities have been implemented towards the workers of the banana industry in the following areas:

   • Education,
• Water and Electricity,
• Health.

2.8 Other Agricultural Sectors of Belize
(Having Possible Links With The Banana Industry)

Belize has four main sectors in agriculture. Each one produces organic matter that is already used or could be used to make organic or mineral amendments. Some of them could be used for banana production, but certainly not all.

Our estimates on the availability of organic matters that could be added to soils are as follows:

<table>
<thead>
<tr>
<th>Sector</th>
<th>Acres</th>
<th>Waste</th>
<th>Estimated Annual Quantity of Organic Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana</td>
<td>6 000</td>
<td>- Rejected bananas and stalks</td>
<td>8 000 T</td>
</tr>
<tr>
<td>Sugar Cane</td>
<td>55 000</td>
<td>- Filter press green waste</td>
<td>55 000 T</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Bagasse ashes</td>
<td>11 000 T</td>
</tr>
<tr>
<td>Citrus</td>
<td>45 000</td>
<td>- Green waste</td>
<td>55 000 T</td>
</tr>
<tr>
<td>Shrimps</td>
<td></td>
<td>- Heads</td>
<td>Not much now, sales with heads to Europe</td>
</tr>
<tr>
<td>Sawmills</td>
<td></td>
<td>- Sawdust</td>
<td>A lot of available sawdust, but necessary study</td>
</tr>
</tbody>
</table>

Table 3: Agricultural sectors in Belize having potential links with the banana sector for SOM

Some attention will have to be paid on the value of this green matter, for its organic carbon and nutrients contents.

Some research could also be done on the possibility of getting calcarus directly in Belize rather than importing these mineral amendments.

2.9 BAH A (Belize Agricultural Health Authority) and the CIL (Central Investigation Laboratory)

2.9.1 BAH A

BAHA is the statutory body in charge of food safety, quality insurance, consumer education and market access in Belize. It is also the internationally recognized competent authority for animal health, plant health, pest and disease of plants, food safety, import and export certificates for food, food process inspection and food analysis. It also has a quarantine service.
BAHA is responsible to the Ministry of agriculture and fisheries. BAHA is in partnership with Foreign trade, Economic development, Citrus and Aquaculture Industries, Livestock farmers, and Chambers of commerce.

The administration services of BAHA are located in Belmopan, and its staff consists of 92 people shared among 40 people for the quarantine service, 18 for the food safety department, 17 for the plant health department, 11 for the plant health department and 6 for the general administration.

The plant health department and the veterinary service are located in Central Farm (Cayo district, a 20 minutes driving from Belmopan). The plant health department runs its own laboratory dedicated to plant pathology and entomology.

The costs of BAHA are covered by its own services to the extent of 60%, with the government financing the remaining 40%.

2.9.2 CIL

The Central Investigation Laboratory (CIL) is under the umbrella of the food safety department. It is committed in providing high quality, cost effective and accurate product testing services in partnership with the food and agricultural industries and other regulatory bodies of Belize.

The Central Investigation Laboratory is made of 10 people:
- Mr. Michael W De Shield runs the CIL as Director
- Six food safety inspectors, who collect samples and operate inspections in the food industry and distribution,
- Two lab technicians, one for chemical testing, the second for microbiology.
- One secretary.

The CIL was established in Belize City in 1985 as the central Veterinary Investigation Laboratory operated by the Ministry of Agriculture and Fisheries.

In 2002, the laboratory was completely refurbished and equipped with sophisticated analytical equipments under the Government of Belize modernization of Agricultural Health Services Project, funded by the Inter-American Development Bank. However, and partially because of the floods in 2007, equipment for chemical analysis is not in use (see § Analytical equipments). Microbiology seems to be fully operational.

A major problem: The CIL building is in a sensitive area

The CIL is a one storey building with an imbedded inner patio. The total area is about 600 m²: The ground floor (365 m²) includes entrance and three offices. The rest is divided into small rooms (15 m² in average) dedicated to lab activities. Each room was originally designed for a specific purpose: water quality, sample preparation of water, sample preparation of food, residues...
analysis, incubation, microbiology, hematology, biochemistry, histopathology, sterilization room, media preparation, glassware clean up, documentation, storage, water storage, water distillation unit, waste storage; but because of water infiltrations, they cannot be used. The more sensitive devices have been moved to the first floor where humidity conditions are less detrimental.

Pictures 2-3: BAHA, Central Investigation Laboratory – Damages caused by flooding

The first floor includes a large conference room (94 m²), a registration office (46 m²) and the microbiology unit on 80 m². A kitchenette, bathroom facilities, and a generator complete the facilities.

2.9.3 CIL Activities

Analysis activities of the lab are shared between microbiology (60%) and chemistry (40%). The number of analyzed samples is low: 550 per year on average.

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>Average / year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>222</td>
<td>255</td>
<td>496</td>
<td>215</td>
<td>324</td>
</tr>
</tbody>
</table>

Table 4: CIL, Number of samples for microbiology testing 2004 - 2008

The 2005 figures give a good picture of the usual activities performed in chemistry:

<table>
<thead>
<tr>
<th>Number of samples</th>
<th>Analysis and Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>140</td>
<td>CHARM II methods for residues and drugs</td>
</tr>
<tr>
<td>75</td>
<td>Histology or histopathology</td>
</tr>
<tr>
<td>10</td>
<td>Mineral chemistry</td>
</tr>
<tr>
<td>Total = 225</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: CIL Chemical Analysis, Year 2005
Methods derive from scientific institutions (AOAC, BAM, PAM, FDA, EPA) and are officially recognized. The microbiological service, installed at the first floor, is fully operational, but all activities of the chemistry department (residues, heavy metals ...) have been suspended, following floods in 2007. Since then, all samples for chemistry testing are sent to laboratories abroad. The main subcontractor is Eurofin, a certified lab in Louisiana.

2.9.4 Clientele Distribution:

- 60% Aquaculture (fish and shrimp industries)
- 10% Quarantine services (import)
- 10% Poultry products
- 5% Dairy production
- 5% Feed providers (for cattle, pet ...)
- 10% Various agronomical products

2.9.5 Analytical equipments

*Equipment for chemical analysis*

The whole chromatographic equipment is excellent. The manufacturer AGILENT is recognized for its extremely efficient and robust apparatus.

The flame atomic absorption spectrophotometer is fairly new and supplemented with several hollow cathode lamps. Hydride generators for mercury and arsenic can be coupled.

Among the others equipments, we find the following items:

- A VIS colorimeter,
- A microwave digestor (ANTON PAAR),
- A Soxhlet extraction unit 6 positions (AVANTI),
- An autodistillation unit for ammonia (FOSS),
- A bomb calorimeter,
- Two drying oven (FISHER SCIENTIFIC),
- Some top load balances (DENVER INSTRUMENTS),
- A set of micropipettes (THERMO LABSYSTEM),
- Several laboratory fridges,
- Two laboratory freezers,
- A unit of distillation and purification of water,
- Several fume Hoods,
- A set of basic glassware.

See the comprehensive list of equipments in the attached annex.
Most the equipment is high class products, currently in very good condition. Some of them have never been used. A few of them present minor breakdowns (microwave digestor, fridges, freezer) but could be easily repaired. The equipment should enable the laboratory to implement residues analysis (organic and mineral) according to the official methods (BAM, AOAC, EPA ...). However, none is performed. At the moment, except for microbiology, operational equipment has been put aside and is not being used.

Pictures 3-4: Atomic absorption spectrometer Perkin Elmer - Spectrophotometer Jenway

*Equipment for Microbiology:*  
This service is well equipped with functional equipment(s): autoclave, incubators, refrigerators, centrifuge, microscopes.

*Plant health department*  
This department, located in Central farm in the Cayo district, owns a laboratory dedicated to the observation and determination of plant diseases (fungi) fairly well equipped with several microscopes. This department could collaborate with the nematode laboratory of the BGA.
2.9.6 Staff and qualification

The lab has only two qualified technicians. The analytical chemist, Miss Isabel Diana Enfinger, was educated at the University of West Florida in Pensacola where she attended relevant courses in Advanced Organic Chemistry, Physical and Analytical Chemistry, Instrumental Analysis, Inorganic Chemistry, Biochemistry, Physics. Besides, she has been working for seven years in three different labs. She is presently the only analytical chemist at CIL. Due to fact that most of the equipment is not presently installed, she has no real analysis activities. Her present tasks are on research, sampling, receiving or sending samples (to Eurofin), preparing and organizing the equipment and supplies. She also attends training workshops in various areas dealing with pesticides, collaborating with other labs, etc ...

At the moment, only one experienced technician carries out all tests in microbiology.

As for all services in BAHA, a major concern is to find and keep qualified technicians and maintain a good level of skills with few personnel.

2.9.7 What analysis the CIL can do

Organic residues:
The two main chromatographic technologies (gas chromatography and liquid chromatography) coupled with a set of specific detectors (ECD, FPD, Diode array, UV/VIS, Fluorescence...
detector) enable the laboratory to measure a very large set of pesticide residues with very low detection limits, in particular almost all the chemicals approved in the banana Industry by the Pesticides Control Board (list attached in Annex).

Some active ingredients (tridemorph, fenopropimorph) including nitrogen, would require a NPD detector which can be added to one of the pieces of gas chromatography apparatus. Sensitive molecules like polycyclic aromatic hydrocarbure and PCB can also be detected. Glyphosate, paraquat, diquat, fosetyl, mancozeb, metiram are very specific measurements that cannot be coupled with the others. Organic residues can be easily extracted from any solid matrices by a Soxhlet extraction system.

The laboratory also owns a radio-immuno chemistry analyser (CHARM II) for mycotoxins (aflatoxins) and drugs (antibiotic) research or pesticide screening.

The laboratory offers also organochlorine, organophosphate and carbamate profiles.

Mineral residues:

The flame atomic absorption spectrophotometer is supplemented with several hollow cathode lamps permitting the measurement of potassium, sodium, magnesium, calcium, iron, cadmium, copper, lead, and chromium can be determined directly on solution. Arsenic and mercury can be quantified via a hydride generator but this former may be not very precise. All these elements are proposed by the CIL.

The basic colorimeter can be used for some elements or common molecules after formation of colored complex (ammonia, cyanide, chromium VI, silica, nitrate, nitrite, phosphate ...)

Microbiology :

A basic program in water and food control is regularly performed:
Standard plate count, Total coliform count, Faecal coliform, Salmonella, Staphylococcus aureus Vibrio, Mycology plate count and identification

2.9.8 Certification ISO 17025

The food safety department laboratory staff has been trained in ISO 17025 Management System for the laboratory and Quality Insurance for Microbiology Laboratories through official courses in the USA. The laboratory participates in an international ring test (INFAL network).

However, the laboratory is not yet certified ISO 17025. So its results may not be recognized by some clients and particularly by European partners, stakeholders or consumer associations.

2.9.9 Other Laboratories in Belize

The Public health laboratory is the official service in charge of monitoring drinking water. Its equipment is quite basic and does not permit pesticides analysis.
Other laboratories are small control units attached to local industries:
- Brewery (mainly microbiology)
- Citrus industry (at the Citrus research Education Institute)
- Sugar cane Industry,
- Bowen & Bowen Ltd linked for local production of Coke

None of these laboratories can operate soil, plant or pesticides residues analysis.
3 Assessment of the Environmental Monitoring at Farms Level

3.1 Soils Characteristic - Environmental Impact

3.1.1 Taxonomy, physical characteristics of the soils

Our description is based on the Reports from Agrosoil Internacional SA (2000), which made the necessary soil studies for the installation of the irrigation and drainage systems on all farms, and from a study made in 1968-1969: Characterization and Classification of some Belize soils (from D.A. Lietzkz and E.P. Whiteside).

According to this last report, the Stann Creek District is constituted of several fluvial terraces characterized by their soil characteristics and vegetation. Ten different soil types are listed but unfortunately, no map is shown in this short report. Soils are classified as Aquic Tropudults or Aquic Tropaqualfs (under USDA taxonomy) including sub-classes according to their texture that varies from fine loam to clay. According to this report, the clay type is Kaolinite.

The agrosoil report classifies the majority of the soils as typic Dystropepts, recent soils of alluvial origin with a cambic horizon and a low base saturation.

On average, the Agrosoil report defines four to five different types of soil per farm; here is the description given for farm 7 that can be presented as a sort of representative example:

<table>
<thead>
<tr>
<th>Soil Symbol</th>
<th>Main Characteristic before drainage</th>
<th>Soil Class</th>
<th>acres</th>
<th>% area</th>
</tr>
</thead>
<tbody>
<tr>
<td>636</td>
<td>Moderate drainage, fine loam and sandy loam texture on the entire profile</td>
<td>I</td>
<td>5</td>
<td>1%</td>
</tr>
<tr>
<td>222</td>
<td>Imperfect drainage Silty clay loam textures</td>
<td>IV</td>
<td>54</td>
<td>10%</td>
</tr>
<tr>
<td>422</td>
<td>Imperfect drainage, Clay loam with silty clay loam below compaction in subsoil</td>
<td>IV</td>
<td>205</td>
<td>38%</td>
</tr>
<tr>
<td>420 M</td>
<td>Imperfect drainage, Clay loam with clay or sandy clay below compaction from 60 cm</td>
<td>IV</td>
<td>198</td>
<td>37%</td>
</tr>
<tr>
<td>420 S</td>
<td>Imperfect drainage Clay loam with clay or sandy clay below compaction in subsoil</td>
<td>IV</td>
<td>73</td>
<td>14%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>535</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 6: Soil Characteristics, Farm 7 (from Agrosoil Report, 2000)

All soils are of alluvial or a washed colluviums origin, located on flat land to gentle slopes (less than 4%). They generally present a fine loam or silty loam texture on the first horizons, becoming loam, silty-loam or loamy clay below, according to their situation in relation with the river...
(upland – downland), and most likely the region (which we could not study during our assignment).

The table below presents the results of two profiles taken on farm 21, clearly showing that there is indeed a great variety of situations within the farms themselves. These situations should obviously be taken into consideration when defining and implementing agricultural practices.

<table>
<thead>
<tr>
<th>Depths (on 2 profiles)</th>
<th>0 - 29 cm</th>
<th>30-70 - 30-50cm</th>
<th>70-95 - 50-80 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>56 - 50 %</td>
<td>4 - 56 %</td>
<td>30 - 10 %</td>
</tr>
<tr>
<td>Silt</td>
<td>33 - 45 %</td>
<td>68 - 35 %</td>
<td>45 - 50 %</td>
</tr>
<tr>
<td>Clay</td>
<td>11 - 5 %</td>
<td>29 - 9 %</td>
<td>25 - 40 %</td>
</tr>
<tr>
<td>Texture name (USDA)</td>
<td>Sandy loam</td>
<td>Silty clay loam</td>
<td>Silty loam - SC Loam</td>
</tr>
<tr>
<td>Color</td>
<td>Dark brown</td>
<td>Dark brown</td>
<td>Yellowish red</td>
</tr>
<tr>
<td>Bulk density</td>
<td>1.17 - 1.1</td>
<td>1.2 - 1.15</td>
<td>1.5 - 1.15</td>
</tr>
<tr>
<td>Porosity</td>
<td>51 - 46 %</td>
<td>46 - 46 %</td>
<td>46 - 42 %</td>
</tr>
<tr>
<td>Hydraulic conductivity</td>
<td>1 - 1 m/day</td>
<td>10.6 - 1 m/day</td>
<td>1.1 - 0.9 m/day</td>
</tr>
<tr>
<td>Available water content</td>
<td>12.1 - 14</td>
<td>9 - 11</td>
<td>9.6 - 10.9</td>
</tr>
</tbody>
</table>

Table 7: Farm 21, Soil physical data on 2 profiles, (Agrosoil, 2000)

3.1.2 Soil Class for the production of bananas, Main Constraints

Soils are generally classified as moderately deep, with no apparent limitations in texture or structure to a depth of 40 cm to 1m, moderate drainage and slow to moderate conductivity class. The physical impediment is basically a compact subsoil, which influences soil water relations, especially hydraulic conductivity and permeability in the upper layers (hydromorphy is noticeable).

They are generally dark brown in color in the first layer and yellow-brown below, with possible traces of red due to iron oxides.

The Agrosoil report classifies them as belonging mostly to the Class IV or III for the production of banana, becoming Class II (and scarcely Class I) with irrigation and drainage.

Soil compaction is confirmed by nearly all farmers as being the n° 1 constraint to root development.
Pictures 7-8: Non agricultural Soil Profile and Agricultural Soil Profile, Stann Creek District

The pictures (above) show two typical profiles observed in the Stann Creek District. On the left, a natural area covered with pines, classified as unsuitable for agriculture; on the right, closer to the river terrace, a typical soil profile of a banana plantation. We can see a very shallow layer of arable soil that becomes more compact the deeper it is.

These pictures clearly show that:

1. **Agricultural land is** somewhat **limited** even though a simple visitor might think that there is plenty of available land for banana-growing. **Some farms have reached their maximum size for growing bananas.**

2. **Soil compaction prevents a fair development of the roots** to a maximum depth of 30 to 40 cm, except on lands close to the river or to the sea (farms 7-8-15-16).

**Soil erosion** did not appear to be a major issue during our mission, although it certainly exists in sandy and coarse textured areas.

3.1.3 Environmental appraisal regarding soil characteristics

**Soil compaction:**
Farmland development leads to a (normal) degradation of the macro-porosity of the soil and to compaction. This increase of soil compaction may further lead to some horizontal transfers of pesticides residues by run-off waters and sediments. In the Belize case, one may assume that the very dense drainage system that is present on the banana farms play a part in these transfers that will end-up into the rivers.

**To increase the macro-porosity of the soil, tillage (including ripping) will have a temporary effect, but only land left fallow improves it on a long-term basis.**

Humus, a well developed roots system and an active micro-fauna create galleries in the soil limiting therefore run off.

**Soil erosion:**

According to a study made in the Stann Creek District during the 90s (see ANNEX 5: Evaluation of pesticide and fertilizer use in bananas and potential risks to the environment), most of the pesticides that have been used in the banana belt are strongly adsorbed to soil particles and thus can move due to sediment flow.

In case of acidic soils, phosphate brought by fertilizers may also be attached to soil particles and move to rivers. Added to the nitrates released from the mineralization of the soil organic matter or coming directly from the fertilizers, phosphate increases the eutrophication potential of these water ways. **Erosion therefore increases the risks of environmental pollution of the rivers and coastal areas.**

All farmers say that soil erosion is not a major issue. This might be due to the acidity of the soil and its clay content that maintains a certain level of micro-aggregation by its oxy-hydroxides of iron. **But, the structural stability of the soil will strongly depend on its organic matter content:** According to Pieri (1992), if the mass of soil organic matter (SOM) exceeds 9% of the mass of the fine mineral fraction (silt + clay), the SOM content is likely to be sufficient to assure structural stabilization and protect the soil from physical degradation.

![Graph showing the relationship between organic matter to silt+clay and soil stability](image)

**Table 8: Soil organic matter as a % of the silt+clay content and micro-aggregate stability (from Pieri, 1992)**
In order to maintain the risks of erosion at a reasonable level and for reasons related to the competition between cations, mineral applications should also be made regularly, using rather small quantity of inputs.

Besides, and according to M. Carlos MOYA (PIU engineer), the upgrading of the drains that is presently implemented integrates a resurfacing of their sides in order to open the angle with the bottom and reduce the risks of erosion. Besides, drains do not normally receive any herbicide for this purpose.

**Heavy metals (Metallic trace elements):** Only soil and water analysis will show the level of heavy metals present in the soil and their potential availability. However, the lack of geo-chemical funds vis-à-vis these elements and the lack of heavy industries in the region are the likeliest reason for the low level of metallic trace elements.

3.1.4 Soil fertility and soil organic matter (SOM)

All the analysis that we have seen show a poor soil fertility. Soils are acidic (pH can go as low as 4, poor in cations (more especially in potassium that can reach 0.20 cmol+ /kg, which can be considered as a deficiency rate) and they present a very low content of organic matter.

This low fertility can be partially related to clay type: The results of soil analysis are typical of those obtained in kaolinitic soils: Kaolinite is a common 1:1 dioctahedral phyllosilicate (clay) mineral found throughout the world in highly-weathered environments. Being a 1:1 mineral, it has one silica tetrahedral layer and one aluminium octahedral layer. This 1:1 structure (compared to the 2:1 structure of smectite as for example) gives to kaolinite a small number of available negative charges and therefore a low cationic exchange capacity (CEC), as well as high risks of aluminium release into the liquid phase of the soil when conditions are acidic.

The relative contribution of clay and SOM to soil cation exchange capacity is largely determined by the amount of SOM, the amount and mineralogy of clay, and the soil pH (Ray R. Weil and Fred Magdoff, 2004). The only way to increase the fertility of such soil types is to increase their organic content (see table 9 below).
Unfortunately, the study of soil data taken at random on the farms (We took in general four to five results of the last set of the 2008 analysis) compared with analysis performed in 2000 (seen in the Agrosoil study) generally show a decrease in the CEC and in the Soil Organic Content. Out of thirty soil analysis picked up at random, the average organic content is below 1.1%.

In order to judge this average organic content, we can use the two references already cited:

- Pieri (1992) is saying that in order to avoid structural degradation, SOM should be at 9% of its Clay + Silt content. If we consider that all soils in the banana Belt contain a minimum of 30% of silt + clay in their first 15 cm layer, it means that their SOM should be 2.7%.

- According to Fred Magdoff and Ray R. Weil (2004), speaking about Soil Organic Matter Management Strategies and Net Organic Carbon Change, an addition of 2 T/ha of dry organic matter (a high rate of application) to a very well drained sandy loam soil with a rate of SOM loss of 4% per year (C-CO2 lost by mineralization + C lost by erosion), the soil will have 2.5% SOM at equilibrium after the rapid decomposition phase of the fresh material.

In very clear words, these references (among many others) confirm that the present situation of the soils regarding organic matter is very preoccupying. And more especially when we include the other biological and chemical properties of SOM described in the literature:

**Biological properties of SOM** (from Dalal, 1998):

- A labile source of carbon, nitrogen, phosphorus and sulfur,
- An immediate sink of carbon, nitrogen, phosphorus and sulfur,
- An agent of nutrient transformation and pesticide degradation,
- An agent of mineral weathering and soil formation,
- Includes organisms, especially in association with plants roots, that from and stabilize soil aggregates,
- Includes organisms that are antagonistic to plant pathogens and parasitic nematodes,
- Produces plant growth regulator.

Chemical Influence of SOM on soil properties (Ray R. Weil and Fred Magdoff, 2004):
- Increases nutrients storage and release: Nearly all the nitrogen and large proportion of the phosphorus and sulfur found in soils occur as constituents of SOM.
- Increases microbial enhancement of nutrient availability.
- Increases Cation Exchange Capacity (INRA has dosed the CEC of SOM in Guadeloupe at more than 100 cmol+/kg: Cabidoche, 2005).
- Sorption of organic compounds as well as inorganic cations, including organic pesticides and carboxylic acid herbicides.
- The importance of SOM for the sorption of pesticides is also illustrated by the fact that 10 times more smectite clay than SOM was necessary to retain 50% of a PCB herbicide (Strek and Weber, 1982).
- Anion Sorption: Increasing SOM not only provides a source of P from mineralization, but also reduces the capacity of acid soil to lock up P by fixation.
- Decreases Metal Mobility: The effect of SOM on metal mobility is generally recognized as being negative.
- Soil pH Buffering and Amelioration: SOM exerts a major influence on the pH buffering of surface soils, because it contributes much of the soil CEC. SOM also reduces exchangeable aluminium by binding the Al ions in non-exchangeable forms.

SOM also influences the population of soil fungi, decreasing the population of pathogen fungi, while increasing the population of saprophytes fungi, which play a main role in the degradation of plant debris (recycling nutrients such as N, C, P, K) and mutualist fungi such as the Arbuscular Mycchirizal Fungi that live in association with the plants roots and allow them to accede to a greater volume of soil thanks to their hyphae (Kristine A. Nichols and Sara F. Wright. 2004). These fungi are also recognized to have various functions in plant nutrition (a better intake of nutrients), disease suppression, and improvement of the soil structure.

3.1.5 Climate

At a global level, the climate is marked by two seasons:
- A dry (and cooler) season from January to April-May
- A wet (and hotter) season from June to December.

The following table made from the rain data collected over seven years in the South Stann Creek District shows that farmers face 4 to 5 months of dry season during which precipitations are not
sufficient for the production of banana, and 7 to 8 of months, during which monthly rainfall is equal to two or three ETP (evapo-transpiration).

<table>
<thead>
<tr>
<th>Precipitation and ETP</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>P (mm/month)</td>
<td>111</td>
<td>60</td>
<td>47</td>
<td>53</td>
<td>89</td>
<td>286</td>
<td>312</td>
<td>373</td>
<td>378</td>
<td>304</td>
<td>191</td>
<td>141</td>
</tr>
<tr>
<td>P (per day)</td>
<td>3.6</td>
<td>2.1</td>
<td>1.5</td>
<td>1.8</td>
<td>2.9</td>
<td>9.5</td>
<td>10.1</td>
<td>12.0</td>
<td>12.6</td>
<td>9.8</td>
<td>6.4</td>
<td>4.5</td>
</tr>
<tr>
<td>ETP/day</td>
<td>3.1</td>
<td>3.3</td>
<td>4.1</td>
<td>4.3</td>
<td>4.7</td>
<td>4.5</td>
<td>4.2</td>
<td>4.3</td>
<td>3.9</td>
<td>4.0</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>P/1.25 ETP (*)</td>
<td>0.9</td>
<td>0.5</td>
<td>0.3</td>
<td>0.3</td>
<td>0.5</td>
<td>1.7</td>
<td>1.9</td>
<td>2.2</td>
<td>2.6</td>
<td>1.9</td>
<td>1.6</td>
<td>1.1</td>
</tr>
</tbody>
</table>

(*) 1.25 represents the average k factor currently used in the region in banana production.
P/1.25 ETP < 1 means that water requirements are not fulfilled by the rains (recorded on a monthly basis).

Table 10: Average precipitation and ETP in South Stan Creek District 1993-2000

The farms that are situated on the eastern side of the district, close to the sea (farms 7-8-15-16) receive less rain than the farms situated more to the West. This has an impact on the prevalence of disease and more especially Black Sigatoka.

During the rainy season, the climate is irregular, and three types of situations may be observed:
- Periods during which the amount of rain is favorable to the production,
- Periods during which the rain exceeds field capacity,
- Periods of drought (see below).

During our own assignment in August-September 2008, we saw two different conditions: a period of drought and a period marked by heavy rains. Here is the data recorded for 33 days, from July 24th to August 26th (see ANNEX 6 for daily data):

<table>
<thead>
<tr>
<th>Rainfall over 33 days</th>
<th>125 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needs for banana plants <em>33 days (ETP</em>1,25 = 4.25*1,25=5.30 mm/day)</td>
<td>175 mm</td>
</tr>
<tr>
<td>Overall deficit</td>
<td>50 mm</td>
</tr>
<tr>
<td>Number of days with no water available for the plants</td>
<td>20 days</td>
</tr>
<tr>
<td>Days without water for the period: Estimated loss of production / Potential yield:</td>
<td>60% - 20%</td>
</tr>
</tbody>
</table>

Table 11: Rainfall data and availability of water for plants 23rd July – 24th August 2008, Farm 7
During 33 days of July-August 2008, the farm received 175 mm of rain (3.8 mm per day), a quantity that fits plant requirement for this period. However, the distribution of the rain was not regular, and the plants did not have any available water for 20 days. Considering a 90 days period from flowering to harvest, we may estimate a loss of approximately 20% on the potential yield.

Remark: Each farm has a small weather station registering temperature and rain. The rain gauge could also be used for the management of the fertilization that could be done every 200 mm, or rather every 100 mm because of the low CEC.

![Weather Station](image)

**Picture 9 : Farm 12: Weather station (the rain gauge should be on its own or higher)**

### 3.2 Crop Management

#### 3.2.1 Human Resources on the farms

More than 90% of the workers are immigrants of Central America origin, and the language used on the farm is Spanish. Each farm numbers 0.28 to 0.40 workers per acre with an average of 0.35 worker/acre (0.85/ha) and approximately 3 workers per 100 T of bananas. Casual workers must be added to these figures.

Such figures are commonly seen in banana production in the Caribbean. However, a working day in Belize is far longer than a working day in the Caribbean (from 6 am to 5 pm in Belize versus 6 am to 12 noon or 1 pm in the Caribbean).

Overall, we can estimate that the farm employ approximately 2100 permanent workers plus casual workers.

The farm employs three types of personnel:
Administrative personnel: From one to fifteen persons, including one person dedicated to environmental matters and record keeping,

- Field workers: 55 to 60% of the workers, including captains and field supervisors,
- Packing shed workers, who constitute 40 to 45% of the labour force, with one to three supervisors.

One of the problems encountered by farmers is a relatively high level of turn-over.

On the biggest farms, the personnel can be divided into three groups:

 ✓ Personnel who stays for a long time: One third
 ✓ Personnel who stays one or two years: One third
 ✓ Personnel who stays a couple of months: One third

This characteristic leads to two difficulties:

- It is sometimes difficult to find workers: The rate of unemployment is relatively low and regularly decreasing in Belize (8.5% in April 2008) and wages are low in the banana industry (23 to 40 B$ per day).

- Training needs are high, so high that the Pesticides Control Board has trained several permanent workers per farm who are now ‘Certified Trainers’ for new workers. However, the Pesticides Control Board is the only statutory body entitled to deliver the “Certified Pesticides Applicator License”.

3.2.2 Land Protection (Conservatory measures)

As mentioned in the individual assessments (see Annex 4), most of the farmers say that they are following strong conservatory measures on lands, and are keeping large areas without any crop.

The national Lands Act of 1992 and the Land Utilization Act mandate that a 66 feet riparian buffer zone be left undisturbed on all natural water ways in order to encourage a natural filtration and degradation of organisms. Farmers usually say that they follow this rule, but it is not always true (see pictures):
Two rows of young banana Plants

Pictures 10-11: Bananas planted in flood plains, too close to the rivers (on two different farms)

3.2.3 Land development and management

All farms are equipped with irrigation systems, using under-tree sprinklers in order to avoid any disturbance in the control of the Black Sigatoka. Irrigation is done under the supervision of the PIU: The irrigation engineer visits each farm at least once a month during the rainy season, and twice per month in the dry season to check the soil moisture using the Mini Trase Technology, a job that should be performed by the BGA since six people have been trained and material has been provided.

The quantity of water to be used is decided accordingly. The objective (to make it simple) is to reach an average 6 mm of rain + irrigation water per day (a data range that is also used in the Windward Islands).

The drainage system is very dense and is constantly upgraded, with the support of the PIU. Primary ditches are every 1500 feet and secondary ditches are every 240 feet. This is more or less the same thing on all farms, except farms 9-10-11, where they are wider apart.
Pictures 12-13: Drainage system, farm 5 – Rehabilitation of drains, Carlos Moya (PIU Engineer)

Why not irrigate during the wet season?
Irrigation is not done in the rainy season because the pumps are close to the rivers and the farmers remove them to avoid possible flooding. Farmers are not ready to make the necessary investments because of the price paid for banana that they consider as being too low.

Pictures 14-15: Water pump at river level and flooding risks in Belize (sept 2008)
3.2.4 Crop Planning - Use of Vitro-plants

We are in a system of permanent crop. However, since 2001 (year during which Belize experienced a strong hurricane), **56% of the lands have been ‘rehabilitated’ with the support of the European Aid**.

When a plot is replanted, farmers use vitro-plants (that are incorrectly called *Meristems* here). The variety that farmers prefer is *Williams* because it is more resistant to stress and to soil and climate conditions. Other varieties are *Grande-Naine*, *GALIL 7 or 12*.

The use of vitro-plants allows crop planning and planting in order to get the best price (which varies during the year). However, these tissue culture plants have been planted until now on land that has not been previously cleansed (by a fallow or crop rotation or a flooding), thus losing its unique agronomic advantage.

The vitro-plants come from Honduras and are certified as being free of pests, disease and free of genetically modified organisms. They are put in quarantine for 6 weeks on their arrival in Belize. A controller (from the company) visits the farm two weeks after planting to check variants and other possible problems.

**However, no tests are done during quarantine such as tests on Banana bunchy top virus, Cucumber Mosaic Virus, Banana Bract Mosaic Virus (BBrMV), Banana Streak Virus, and Banana Mild Mosaic Virus.**

3.2.5 Plant Population Management – Pruning -

The management of the plant population during the crop is based mainly on pruning, done every six to eight weeks with a cutlass in all farms, except on farm 14 where they use a narrow shovel. This narrow shovel was found in Costa Rica and could be compared to the tool that has been specifically made in the French West-Indies. We left one of these tools at the BGA for possible copies (see pictures below).
Plant density is at 825 mats per acre on average (2000 mats/ha), but may be higher when the plants do not grow well (ex: Farm 4 where plant population can reach 2300/ha).

**Number of hands per bunch: ‘Yield management’**

The number of hands per bunch observed on the farm is generally low: Six to eight on average during our mission. This is also the number managers refer to. However, on some farms, and more especially on farm 8, this number is significantly higher, and can reach ten to eleven hands with an average of nine hands. This is due to the location of the farm (in a more sunny area) and most likely good agricultural practices (see Annex). This farm also receives less chemical treatments for the control of sigatoka (42 applications per year).

On this farm, the grower uses also a market led strategy that one could call ‘yield management’:
- During the dry season, at the time of higher prices, the target is to get a fair number of hands, with the lowest acceptable number at six.
- From May to October, the number of hands is usually higher because of the climate (day light, heat, rains) and can reach 11 to 12, but the policy is to get about 9 hands in order to get the right grade. During this season, the price is lower, and it is not profitable to harvest 6 hands bunches. The mats carrying less than six hands are therefore rapidly identified and eliminated, while the follower is ‘forced’.

3.2.6 Environmental assessment regarding land management and plant population management

As shown by pictures 10-11, some banana have been planted in buffer zones where they have nothing to do, and we feel that **deeper surveys should be carried out by the BGA in order to make a complete assessment on that specific matter.**
Considering land infrastructures and management, the “Land Rehabilitation Programme” implemented since 2001 has considered solely the water component, installing irrigation and drainage infrastructures. In doing so, soil compaction has apparently increased on most of the land (at least these farms where no compensation measures have been taken on the long term). **Besides, drains are exiting directly into the rivers without any buffer zones or sedimentation ponds where chemical residues could be metabolized into safe forms before being released in natural water ways.**

Because of the perennial system, the parcels present a heterogeneous aspect (plants of all ages) that structurally leads to a possible mismanagement of mineral fertilizers.

### 3.2.7 Management of soil fertility and fertilizing practices

**The basic notions of integrated and biological approaches to sustainable soil systems seem to be unknown in the banana industry of Belize:**

From our appraisal, the situation regarding soil fertility and related practices can be described as follows:

- First type of farm corresponding to the majority of the farms: Since bananas have been grown, fertilization has only or mainly consisted in bringing mineral fertilizers to the plants: Cations may be at a higher rate in 2008 than in 2000 (the 2000 calcium data looks wrong) but the level of organic matter has fallen dramatically, and we assume that, considering a low exchange capacity, many of the elements contained in the fertilizers cannot be captured by the exchange complex (which is made of two major components: clay and humus) and must be washed away by the rain or the irrigation waters.

- Second type of farm, corresponding to an exceptional farm (group of farms 1-2-3), where considerable amounts of compost have been used for a couple of years: The soil fertility has globally increased, including the organic content.

- Third type of farm: Two analyses carried out in 2008 are presented, one from a plot planted roughly ten years ago, and one from a plot having which was formerly forest: In less than two years, the organic content has dropped from a high 8% (showing a certain level of hydromorphy) to 4%.
Soil analyses are made once a year per farm, and leaf analyses twice. The samples are taken by the technician of the BGA on approximately half of the farms (not the Soerensen group of farms), and the analysis are done in Costa Rica (by Agrotec) or in Honduras (by FHIA), the farmer choosing one or the other of the two laboratories.

First, many questions about the soil analysis remain unanswered:

- Each sample (made up of approximately 15 sub-samples) represents a section of the farm that may vary from 20 to 30 acres. The problem is that this number is not necessarily representative of such a big area, since no study has apparently been made previously to determine what the appropriate area per sample would be. We can also wonder if they correspond to the soil maps made by Agrosoil. We consider that the sampling area has to be redefined on each farm, which will require a whole set of soil analysis per farm.

In comparison, in Guadeloupe (where six types of soils are represented), one sample (made of 15 sub-samples) generally represents five acres, sometimes ten, but no more.

Besides, since the samplings are done once a year, the timing may not be appropriate to judge the real fertility of the soil: How many days after fertilizer application was the sample taken? This data is not even recorded. What is analyzed may therefore be the fertilizer, preventing the comparison between samples.

- Neither of the lab presents the method used to do the analysis (extraction and dosage). One cannot therefore know what has been really extracted.

One of the laboratories (possibly both) seems to use only one extractor for all the elements, which would mean that these analyses are more like soil test than soil analysis. In order to know the exchangeable element, each family of elements (at least) requires a specific extractor (ex: Acetate of ammonium for the cations, sulphuric acid for P, etc…). Organic nitrogen is not dosed by Agrotec, but the mineral nitrogen is, which does not give much information on the fertility of the soil since this N is most likely the nitrogen coming from the fertilizer. The pH KCl, which is a strong indicator to estimate the urgency of

Table 12: Results of soil analysis made on three farms in 2000 and 2008

<table>
<thead>
<tr>
<th>Elements</th>
<th>Farm 7 : Zero organic amendment</th>
<th>Farm 1 : Compost used at 7 T/acre</th>
<th>Farm 9-10 (2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year (analysis)</td>
<td>2000</td>
<td>2008</td>
<td>2000</td>
</tr>
<tr>
<td>pHwater</td>
<td>4.95</td>
<td>4.84</td>
<td>6.24</td>
</tr>
<tr>
<td>Org Mat %</td>
<td>2.52%</td>
<td>0.93%</td>
<td>1.67%</td>
</tr>
<tr>
<td>P ppm</td>
<td>?</td>
<td>35.7</td>
<td>?</td>
</tr>
<tr>
<td>Ca cmol+/kg</td>
<td>2.61</td>
<td>5.86</td>
<td>3.92</td>
</tr>
<tr>
<td>Mg cmol+/kg</td>
<td>1.22</td>
<td>2.57</td>
<td>1.07</td>
</tr>
<tr>
<td>K cmol+/kg</td>
<td>0.21</td>
<td>1.16</td>
<td>0.71</td>
</tr>
<tr>
<td>CEC cmol+/kg</td>
<td>?</td>
<td>10.3</td>
<td>14.5</td>
</tr>
</tbody>
</table>

Soil analyses are made once a year per farm, and leaf analyses twice. The samples are taken by the technician of the BGA on approximately half of the farms (not the Soerensen group of farms), and the analysis are done in Costa Rica (by Agrotec) or in Honduras (by FHIA), the farmer choosing one or the other of the two laboratories.
liming amendment, is not recorded. And so on, and so on…we could add a long list of questions.

• One of the main questions is related to interpretation: One laboratory gives the results of the analysis, and expresses a judgment on these results, but we wonder how it can do so, since no studies of the Belizean data have apparently been done in order to define thresholds (or at least, the Belizeans would like to see these studies).

We must say that as plant nutritionists, we wonder how any advice can be given from these results at the present time. **What is needed now is a statistical and agronomic study of all data** already acquired since the year 2000 in order to see what we can get from it, **define norms adapted to the region, and set up a computerized system of interpretation**, which does not exist yet. These norms will also depend on the future methods of analysis implemented by the BAHAlab.

Fertilizing plans are proposed either by the lab, or by a consultant who comes from Honduras. Once more, many questions remain concerning the logic that is behind the proposed plans, which are only dealing with minerals (liming amendments and fertilizers) when the problems of these soils are obviously more complex.

3.2.8 Environmental assessment regarding soil systems and fertilizing practices

According to Norman Uphoff and al (2006), a soil system has four components:

• Mineral elements (in different-sized soil particles: sand, silt or clay)
• Water,
• Air (containing oxygen, hydrogen, nitrogen and carbon in gaseous forms),
• Organic matter (of all origins),

**In this soil system, two elements only are being taken care of in Belize: Water** (with the irrigation and drainage systems), **and minerals** (with the liming amendments and mineral fertilizers). Concerning the air, we have seen the problem of soil compaction that farmers are facing on each farm, and concerning organic amendments, they are limited, most of the time, to one ton of citrus compost (sometimes chicken manure) per acre and per year, a quantity that cannot have a significant impact on the organic Carbone content of the soil.

The purpose of this mission was not to study fertilization, but some plans implemented on some farms (which are not necessarily those advised) have shown some incoherences. Just a few examples here:
• On one farm, obviously having a low capacity for K and a low organic content as well as a low CEC, fertilizer application is proposed once a month to reach (in Lbs/acre) 350 N – 100 P2O5 – 400 K2O, which does not fit our data concerning the requirements of nutrients for banana production (see below), and more especially when the clay is kaolinite. A lime amendment is advised, but no comment is made on the organic components.

• Out of the four to five fertilizers existing, one or two do not contain phosphorus. On one farm, the followers did not received any phosphorus in 2008 before flowering because the farmer had used urea at shooting time and then a 20 0 23 from pruning to flowering.

• On another farm, the farmer put half of the advice because the price of fertilizers is too high. He apparently sees no difference in yield (which is not amazing since his soil requires organic matter above all).

• Considering that the plots are in production for many years, the plant population is not homogeneous, but all the mats, which are at different stages, receive the same fertilizer. A single grower referred to some trials that he had done on adapted nutrition programmes (farm 8).

• Fertilizing programmes are seen as cycles, (one cycle corresponds to one application of fertilizer) rather than real plant nutrition programmes. Very amazingly, we shall see that the same concept is used for the control of pests, disease, and weeds: The number of cycles.

The environmental impact of fertilizing practices is linked to the quantity and quality of fertilizers used by the farmer, as well as their efficiency: Fertilizer used by the plant / fertilizer lost, either by lixiviation, leaching (through the drainage system in Belize), or vanishing into the air (from the de-nitrification process). This efficiency will depend on soil characteristics (Texture, clay, organic matters, cationic exchange capacity). We have seen that these characteristics are far from being optimal at the present time on most of the farms.

The fertilizers used in Belize are only mineral fertilizers, compounded under various formulas: urea, DAP, Kcl, sulphate of ammonia, phosphoric acid, sulphate of potash, N-P-K+Mg+S, etc. Quantities used by the growers (1,5 to 2 T of fertilizer per hectare and per year) are comparable to quantities used in various countries producing bananas but two negative factors are present in Belize that may not be seen in other countries:
- The poor organic content of the soils,
- The proximity of the farms to the river and the drainage systems that exit directly in these water ways.
The main pollution risks are nitrogen and phosphorus that will contribute to the eutrophication potential of river waters and possible ingestion by the fauna.

3.2.9 Needs for a new approach

The results of the various soils and leaf analysis made on the farms and the low average yields obtained by all the growers show a low level of efficiency of the present fertilizing practices. A new comprehensive and biological approach is needed on soil fertility and fertilization.

Just two bibliographical references on this alternative approach:

“Nutrient availability is not enough for plant growth and health. The uptake of nutrients depends also on physical and biological conditions: Favorable soil structure with sufficient porosity is needed for air and water to permeate. Organic matter is not just a source of nutrients but it provides also carbon to feed the soil biota and build up soil aggregation” (Ana Primavesi, 2006).

We are exactly situated at the opposite of these recommendations in Belize.

“When organic matters disappear, soils get compacted and impermeable to water and air, water absorption diminishes with increased runoff and erosion, and flooding as a consequence. Soil may become salinized.

Liming may correct pH and avoid Al Fe and Mn toxicity, but it may also increase the mineralization and disappearance of organic matter by increased activity of some bacteria, leading to the loss of aggregated soil structure.” (Same author, 2006)

This is where we are in Belize, now, on most of the farms.

Below are some data concerning the immobilizations of nutrients by a banana plant: Nutrients Immobilization of a Banana Plant (in Le Bananier et sa Culture, A. Lassoudiere, CIRAD 2006)

<table>
<thead>
<tr>
<th>Plant</th>
<th>Dry matter (g)</th>
<th>N</th>
<th>P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;</th>
<th>K&lt;sub&gt;2&lt;/sub&gt;O</th>
<th>CaO</th>
<th>MgO</th>
<th>S</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>B</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother foot</td>
<td>8 300</td>
<td>85</td>
<td>21</td>
<td>472</td>
<td>123</td>
<td>42</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bunch</td>
<td>7 600</td>
<td>66</td>
<td>19</td>
<td>268</td>
<td>10</td>
<td>18</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follower</td>
<td>1 400</td>
<td>19</td>
<td>5</td>
<td>82</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17 300</td>
<td>170</td>
<td>45</td>
<td>822</td>
<td>141</td>
<td>66</td>
<td>19</td>
<td>2-8</td>
<td>&lt;0.2</td>
<td>2-10</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
</tbody>
</table>

Table 13: Immobilization of nutrients by a mat (mother plant + follower) at harvesting (bunch of 40 kg, bulk weight), 2<sup>nd</super> cycle
<table>
<thead>
<tr>
<th>Export (kg)</th>
<th>Dry matter</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>CaO</th>
<th>MgO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per ton</td>
<td>190</td>
<td>1.90</td>
<td>0.47</td>
<td>6.60</td>
<td>0.30</td>
<td>0.43</td>
</tr>
<tr>
<td>For 50 T/ha</td>
<td>9 500</td>
<td>100</td>
<td>20</td>
<td>330</td>
<td>15</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 14: Exports (Bananas + Stalks) for a production of 50 T/ha

To close this chapter on a positive note, we must relate some environment friendly experiences that are presently being tested by a few farmers:

3.2.10 New approaches presently tested by a few farmers

The setting up of a compost Facility on farm n°1:

With the technical support of Earth University of Costa-Rica, the farm has just started to make its own compost from green wastes collected at the boxing plant (rejected bananas and stalks which amount to approximately 10% of the production): Saw dust is also used in the process as source of carbon.

A swath, 1.2 m in height, is made as follows:
- First layer: Saw dust, 3 inches
- Second layer: bananas and poles, 40 inches
- Then, a bacteria is spread to accelerate decomposition: Efficient Micro-organism 5
- Third layer: Saw dust, 3 inches
- Fourth layer: bananas and poles, 40 inches
- EM5
- Fifth layer: Saw dust, 3 inches
- Sixth layer: bananas and poles, 40 inches
- EM5

The process of decomposition and humification is intended to last no more than six weeks. The compost obtained will then be spread on the banana land.
The process of compost is a controlled aerobic fermentation of organic matters. It aims at increasing the rate of humus. It is characterized by an increase of the temperature, a modification of the volume, a cleansing of pathogen organisms, seeds and various residues. The problem that the compost plant might face is the rains that may make the fermentation anaerobic with the development of unwanted germs. A roof may therefore be necessary. The permanent removal of the swath is also necessary for allowing its oxygenation.

**Storage and Re-use of rejected bananas on farm 8**

The method as it is performed now cannot be considered as composting, since the fermentation of the organic matters is mostly anaerobic. But at least, the farmer is trying to salvage part of the biomass that is generally thrown away.

**New fertilizing practices on some farms**

On some farms (Zabaneh), the citrus waste amendment is now done at 7 T/acre instead of one.
On farm 12, after harvesting, an injection of phosphoric acid (with or without potassium nitrate) is made into the mother mat that has just been cut. The injection (6 to 12 ml) is made at a height of 1.5 to 2 feet. It speeds up the growth of the follower.

Some farms are using foliar fertilizers (7-8, 15-16), while others (or the same) use drip irrigation and fertigation on some sections.

All these new trials made at the initiative of the farmers and by themselves give some hope for the future. It is certainly this kind of attitude that should be supported.

### 3.3 IPM: Integrated Pest Management

#### 3.3.1 Black Sigatoka

**3.3.1.1 Monitoring and management of the disease**

The *Black Sigatoka* is the n°1 disease. Its monitoring is ensured by the BGA and follows a protocol set up by a consultant (Dr. Luc de Lapeyre): The strategy adopted since 2007 is based on a biological forecasting system, but due to the high level of contamination, the number of applications remains very high.

The strategy is based on:

1. Disease assessments regularly made on the farms,
2. Management of field inoculum by application of chemicals by plane and constant elimination of inoculums sources (leaf spots) through regular deleafing of spotted leaves.

Concretely, the activities implemented by the team are as follows:

- Field Supervisors visit every block of every farm once a week,

- A sample of mats is checked per block, following a specific diagram: leaves 2-3-4, youngest leaves infected, youngest leaves spotted (burning stage). A calculation is made and the decision on what treatment to use will depend on the result.

- It is up to the technical staff to decide if the spraying of fungicide has to be done or not. In order to do so, collected data serve to follow up the evolution of the disease per block. This data is then related to the climatic data (rain-temperature) and to the type of chemical and oil that have already been used. The best possible strategy (treatment) is then determined.
• All this data, monitoring and follow-up activities are recorded on graphs that are presented at the mixing station. It must also be noted that the field supervisors take advantage of their presence in the fields to count the number of functional leaves at harvest time and inform the farmer if they are not reaching an average of 4.5 leaves per plant. In this case, the farmer will send a team of workers in order to get rid of those mats.

Pictures 20-21: BGA Mixing Station, Savannah Airport

3.3.1.2 Chemicals used, doses

Only protective (contact) fungicides are spread in the dry season, mixed with water (18 to 25 L/ha) and a sticker. During the wet season, all types of fungicides may be used, mixed with a mineral oil BANOLE V/N in order to avoid washing by the rain. Special attention is paid to the amount of oil used since too much oil may be phytotoxic and leads to a decrease of yield. In average, 52 cycles (spreading) are done every year on each block in the southern and western parts of the district. This number may fall to 42 cycles on farms closer to the sea that receive less rains (farms 7-8-15-16).

Fungicides used, and doses for the year 2008 are as follows:

<table>
<thead>
<tr>
<th>Fungicide Name and class</th>
<th>Active ingredients</th>
<th>Dose /Ha /spray</th>
<th>Environmental impact L per Ha for the year 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chemical</td>
</tr>
<tr>
<td>Systemic fungicides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SICO 25 EC</td>
<td>Diphenonazol</td>
<td>0.4 L</td>
<td>0.4 L</td>
</tr>
<tr>
<td>BAYCOR 50 SC</td>
<td>Bitertanol</td>
<td>0.5 L</td>
<td>0.5 L</td>
</tr>
<tr>
<td>BANKIT 25 SC (Dry season)</td>
<td>Azoxyystrobin</td>
<td>0.4 L</td>
<td>0.4 L</td>
</tr>
<tr>
<td>TEGA 7.5 EC (Wet season)</td>
<td>Trifloxystrobin</td>
<td>Not used in 2008</td>
<td>0</td>
</tr>
<tr>
<td>Penetrant fungicides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Translaminar)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOLLEY 88 OL</td>
<td>Fenpropimorph</td>
<td>1.75 to 2.5 L</td>
<td>2.8 L</td>
</tr>
<tr>
<td>SIGANEX</td>
<td>Pyrimethanly</td>
<td>2.5 L</td>
<td>3.0 L</td>
</tr>
<tr>
<td>Protectant Fungicides</td>
<td>Mancozeb</td>
<td>1 to 1,5 L</td>
<td>51 L</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------</td>
<td>------------</td>
<td>------</td>
</tr>
<tr>
<td>DITHANE 60 SC DITRAKO</td>
<td>Chlorothalonil</td>
<td>51 L</td>
<td>21,5 L</td>
</tr>
<tr>
<td>BRAVO 72 SC</td>
<td></td>
<td>80 L/Ha/year</td>
<td>51 L/Ha/year</td>
</tr>
</tbody>
</table>

**Table 15: Sigatoka Control - Fungicides and oil used in 2008 (projection for the period 1st sept to 31st dec)**

It must be noted that two years ago, the distribution of fungicides was 50% Systemic – 50% Contact (protective). This distribution is now 10% Systemic – 90% Contact, because the fungus has built up a resistance to systemic fungicides that were over-used.

- Systemic fungicides penetrate inside the leaf tissue and can be redistributed in the leaf. They have a curative action.
- Penetrant fungicides have a translaminar diffusion inside the leaf, and so, have a moderate curative effect.
- Protectant (contact) fungicides do not penetrate inside leaf tissues, and act by contact. They just have a preventive effect on the disease inhibiting fungal infection before host penetration.
- Dithane SC is a formulation of Mancozeb that is supposed to ensure a better adhesion on the banana leaves.

Foliar fertilizers may be added to the solution when leaf analysis has shown a deficiency in microelements such as Zn, Cu, B, Fe, etc. This is mostly performed on farms 7-8-15-16, farms that receive the least amount of fungicides (42 applications in 2008).

![Pictures 22-23 : Sigatoka Negra, Leaves presenting an advanced stage of infection](image-url)
3.3.1.3 Environmental Impact of the Control of the Black Sigatoka

In all, the control of the Sigatoka was the first noticeable agricultural practice using a systematic, science-based approach (beside the trials made on compost by a few farmers). However, the disease is now so anchored in the environment that this approach has not been reflected until now in a lesser consumption of chemical fungicides.

Risks of contamination concern the people who are working on the farm. In order to avoid it, farmers know when spreading will take place and can therefore warn their workers by several means, including notice boards. On one farm at least, the farmer and the Sigatoka team use an even-odd numbers system: On even days, half of the area is occupied, and the next half on odd days.

The second risk concerns the people living nearby. Some years ago, people living in a hamlet close to the Swasey river farms had to move and settle down a bit further, because of the spray.

The third risk of contamination concern the fauna. In his report, Dr Luc de Lapeyre notes that Chlorothalonil (Bravo 72 sc) is considered as possibly hazardous for the fauna leaving in the stagnant water.

In their report on potential risks to the environment from pesticides used in banana production in Belize in the 90s (see an abstract of the study in Annex 5), the authors estimated that approximately 32 T of Mancozeb (Dithane 60 SC) accumulates in the environment annually. Most of it will be attached to sediment that can be moved to the ocean during periods of rapid water flow. Considering that the amount of Mancozeb has rather increased since this period, we can assume that the quantities accumulated in the environment have reached a high level.

According to Gillian Ferguson (2006) regular spreadings of Mancozèbe are known to have negative impacts on a family of useful mites (Phytoseiidae) that are thrips predators (Amblyseius cucumeris). We don’t know if this species of mites is present in Belize, but it means that when biological means are used in IPM, one must pay a lot of attention to the side effects of the pesticides spread against another pest or disease.
3.3.1.4 Needs for an integrated approach at farm (and regional) level
Well aware of the risks for the environment, the Sigatoka team will now embark on a more intensive use of organic fungicides. 3 kg of Frutiver 2000 have already been used in 2008 (as a trial), and the use of Timorex (an extract of Melaleuca Alternifolia that is supposed to stimulate the natural defense of the banana plant against the fungus) will be experimented in 2009 with new bio-fungicides. The objective is to bring the contribution of these environment friendly molecules up to 15% of the spray programme.

However, we consider that this positive initiative should be part of a more integrated and biological approach of the entire farming system, taking into consideration other stress parameters that plants have to endure: We have already seen a soil factor – lack of organic matter and correlatively lack of air (compaction) – and we shall see now a second stress factor: The very high level of nematodes affecting the development of the roots. All these factors are weakening the self-defense capacities of the banana plants, and in a way call for a continuous intensive use of chemicals.

3.3.2 The Control of Nematodes

Since three missions are being done on this matter by a nematode specialist (Dr J-L Sarah), we did not study the details of the data. The monitoring system is in the hands of the BGA and is presently changing according to his recommendations.

Until 2008, one checking was made per year (usually in May) on a certain number of sections representing the farm (as for soil analysis). Two species of nematodes are numbered: Radopholus similis that is an endoparasite very harmful to the banana and Helicotylenchus sp that is an exoparasite and less harmful.

According to the figures shown in the report of Dr. Sarah, populations show the following profile:

![Graph showing nematode populations](image)
Table 16: Nematode monitoring 1999-2007: Average number of radopholus similis per gram of root (J-L Sarah, 2008)

Our own appraisal, made on the more recent data of 2008, shows the same degree of infestation, with populations over 80 nematodes per gram of root in general (See Annex 4).

Until 2008, the farmers used to treat once per year (sometimes more) using a nematicide from the following list, at 3 g of active ingredient per mat, as recommended (in average 2.5 kg/acre).

<table>
<thead>
<tr>
<th>Product</th>
<th>Active ingredient</th>
<th>Family</th>
<th>Formulation</th>
<th>Main Action</th>
<th>Rate / plant</th>
<th>Water solub.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mocap</td>
<td>ethoprophos</td>
<td>organophosphate</td>
<td>Granular 15%</td>
<td>contact</td>
<td>20 g</td>
<td>0.75 g/l</td>
</tr>
<tr>
<td>Nemacur</td>
<td>fenamiphos</td>
<td>organophosphate</td>
<td>Granular 15%</td>
<td>systemic</td>
<td>20 g</td>
<td>0.7 g/l</td>
</tr>
<tr>
<td>Counter</td>
<td>Terbuphos*</td>
<td>organophosphate</td>
<td>Granular 15%</td>
<td>systemic</td>
<td>20 g</td>
<td>0.015 g/l</td>
</tr>
<tr>
<td>Rugby</td>
<td>cadusaphos*</td>
<td>organophosphate</td>
<td>Granular 15%</td>
<td>contact</td>
<td>20 g</td>
<td>0.25 g/l</td>
</tr>
<tr>
<td>Vydate</td>
<td>oxamyl</td>
<td>carbamate</td>
<td>Liquid 24%</td>
<td>systemic</td>
<td>12.5 ml</td>
<td>280 g/l</td>
</tr>
<tr>
<td>Furadan</td>
<td>carbofuran*</td>
<td>carbamate</td>
<td>Granular 10%</td>
<td>systemic</td>
<td>30 g</td>
<td>0.7 g/l</td>
</tr>
<tr>
<td>Nemathorin</td>
<td>fosthiazate</td>
<td>organophosphate</td>
<td>Granular 10%</td>
<td>systemic</td>
<td>20 g</td>
<td>9.0 g/l</td>
</tr>
</tbody>
</table>

*Terbuphos, cadusaphos and carbofuran withdrawn from Annex 1 of the Council directive 91/414/CEE

Table 17: Nematicides used in banana production in Belize (from J-L Sarah - 2008)

Dr Sarah is proposing a new comprehensive and biological approach to control nematodes, which consists in lying fallow for a year and planting vitro-plants afterwards. However, it is not possible to let all the land lie fallow at the same time. Dr Sarah therefore recommends doing so for the most infected plots, while continuing chemical treatments in other areas, but at three applications per year.

3.3.2.1 Environmental impact of the nematodes control and strategies

Many studies have shown that the use of chemicals against pests and diseases is a race lost in advance, and that the biological approach is the only strategy to use in the long term. This is particularly true for nematodes:
Antoine Laffont and others (2005) studied the effect of the earthworm Pontoscolex corethrurus on Radopholus similis and on the banana roots in Guadeloupe. They found a negative correlation between the population of earthworms and the percentage of roots necrosis due to R. Similis.

Besides, other studies have shown that massive use of nematicides diminishes the population of the useful macro fauna (worms and insects) or even useful nematodes, thus being detrimental to the biological activity of the soil.

We can also add that out of the four nematicides used in Belize, only one (Vydate) is authorized in Europe. The three other nematicides (Rugby, Counter, Nemacur) are forbidden for environmental reasons.
In their report on potential pollution by pesticides used in banana production (Annex 5), the authors estimated that leaching of Ethrophos (i.e. MOCAP) into the environment amount to 1.9 T of product per year, and that this product has obviously already entered the coastal areas.

We are in fact faced with the same problem as for the use of fungicides to control the black Sigatoka or mineral fertilizers in soils deprived of organic matter: Is the Belizean banana industry running for the use of more and more inputs, potentially harmful to health and environment, and which obviously do not give expected results in terms of production, or is the banana industry ready to implement alternative means, such as integrated and biological approaches?

Safe use of nematicides
Every farm apparently complies with all safety requirements from GlobalGAP related to the use of chemicals (see pictures). However, we were unable to see this for ourselves since no spreading of nematicides was performed during our assignment.

Pictures 25-26: Safe storage of Knapsacks and eye cleaning jet “Lavabo de emergencia”

3.3.3 The control of insects and other pests

The control of thrips, cochineals, colaspis and other parasites of the fruit is made by the bagging of the bunch, done most of the time at the horizontal finger stage one day after deflowering. The blue plastic bag is covered with Chlorpyrifos at 1%.

At harvesting, bags are rolled and tied to the stalk, then collected at the packing station to be burnt.

In Costa Rica, the bags are now presented in rolls that are cut to the length of the bunch. The use of this material has decreased the consumption of plastic by 30%.
The method called “early bagging” that could be used at the “Horse head” stage in order to improve pest control is not practiced because of the deflowering. Therefore, in order to avoid thrips attacks before this stage, a ribbon that repels them is stuck around the stalk at the “horse head” stage.

![Picture 27-28: Transportation of bananas to the packing shed on farm 7, The blue bags will then be burnt](image)

3.3.4 Weed Control

As for fertilizing or pest and disease control, the notion of weed control is seen in Belize as a number of cycles, referring to the number of herbicide applications done per year. This number varies from 4 to 6 applications of Glyphosate per year (or a contact herbicide such as Trimazone on some farms). Usual rates are between 150 to 200 cc/20 L of water, according to the weeds (600-700 ml/acre). The cutlass (machete) is also used.

We must say that we were sometimes shocked by the state of cleanliness of some plots, and more especially around the mat, with no weed to be seen. The problem is that a ‘clean’ state is preventing all chance of biological activity in the soil as well as triggering soil erosion. According to one farmer, this cleanliness around the mat foot is demanded by Fyffes.

However, on some farms (5 25-26, 4-15-16, 8) chemical weeding has been reduced to a couple of cycles per year, with apparently no negative impact on the yields (these farms are in fact obtaining the best yields).

Also, No chemical weeding is normally done in the drains in order to reduce soil erosion.
3.4 Pesticides Used by the Banana Industry: Environmental Impact

From the data collected at farm level and at BGA, we can estimate the average quantity of chemicals (pesticides + fungicides + herbicides) used per acre and per year. We consider here the exact figure of fungicides used by the BGA against sigatoka divided by the acreage, one nematicide treatment carried out per year (2.5 kg of active ingredient), and 5 herbicides treatments made at 600 ml of Glyphosate.

<table>
<thead>
<tr>
<th>Type</th>
<th>Use</th>
<th>Dose per acre per year</th>
<th>Dose per hectare per year</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Chemical</td>
<td>Active ingredient</td>
<td></td>
</tr>
<tr>
<td>Fungicides</td>
<td>Sigatoka</td>
<td>32 L</td>
<td>20.5 L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nematodes</td>
<td>16.5 kg</td>
<td>2.5 kg</td>
<td></td>
</tr>
<tr>
<td>Herbicides</td>
<td>Weeds</td>
<td>3 L</td>
<td>1.1 L</td>
<td></td>
</tr>
<tr>
<td>Total Pesticides</td>
<td>80.5 kg</td>
<td>24.1 kg</td>
<td>128.4 kg</td>
<td>59.8 kg</td>
</tr>
</tbody>
</table>

Table 18: Quantity of pesticides and herbicides used in the Belizean Banana Industry, year 2008

We must say that if we consider 3 nematicide treatments per year, as presently advised when it is not possible to lie fallow, the figure jumps to 70 kg of active ingredient per ha.

Two types of chemicals should be added to this list: The Chlorpyrphos contained in the plastic bags that are burnt in registered drums (registered by the Pesticide Control Board), and the fungicides (Thiabendazole, Imazalil) spread on the bananas after harvesting to avoid crown rot, which are going to a sedimentation tank (see § Environmental Policy and Procedures).

This data places Belize among the highest consumers of pesticides (active ingredients) in banana production. However, this position is due to the prevalence of the Black Sigatoka:
In the first instance, the environmental impact of pesticides concerns the people, who can be sub-divided into three groups according to their potential exposure to pesticides or herbicides:

- **High risk group**: Mainly workers of the banana industry itself, either using the chemicals or other field workers.
  
  All of the employees using chemicals carry a Pesticide Applicator License meaning that they have been well trained in the safe use of chemicals and first aid and that they have passed an exam. They also wear a complete protective gear when they spray chemicals. They take a shower after having used chemicals. They are submitted to two blood tests per year to detect any traces of cholinesterase.

  Other workers of the farm and in particular field workers are aware of the use of chemical on this or that block thanks to information boards (see picture 25) or by fields supervisors.

- **Moderate risk group**: This group is composed of the people living in the vicinity of the farm. They can be concerned either by the spreading of fungicides and oil by plane (Sigatoka) or, if they live alongside the river below the farms, by all pesticides and herbicides residues flooding from the drains to the river.

- **Low risk group**: people living in the Stann Creek district, but not close to the farms. This group did not appear to us to be particularly exposed to possible intoxication, except if we consider the litter of a few plastic bags left in the bush by some banana farms (see § Waste Policy)

The applications of pesticides and herbicides undoubtedly affect the environment and notably the river waters, the fauna and marine resources.

An approach of the real pesticide contamination in natural environment cannot simply be estimated by some random measurements made in the soil or rivers. These studies are complex
and long because contamination rates will depend on various factors such as the molecules used, the rates of application, the medium (soil, sediment, water) and the climate.

That may be why we have found very few studies about the estimation of pesticides pollution in Belize:

**1997-1999: Investigation of the impact on reef environments of changing land use in Stan Creek District**

It involved annual river flow measurements at different periods of the year, calculation of the sedimentation speed, C N P contents, heavy metals, radio nucleids. Soil analysis had also been done on 12 samples in forest, citrus and banana area showing no significant concentration of heavy metals. Only five pesticide molecules were detected: *dieldrin, bitertanol, prometryn, diuron* and *monuron*, albeit at a very low rate. No pollution was detected.

**1994: Evaluation of pesticide and fertilizer usage in bananas & potential risks to the environment** (See an Abstract in Annex 5).

According to the chemical and physical characteristics of each active ingredient (solubility in water, soil absorption coefficient, rate of degradation ...), estimation of the half life of each molecule and evaluation of its propensity to move out of the soil or to bio-accumulate.

Calculation made for the 1994 data. Recommendations to banana industry to limit contamination. But no measurements of pesticide were made.

**1996: Assessment of pesticide impact on the agricultural communities of the Cayo District and the Banana belt of the Stann Creek District**

Analysis in 12 vegetable samples in Cayo district and 12 river water and sediment samples in SC district. The results showed fairly innocuous amounts of measured organic residues: organochlorines, organophosphates and dithiocarbamates,

**1996: Organochlorine pesticides in ambient air of Belize**

Concentration of DDTs and aldrin/dieldrin was found to be extremely high relative to levels measured at Great Lake monitoring stations in North America.


Preliminary testing of marine organisms and human breast milk was initiated in Belize in 2003 2004. Further studies in 2007 were conducted to explore the potential relationship between environmental contamination and human (breast milk) contamination and relate the levels of contamination to dietary intake. The dominant residues detected were DDT and its metabolite or Lindane (one sample), chemicals that are not used in the banana industry nowadays. No nitrogen or phosphorus crop protection residues were detected.
Let us add an extract from an Overview of WWF’s monitoring program of agrochemical contamination in marine life and sediment (from Melanie McField, Nadia Bood and Craig Downs) that seems perfectly adapted to the Stann Creek District in Belize:

“The limited data that are available on coral reefs, corals and other reef organisms (to which we could add shrimps in the Stann Creek District), suggest they are highly sensitive to chemical perturbations. Many chemicals used far inland can be transported via rivers to sea. Some bind to sediment or organic matter while others quickly become incorporated to plankton, invertebrates and fish through the process of bioaccumulation through food webs. Some agrochemicals such as chlorothalonil (used at 21.5 L per acre in Belize) have been proved very detrimental to coral planula survival and settlement.

Agrochemicals and other contaminants can be measured directly from tissue samples and sediments: The WWF/ICRAN and the MBRS Synoptic Monitoring Program have developed various protocols depending on the analyzed mediums: Coral, Queen conch, white grunt, sediments and fish tissue for stress biomarkers associated with chemicals. However, great care and attention must be taken in field sampling protocols to avoid cross-contamination and subsequent contamination of samples. Likewise, strict laboratory procedures and controls are required to ensure consistent and accurate results.

Preliminary data indicate that the most prevalent compounds in reef organisms include chlorothalonil, imidaclopril, malathion, DDT, deltamethrin, fipronil, propanil, lindane and aldrin. Contaminant concentrations in marine organisms can range from non-detectable value to relatively high 2 ppm (mg/kg). More eco-toxicology studies are needed.”

An outline of a possible study on pesticides contamination will be presented in our proposals.

3.5 Environmental Policy and Procedures

3.5.1 Integrated Crop Management and Environmental matters (Fyffes and GlobalGap)

All farms are Global GAP certified, meaning that they answer to the environmental, safety, health and security requirements of GlobalGAP, plus those of Fyffes (plus Dole for some of them). We have reviewed some of these matters on the farms, but it was impossible to check each of these matters on every farm since the list contains hundreds of topics. We looked more particularly at the “Integrated Crop Management and Environmental matters, and Equipments”.

Procedures concerning these matters are written in several books (more than fifteen books or files on each farm), and information is displayed in and around the packing shed or on the farm. They concern various obligations that all farms are following (as a matter of fact, various inspectors from Dole, Fyffes and Global GAP were present at the time of our assignment and we could therefore exchange information on which we all agreed).
The subjects treated in the book “Integrated Crop Management and Environmental matters, and Equipments” are as follows:

✓ Risk assessment,
✓ Health and Safety Committee,
✓ Map,
✓ Analysis,
✓ Risk study,
✓ Plant density,
✓ Technical staff, training,

Pictures 31-32: Signs on pesticides use and Training session on chemical handling and safety

✓ Equipment maintenance,
✓ Desinfection of knives and machetes (once a week),
✓ Bacteria and chlorine applications,
✓ Management of wildlife and conservation plan,
✓ Safety data sheets,
✓ Procedures for reacting to adverse water analysis results,
✓ Retesting of water by 7 laboratories,
✓ Cleaning of wells,
✓ Chlorinating of water contaminated by bacteria,
✓ Using of neutralizer for water with high level of chemical elements,
✓ Using of filter for water with high level of suspended solid,
✓ Procedures for handling empty pesticides containers:
  - Empty containers are triple washed, and the water put back along crop borders
  - Containers are stored in a secure place,
  - Empty paper bags and small plastic bags are burnt in approved on site incineration unit (such as perforated drum)
  - Containers that don’t burn are perforated to make them unusable,
  - Containers are then returned to the supplier.
Farm chemical use and storage,
Use of chemicals and storage of chemicals and fertilizer,
Certified Pesticide Application Licenses,
Fyffes Audit,
Record: Nematode tests, nematicide application,
Chemical inventory,
Electricity usage (bulbs of the packing house),
Equipment calibration file,
Knapsack Sprayer Inspection Log: Completed by the environment supervisor every 6 months,
Fungicide Application Record, Aviso de Fumigacion,
Fyffes Quality Control Manual: Packing specification configuration,
Sigatoka control book (BGA),
Individual Record of protective and safety equipment and training record (per type of workers), an information is given to the employee that he must sign.
Spray record (BGA): Date, chemicals used,
Use of protective clothes by the workers: Not always done according to Fyffes
Information on recently treated areas,
Storage of chemicals. Chemicals and fertilizers are kept in well ventilated store rooms, separated from each-other. Wearing a mask is compulsory in the chemical rooms.

Pictures 33-34: Storage of chemicals and other inputs

Procedures for washing and storing protective gears:
- All protective gear is collected after application
- Washing is done with soap powder and chlorine
- Protective gear is dried outside, in the sunlight
- Storing is done separate from chemicals
Pictures 35-36: A clean packing shed after work – Safety Information Board

✓ Use of fertilizers,
✓ Fertilizer application sheet, including date, cycle, number, fertilizer, dose per plant, dose per acre, authorizing person, application name, manager signature,

✓ Human Resources (environmental matters):
  - Diplomas,
  - Training,
  - Welfare of employees / Social Security,
  - Information on health and safety policy,
  - Health and safety audits,
  - Cholinesterase Reports, Record of analysis,
  - Training on Pest and Disease,
  - Information on emergency procedure,
  - Number of work day per week,

✓ Packing House:
  ✓ Disposal of waste (done regularly)
  ✓ Post Harvest treatment Record
  ✓ Stain ways, waste water going to a septic tank
  ✓ Safe electrical installations
  ✓ Clean Toilets and washing facilities for workers
  ✓ Bagging and Harvesting Records
  ✓ Packing shed cleaning cycle
  ✓ Packing house waste disposal
  ✓ Rejected bunches: Caída de cable (bunches falling from the cable = 1%)
  ✓ Harvesting Quality evaluation
  ✓ Record on packing shed lights
  ✓ Record on packing rat trap record,

GlobalGAP and the environment
When one looks carefully at the requirements of GlobalGAP concerning environmental matters, it is noticeable that a lot of emphasis is paid on record keeping, origin and safe use of inputs (fertilizers, pesticides, etc), farm and land management, residues analysis in the fruit, pesticides handlings… but two environmental issues are neglected:

- The quantities of chemicals applied per acre (or per kg of produce),
- Soil or water (such as river water) analysis regarding pesticides residues.

In other words, to be GlobalGAP certified does not give any guarantee against possible pollution of the environment (see also § River and well water analyses).

3.5.2 Farm Waste Analysis

All growers have procedures in operation for the removal of waste materials from their farm, ensuring environmentally sound practices. These procedures are as follows:

3.5.2.1 Waste from field operations:
- Used nursery bags (polyethylene): To be incinerated in a designated area,
- Tree bags (polyethylene): Recycled (5) times for diapers, then incinerated,
- Empty fertilizer bags: Reused in various ways as bags,
• Propping twine (polypropylene): Recycled twice, then incinerated,
• Ribbons (polypropylene): Recycled twice, then incinerated,
• Excess chemical mixtures: Excess must be spread in farm boarders as recommended by the Pesticides Control Board,
• Obsolete chemicals: Are returned to the supplier,
• Contaminated materials: Not applicable,
• Insecticides treated strips (Dursban): Incinerated using legal method,

3.5.2.2 Waste from packing operations:
• Fruits stalks: Applied in the most unfertile areas,
• Rejected fruits: Dumped in a designated area, can be used as organic
• Stalk trimming (ribban) Recycled twice, then incinerated,
• Excess post harvest mixture: Sedimentation tank (see next §),
• Empty Post harvest chemical containers: Return to supplier (BGA),
• Waste water from de-handing tanks: Drainage system,
• Waste water from the de-latexing tanks: Drainage system,
• Damage cartons: Returned to Fyffes,
• Damage packaging plastic: Incinerated using legal method, or returned to supplier,
• Waste paper from fruit labels: Incinerated,
• Broken tools: Buried.

3.5.2.3 Waste from maintenance and repair operations
• Waste lubricating oils: Given to people who have power saw machines or used to cure lumber,
• Waste battery: Buried,
• Damage or useless parts: Buried,
• Empty paint containers: Buried,
• Waste paint solvents: Buried,
• Scrap machinery and metal: Buried,
• Scrap wood: Incinerated.

3.5.3 Treatment of Fungicide-alum waste from packing station

In order to protect water resources, a sedimentation tank has been designed at EARTH (Escuela Agricola Regional Para el Tropico Humedo) with the purpose of treating the fungicide-alum effluent resulting after spraying bananas just before packing to control rot and other post-harvest diseases. Chemical analyses have shown that the fungicides (Imazalil and Thiabendazole) are decomposed within seven days in the absence of light and no additional aeration. Following is a brief description of the tank, present on each farm:
• The fungicide-alum waste resulting from spraying the fruits is collected through a funnel located under the spraying chamber, then brought to the underground tank that has the following dimensions: 3mX2mX1.5m.
• The tank is divided into three compartments and stores the fungicide solution for seven days. The internal walls allow sedimentation of solid particles. The water then passes to a pipe containing a stopper.
• Treated wastewater effluent is released into drainage system by which time it is environmentally friendly (even though it contains a certain amount of aluminium).

Pictures 39-40: Fungicide-Alum waste going to Fungicide-Alum sedimentation tank, farm 17

3.5.4 Recyclable materials

All recyclable materials are normally recycled.
Picture 41: Transport of used containers and various rubbish by cable way

Pictures 42-43: Arrival of bananas at the packing station – Registration - Recycling of ribbons

3.5.5 Non recyclable Waste: Empty containers and plastics

Containers that cannot be burnt are given back to the company that sells the input. Plastic bags or small plastic containers are burnt in various ways, some environment friendly within registered drums, some less so:

Pictures 44-45: Proper waste management (Farm 12) - Hazardous waste management (Farm 4)

According to the environment officer of the BGA, M. Oswald Arzu, the disposal of plastics is a main environmental issue. We saw this for ourselves.

3.5.6 Conservation and Wildlife Enhancement Policy

Here is the recommendation given by the BGA to each grower:
“The banana farms are all bordered by forest which is treasured due to its various benefits to both human and wildlife. That is why the forest is not tampered with either by cutting it down or burning. Destroying the forest, we are directly destroying the homes of wildlife, which may tend to migrate or accelerate their extinction. We also put into consideration other species we humans may not have yet discovered that could be lost by destroying the forest. The wildlife around the banana farm also feed on the banana fruit that are dumped. Forest destruction could also result in high water run-off and may cause flashfloods and severe erosion.

Within the farms, we try to use the least toxic pesticides as possible, whenever there isn’t any other environmentally friendly alternative, to avoid any imbalance of wildlife within our productive area. We also have a sound Integrated Pest Management to reduce unnecessary pesticide applications and avoid any chances of pesticides contaminants from entering water bodies, which could eventually kill the aquatic life. Within the farm, we also try to use new technologies in chemicals and chemical application to reduce chances of animals coming into contact with pesticide long after it is applied, which could be fatal to them. Natural controls are welcomed within the farms, because it reduces pest multiplication and therefore pesticide application is avoided. Soil erosion has been a major factor within the farms, which is why we encourage the planting of grass on the side of drains”.

Every year, each grower makes a “Biological Survey”

The aim of this biological survey is to guideline and to ensure that the agronomical practices implemented on the farm do not affect the normal life of the animals and plants inside and around the farm.

During our mission, we saw many different trees (on the farms) such as *Cecropia Peltata* (Trumpet tree), breadfruit trees, mango trees, papayas, coconut palms, citrus, bamboos, hibiscus, crotons, plus many other trees, various species of grass and wild legumes, guava, etc. The fauna is extremely rich. During our mission, we observed various butterflies, a tarantula, lizards, frogs, one big snake, one fox, may be an opossum (or something similar), ants and various birds including vultures and small eagles.
3.6 Rivers and Well Waters Analysis

Once a year, a biological analysis of the river water is carried out by the Belize Agricultural Health Authority (BAHA). Samples are taken by a technician of the BGA. Three samples are taken: One above the first farm up river and one below the last farm (six samples in all). Plus a well sample on each farm:

For the Swasey River: One sample above farm 21, one sample below farm 9-10.
For the South Stann Creek River: One sample above farm 5-25-26, one below farm 7.
For Blade: One sample above farm 6, one below farm 17.

Analysis requested by GlobalGAP and Fyffes are: Coliforms, fecal coliforms, escherichia coli. All the results seen during our mission in Belize were showing results below the defined thresholds.

Besides this analysis on germs, the national brewery of Belize does the following analysis on the well water: pH, Total dissolved (by conductivity), aluminium (UV/VIS spectro), nitrate NO3 (Cadmium reduction and UV/VIS spectro). All the results seen during our mission in Belize were showing results below the defined thresholds.

The waters going out of the fungicides spray made on the bananas after harvesting go to a sedimentation tank (See § Treatment of Fungicide-alum waste from packing station).

Picture 49: Out of the packing station: Overuse of ‘Bacterol’
3.7 Pesticide Residues Analysis

As one notices no analysis of any pesticide residue at farm level is required by GlobalGAP; and none is performed.

However, residues analyses are performed on fruits by a lab in the UK, and Fyffes admits that the supermarkets asks to have them done in the UK.
4 Assessment of the Environmental Monitoring at BGA Level

4.1 Environmental Monitoring

We have already presented the activities carried out by the BGA regarding its agronomic and environmental monitoring activities. And as a matter of fact, all environmental activities carried out within the farms are being supervised by the BGA in one way or another.

We have seen the high level of monitoring done by the Association concerning the control of the Black Sigatoka, a control that uses more than 50% of its financial and human resources. Considering the present financial situation of the Association, the decision that has been taken recently in order to individualize the costs of this service per farm can only be supported.

In the second main technical area (agronomy), we have seen some weaknesses, and more especially concerning the plant nutrition department, since no one can for the moment interpret soil and leaf analysis and advise farmers accordingly. It is obvious that this department needs strengthening if the Association is to play a major coordinating role in the area of crop management; a coordination that appears to us as being fully desirable.

Environmental matters that are dealt with by the Association concern more particularly the proper use of chemicals, waste management, river and well analysis, conservation and wildlife policy.

Considering our assessment at farm level, we believe that this department could be significantly upgraded in the area of waste management (see § Proposals)

We do not think that the role of the BGA is to monitor environmental matters at the level of surrounding villages and river waters. This monitoring is usually under the responsibility of the Government.

4.2 Functioning

One fact that characterizes the Banana Growers Association is the physical division of its premises in two different locations (Administrative departments in Big Creek, and Technical departments at the Savannah Airport two miles away). We must say that this division did not appear to us to be a factor of cohesion and efficiency, since each department seems to act more or less on its own, without much supervision.

This unclear situation even appears on the Organizational Chart, showing the Nutrition and Nematodes Department placed under the Sigatoka Manager, but acting under the supervision of the Quality Manager. There is need for clarification.
5 Proposals for a Sustainable Banana Plan

5.1 Rationale

The production of bananas in Belize is based on a perennial cropping system. This intensive system has been functioning thanks to the use of high levels of inputs, in particular chemical pesticides and herbicides, and mineral fertilizers. Yield remains low, however.

This system of production has now reached its limits and cannot continue as it is for the following reasons:

1. At ‘ground level’, all plots are showing stressed, stunted plants, with a very low production of biomass, a high rate of rosetting, many leaves covered with lesions and necrosis due to the black cercosporiosis, very poor bunches bearing on average 6 to 7 hands, and lastly low production with 10 to 15% of rejected or lost bananas, still thrown away ‘in the jungle’ on most of the farms.

2. Agricultural practices, based on a high consumption of chemicals (54 aerial treatments of oil and fungicides against the black cercosporiosis, 1 to 3 nematicides treatments, 4 to 6 cycles of herbicides), without any attention paid to two major components of the soil (organic matter and air) have led to a very high level of soil fatigue, and a significant level of resistance of pests and fungi to chemicals (ex: systemic fungicides),

3. Consumers are now asking for a ‘greener’ agriculture, which is not detrimental for the environment and human safety,

4. The legislation on the use of pesticides, is likely to become tougher, worldwide,

5. Prices of agricultural inputs and in particular mineral fertilizers are increasing dramatically,

6. Last but not least, Belize has to preserve the health of its people, the quality of its soils, waters, marine resources, and its natural eco-systems as a whole.
In order to ensure the sustainability of the production of banana in Belize and lessen its environmental impact, its stakeholders must therefore review their objectives and strategies at all levels, and implement alternative cropping systems.

The technical outlines of a possible sustainable banana plan are presented here. Accompanying measures aiming at the adoption and appropriation of these alternative techniques by the farmers are proposed.

### 5.2 Present Yields and Hypothesis

The following table shows the average yields obtained during the years 2004-2005-2006 in Belize. The 2007 yields were lower for climatic reasons, and the 2008 yields are expected to be higher.

<table>
<thead>
<tr>
<th>2004 to 2006</th>
<th>Average</th>
<th>Average</th>
<th>Average/Grower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm n°</td>
<td>T/acre/year</td>
<td>T/ha/year</td>
<td>T/acre</td>
</tr>
<tr>
<td>01</td>
<td>9,2</td>
<td>22,7</td>
<td></td>
</tr>
<tr>
<td>02</td>
<td>9,5</td>
<td>23,6</td>
<td></td>
</tr>
<tr>
<td>03</td>
<td>10,1</td>
<td>25,0</td>
<td></td>
</tr>
<tr>
<td>06</td>
<td>8,5</td>
<td>20,9</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>7,8</td>
<td>19,4</td>
<td></td>
</tr>
<tr>
<td>09</td>
<td>9,3</td>
<td>22,9</td>
<td></td>
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<tr>
<td>10</td>
<td>5,4</td>
<td>13,3</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>11,0</td>
<td>27,2</td>
<td></td>
</tr>
<tr>
<td>04</td>
<td>10,8</td>
<td>26,8</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>14,4</td>
<td>35,7</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>14,2</td>
<td>35,0</td>
<td></td>
</tr>
<tr>
<td>05</td>
<td>11,3</td>
<td>28,0</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>12,2</td>
<td>30,2</td>
<td></td>
</tr>
</tbody>
</table>
Conceivable Increase of Yields

If we consider that all farms could be at the level of the best farm (farm n°8) reaching 16 T of bananas per acre and per year, this would mean an average production increase of 50%.

This hypothesis might seem over-optimistic. Let us therefore take a more conceivable increase of 25%.

This yield increase of 25% could be an objective for the next five years.
Sustainable Banana Plan

1 Recommendations for New Environment Friendly Practices

1.1 General Objectives

To reduce the use of pesticides and mineral fertilizers,
To reduce their transfers to drains and natural water ways,
To implement a biological approach to sustainable soil system,
To implement a comprehensive and science-based approach in crop management, lessening the environmental impact of the banana production,
To comply with the requirements of the market, and to the present and future international standards on Good Agricultural Practices,
To increase the average yield by 25% in five years,
To ensure the sustainability of the banana production in Belize.

1.2 Alternative Cropping System

1.2.1 Objective 1: To restore Soil Biological Activity and Fertility

Sub-Objective 1: To decrease soil compaction, and to plant banana in a clean soil, free of *Radopholus Similis*

Rationale

Soils are compacted. The only means to restore their macro-porosity is by lying fallow. Besides, all nematodes analysis performed by the BGA on roots show a high level of contamination by *R. Similis*. Farmers have planted vitro-plants in infested fields, canceling a unique agronomic advantage of vitro-plants.

Action 1: Lying fallow for at least twelve months

This is the necessary time in the West-Indies to reach zero nematode; some trials must be made in Belize to know if it is the right period here.

The first operation is to kill all banana plants of the plot, injecting *glyphosate* into each plant. This operation may have to be done twice (over a two to three weeks period). Not one single banana plant must remain.
Once the plants are dead, a heavy tool such as a Rom-Plow should be used to cut the stems into pieces. Then, there should be ripping, ploughing and leveling if necessary. The introduction of organic amendment is also possible if not recommended before ploughing.

Land development operations such as the making of drains should be carried out before the fallow really starts in order to keep the mulch at planting time: This mulch will prevent the growing of weeds during the first phase of planting.

A 4 feet ditch must separate the plot from any other plot having banana plants, in order to avoid the passage of nematodes.

Then, the fallow may be left as it is, allowing the natural weeds to grow, or planted with species that have proved their cleansing action vis-à-vis R. Similis: As for example Bracharia Decumbens or Perennial Soya, two species presently used in the West-Indies. Mucana is also cited as a possible fallow and cover crop (Annex 5). However, it must be said that the perennial soya has a very low germination rate in the West-Indies (10 to 15%).

In order to get rid of the nematodes, it is necessary to treat the weeds with a systemic herbicide (except if it is a legume that will be kept as cover crop) before they reach the ear emergence stage. Weeding allows the constitution of a mulch that prevents erosion and provides the soil with organic matter. A last weeding done just before planting will reduce the amount of chemical weeding to be done once the crop is installed (mulch effect followed by the shade effect of the plant).

Some trials may be done, such as a second tillage made after six months (during the fallow) in order to bury the weeds and build up more organic matter, or the incorporation of carbon (sawdust, composts: up to 80T/acre) before ploughing, more particularly when the last soil analysis performed on this soil has shown a low level of organic matter.

Pictures 52-53: Lying fallow and Trial on a cover crop (perennial soya) and on mulching crop (Bracharia)
**Indicator: The bio-test**

After twelve months, and in order to be sure that the soil is free of nematodes, a test may be done. The procedure of this test performed in Guadeloupe is as follows (CIRAD Protocole, J-M Risede):

Two months before planting time (on the 12th month here, to start), 24 soil samples (2 L each) are taken with a shovel from a depth of 0 to 20 cm, on three rows A B C (which means eight samples per row). The distance between each row and each sample on a row is equal to 30 feet.

Each sample is put into a plastic bag, closed, and numbered from A1 to A8, B1 to B8, C1 to C8.

Each sample is then put into a plastic pot in a clean area (preferably a green house) and a vitro-plant is planted into it (without its substratum or very little). The pots carry the same mark A1, A2, etc…to C8.

The vitro-plants are grown (without any fertilizer) for two months.

Then, the roots of the plants are taken away and divided into 8 samples: A1+B1+C1 is one sample, A2+B2+C2 is the second sample, etc….until A8+B8+C8

The nematodes of each of these eight samples are counted at the lab. The result must show zero *Radopholus Similis* (or very few) for the go-ahead for planting to be given. If *R. Similis* is seen, the fallow must continue accordingly (some trials are necessary to know how long in Belize).

![Biological test on nematodes after fallow (Carib Agro and CIRAD Guadeloupe)](Pictures 54-56)

**Remarks**

As we have seen, this protocol is very heavy and is adapted to a situation of rather small farming systems. This means that some trials will have to be done in Belize to know if the distance between soils samples could not be significantly widened.

It is also necessary to mark the exact location of the tested area with a GPS, and to note some historical facts such as the results of the last nematodes test done on the plot and the date and chemical used for the last treatment.
When the test has been successful and vitroplants have been planted, nematodes tests are still performed every six months, but no nematodes are normally found in the West-Indies for approximately two years.

A side advantage of fallowing: Laying green waste and increase SOM

We can add that the fallow system also allows to get rid of the green waste of the farm in a very useful way: For these farms where no compost would be made, it will be possible to spread rejected bananas and stalks on lands left in fallow: A good way to increase SOM, which does not require much labour.

Pictures 57-58: Leaving plots in fallow allows an easy spreading of green waste

**Action 2: Crop rotation**

The fallow can be replaced by a crop that is not host of *R. Similis*. Various crops may be used, even vegetables. But two crops would be particularly adapted to the soil and climate conditions of Belize:

Pine apple, very interesting for its cleansing capacity vis-à-vis *R. Similis*, and is also probably profitable. Fyffes, has expressed a strong interest in this crop during our mission.

Sugar cane, for its cleansing function, and also because its residues (when the cane is cut green) leave a very high quantity of organic matter in the soil, as shown below:

<table>
<thead>
<tr>
<th>Elements</th>
<th>Cane (107 T/ha)</th>
<th>Banana (2 years old)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Biomass (T/ha)</td>
<td>14 to 19 T</td>
<td>6 to 11 T</td>
</tr>
<tr>
<td>N (Kg/ha)</td>
<td>45 to 91</td>
<td>86 to 140</td>
</tr>
<tr>
<td>P₂O₅ (Kg/ha)</td>
<td>12 to 23</td>
<td>7 to 12</td>
</tr>
<tr>
<td>K₂O (Kg/ha)</td>
<td>92 to 251</td>
<td>323 to 523</td>
</tr>
<tr>
<td>CaO (Kg/ha)</td>
<td>32 to 58</td>
<td>82 to 133</td>
</tr>
<tr>
<td>MgO (Kg/ha)</td>
<td>18 to 35</td>
<td>20 to 32</td>
</tr>
</tbody>
</table>
Many people at different levels in Belize are very sceptical about the possibility of growing this crop in the district, either for the reason of distance to the factory, or because of the climatic conditions here (rains).

We can simply say that this system of rotation was introduced in Guadeloupe about ten years ago with the same scepticism and in comparable weather conditions. It has not always been easy for farmers to adapt to this new technique, and particularly as far as the organization of the work on the farm is concerned, since sugar cane employs less labour. Today, because of all the advantages that the system offers (increase of organic content of the soil, increase of yields, having one’s eggs in two different baskets, etc) no-one who has adopted this system wants to turn back the clock.

Secondary effects of crop rotations and fallows

Besides their cleansing effect, the fallow and crop rotations will improve soil fertility, by increasing the organic content and its diversity (organic matter rich in carbon from grass, organic matter of microbial origin, etc), and by increasing the porosity of biological origin. Crop rotation is also reducing the pressure of parasites on crops. They may also enrich the soil in nitrogen if legumes are used.

Accompanying Measures that should be set up in relation with Sub-Objective 1:

The first objective is fully in agreement with the rehabilitation projects that are being implemented by the SSD-PIU or are expected to take place from year 2009. These actions should include some moneys in order to compensate farmers for the cost of fallowing and planting. A rough estimate places these costs at approximately 1000 B$ per acre.
A certain number of trials should also be done for the setting up of a protocol for the bio-tests at the end of the fallow, which will require some moneys.

**Sub-Objective 2: To restore Soil Organic Matter (SOM) content**

**Rationale**

Soils analyses done in the banana belt area over the last ten years show a constant decrease in their organic content and their poor fertility. At the same time, soils are becoming more compact, increasing the risks of transfers of pesticide residue to river and coastal waters.

A significant change in soil organic matter appears necessary because of its influence on the chemical and biological soil properties. However, this increase cannot be done by the poor amount of biomass presently produced on the plots. We evaluated the amount of green waste coming out of the packing stations (rejected bananas and stalks) at 1 to 1.2 T/acre of fresh organic matter, which is not significant enough to increase the amount of organic matter in the soil. **We must therefore also find external sources of organic carbon** (see pictures below). Fertilizing practices, they rely on soil and leaf analysis done by two different laboratories, not in Belize, with nobody capable of interpreting them here and advise growers. In the end, low yields are obtained on all farms.

**Pictures 61-62: External raw material for compost : Saw dust (Belize) – Verde Compost Plant (Guadeloupe)**

**Action 1: Making of compost from various sources, internal and external to the farms**

We think that the initiative taken by M. Filiberto Castaneda, manager of farm 1, of composting rejected bananas and stalks should be strongly supported.

We recall here the technique presently used on this farm:

A swath, 1.2 m in height, is made as follows:
- First layer: Saw dust, 3 inches
- Second layer: bananas and poles, 40 inches
- Then, an efficient bacteria is spread to accelerate decomposition: Efficient Micro-organism 5
- Third layer: Saw dust, 3 inches
- Fourth layer: bananas and poles, 40 inches
- EM5
- Fifth layer: Saw dust, 3 inches
- Sixth layer: bananas and poles, 40 inches
- EM5

The process of decomposition and humification is intended to last no more than six weeks. The obtained compost will then be spread on the banana land.

However, this individual initiative might not be able to be reproduced on all farms since not everybody shows an interest in composting.

**We therefore propose the setting up of a Compost laboratory** that could make compost for the entire industry, with raw materials coming from the banana farms, but also from other sources. We use the term laboratory since it would be done on an experimental basis at the beginning. **This project should be seen as top priority.**

**Composting process Overview**

Inspired from Dwight Montero: “Waste management in the Citrus Industry, Belize 2008”.

- All waste bananas and stalks would be brought from farms to the Compost laboratory and laid out in straight lines,
- Chopping, shredding,
- Adding of sawdust (quantity and quality to be tested) and other available green waste (to be studied), making a straight line heap (swath) no more than 14 feet wide to enable compost turner to straddle the bed,
- Lime is also added (at 1%, to be studied) in order to provide suitable environment (pH) for the growth of microorganisms and an adequate decomposition process.
- Application of a bacteria if necessary (bacteria and rate to be studied),
- Turning of swaths to provide oxygen and discharge Carbon dioxide generated by the process,
- Combining rows (the decomposition is reducing bed size that must be combined in order to maintain temperature),
- Temperature testing: Must be between 110°F and 140 ° F
- Sampling of finished products (after 8 weeks or more)
- Expected result: 100 T of green matter gives 40 T of compost
- Loading
• Residue or liquid from the composting process is pumped into a cement structure from which the solids are reused into the composting process, the liquid is collected into a pond and experiments will have to be conducted to see if they could be used for plant nutrition.

Pictures 63-65 : Making of compost in Costa Rica (courtesy Elroy Foreman)

Pictures 66-71: Making of compost in Guadeloupe (Courtesy Verde Enterprise)

Who will run the Compost Laboratory? The Banana Growers Association or a private company may run such an industrial plant.

Indicators:
Indicators will be of various orders:
• They will concern the management of the project itself: Treated Quantities, Obtained performances in terms of composting (quantity, value of the compost), Number of farmers using the facility, economical results,
• And they will concern the results obtained at farm level (increase in the organic content of the soil, increase of yields).
**Action 2: To install analytical tools to monitor integrated fertilizing plans**

A comprehensive and science-based approach is imperatively needed in fertilizing. A specific programme related to this object is already forecasted by the PIU.

**Accompanying measures that should be set up in relation with Sub-Objective 2:**

Considering the crucial needs of increasing the organic contents of the soils on all farms, this project should be given top priority.

It will require the following equipments:
- The building of a shed, with a small office,
- Shredder: 15 000 B$
- Tractor, equipped to load plus swath turner: 60 000 B$
- Truck
- Fencing.

In order to restore the correct level of organic matters of the soils and “to mark” its structure it is necessary to use at least 10 to 12 tons of compost per acre (at the beginning). Farmers could therefore be supported for the first year on the basis of the price of the compost.

**Condition:** To make a soil analysis before. The amount of the grant will depend on its result: For a organic carbone below first quar tile of data, the compost would be subsidized at 50 to 60%. For a result between the norm (to be defined) and the first quartile: 25 to 30% subsidies.

**1.2.2 Objective 2:** To reinforce IPM, and to improve the management of chemicals residues from empty cans.

**Rationale**

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, **in combination with available pest control methods and biological approaches**, is used to manage pest damage by the most economical means, and with the least possible hazard to people and the environment. During our appraisal, we noticed that the BGA team in charge of the *Sigatoka* is adopting this approach, but that the use of chemicals was still very high.

By extension, this concept also refers to the control of weeds. However, we found that weeds are often seen as a real ‘plague’ and that herbicides treatment is sometimes systematic.
**Action 1: Trials on practices allowing a significant reduction in the use of chemical herbicides**

These trials will be carried out on the various techniques that exist to reduce the number of cycle of herbicides: The objective is to reduce erosion and to protect the quality of the river water by reducing the transfers of pesticide residues.

Spatial organization at planting: Using Wide rows (3m80) and narrow rows (1m60), allowing a density of 825 mats/acre to be reached, with many possibilities for a weeding control with no chemical: Lawnmower used on the wide rows while the old biomass is spread into the narrow rows, or biomass left on the wide row and grass left on the narrow and shady row.

The use of cover crops may be proposed too.

![Pictures 72-73: Zero weeding technique - Cover crop trial (T. Dambas-Guadeloupe)](image)

**Accompanying Measures:**

Financing of the trials: When cover crops are planted, costs could be calculated as follows, per acre: Labour to plant (3 hours), Maintaining and two cuts per year (5h). A slight decrease in yield should occur, however well compensated by the lack of herbicide expenses and the effects for the environment.

Overall, a budget of 120 B$ per acre could be allocated to the farmers willing to try out this practice.

**Indicators:**
Decrease in the use of chemical herbicides
Possible monitoring of the pesticide residues in the river.
**Action 2: Trials on Bio-beds**

**What is a bio-bed?**

Usually, farmers clean their knapsacks on the farm and empty the remaining solution in the field or on the side of a plot. This method is considered as an acceptable method all over the world, and is even advised by the technicians.

However, if the soil has its own purifying functions (degradation of the chemical molecules by various means), it is still an added chemical.

In order to avoid this useless surplus of chemicals in the soil, CIRAD has tested the Bio-bed. It is a simple system that consists in digging a concrete hole (of any size), fill it with a mixture made of 50% of bagasse (from sugar cane) and 50% of soil. A cover crop is planted. Then, the bed is covered in order to avoid rain and overflowing.

It has been shown that the substrate degrades chemicals such as Glyphosate or Mancozeb and other molecules used for weeding or pest and disease control. Tests on the innocuousness of the mix (soil + bagasse + residues) are been done.

This technique is not yet certified by GlobalGAP. However, it should be certified in 2009.
2 Recommendations: Environmental Monitoring Activities at BGA Level

2.1 General Objectives

To reinforce the technical capacities of the Banana Growers Association in order to improve its agro-environmental monitoring activities,

2.2 Actions

2.2.1 Action 1: To bring a regular scientific support to the team of the BGA in charge of the Sigatoka Control

In order to improve the monitoring of the Black Sigatoka, a scientific expert on the disease should go on a yearly three-week mission.

2.2.2 Action 2: To strengthen the Agronomic Department

- For the control of nematodes
- On fertilizing.

Actions are already being implemented or will soon be carried out in these areas with the support of the PIU: They consist in several expert missions.

Any delivery of input that would be provided by the project (PIU) should be submitted to a certain number of conditions, including analysis and environmental measures (such as lying fallow).

2.2.3 Action 3: To bring a support to the Environment Department

Needs have been identified for a better management of plastic waste at farm level. Quite often, it is burnt in an unsuitable way in the bush. Two proposals may be made on this matter:

➢ To provide three incinerators to the BGA, to be placed in the three planting areas,

➢ To open a new activity for the BGA that would be to regularly collect plastic waste (including all containers in which chemicals have been kept) on the farm and carry them to an appropriate place for their disposal.

2.2.4 Action 4: Testing of the “Biobed”

The test on the biobed could be carried out by the BGA.
3 Recommendations: Environmental Monitoring at National Level: Baha Laboratory

3.1 Rationale

Today, the BAHA lab is facing three main issues:

1. The needs for a rehabilitation or a complete re-building of the present facilities,
2. The commitment to the accreditation ISO 17025
3. The needs for a well trained and experienced staff

3.1.1 CIL building issue

The bad condition of the CIL building at Belize City must be pointed out. The ground floor has been damaged by flood water and water infiltrates ceilings and walls, which means the air is very often humid. It is unthinkable to install lab equipment in such conditions. Belize is prone to storms and hurricanes. Even if the ground floor is upgraded, it is likely that any future flooding would ruin any restoration efforts.

In our opinion, the project to build a new laboratory in Belmopan is the best one, but it is not expected to be achieved for 5 or 10 years if the government is the sole investor. During this period, a transitory solution exists: some rooms on the ground floor could be revamped and used for analytical tasks requiring robust and simple equipment that could be easily preserved in emergency: that includes reception, preparation, extraction, purification and filtration activities, for instance.

The first floor presents much better conditions for the most sensitive techniques, such as chromatography, spectrometry (ICP, AAS, colorimeter), elementary determination, immuno-chemistry, and some other devices like centrifuges and scales.

The surface area is too small, but according to Mr W. De Schield, one option would be to build a new storey on the flat roof that is part of the ground floor (budget : 70 000 B$).

A solution must be found as quickly as possible to get new premises with the required facilities in terms of power supply, an exhaust system, gas supplies, air conditioning, and laboratory furniture. If new equipment is ordered and delivered, the most sophisticated devices have to be installed, checked and validated by the engineer in charge of the installation.

3.1.2 Trained and experienced staff

At the moment, there is no perennial skill. The staff is limited. The procedures and internal protocols assuring the continuation and transmission of experimentation do not exist.

The present analytical chemist has hardly been near the chromatographic devices in the laboratory.

It is very difficult in Belize to recruit and keep good skilled technicians.
It is eventually planned to recruit a lab supervisor (Masters level), a senior lab technician, (Bachelor), a lab technician and an assistant lab technician for each lab unit (microbiology, chemistry, nutritional). A laboratory administrator would then oversee the whole laboratory and deal with administrative management matters.

Once the equipment is reinstalled in new upgraded rooms, considering the diversity and complexity of the analytical techniques, it is urgent to plan an intensive training program for the entire staff. **Funds will have to be granted for that training purpose.**

This training will have to be very practical and organized on site, on the very specific methods to be implemented by the chemists, using their own apparatus:

- One training course embracing extraction and cleaning and chromatographic techniques of measurements for all type of pesticides residues.
  
  I propose a 4-week course given by a foreign expert with experience in pesticide analysis and in particular with AGILANT technologies.

- A second training course dealing with soil and plant analysis including ICP spectrometry and advanced training on heavy metal residue.
  
  I propose a 4-week course taught by a foreign expert belonging to a European laboratory specialized in these fields.

  For each course, the expert would be granted one week’s preparation.
  
  Prior to this, BAHA will ensure the main devices are checked and validated, and all the intermediate materials are purchased.

  One month in advance, a check list will be sent by the expert to allow the laboratory to complete the basic equipment, if necessary. The lab staff will have to begin a primary apprenticeship on imitation and certified samples.

- Parallel training on ISO 17025 standards will have to set up the guidelines of a quality system scheme and phase in reflex behavior.
  
  One week’s training is needed.

### 3.1.3 Accreditation of the laboratory

Testing laboratories play an important role in the quality systems of the companies. The ISO 17025 is an internationally accepted quality standard. It can be used by laboratories to develop and establish a Quality System in the laboratory and for the assessment by their clients or by third parties. This standard is also being used as a criterion for laboratory accreditation.

The implementation of a quality insurance system in a lab is a very heavy task. It requires a lot of procedures and many obligations have to be respected. That is to say, it’s costly, time consuming, at the beginning when the system is set up, but also every year because the laboratory may have expenses in order to stay in conformity with accreditation requirements and must pay for regular evaluations by external inspectors. So, it is important to share out these costs among a large number of analyses.
The reliability of a specific analysis also depends on its frequency. It is much more interesting to carry on relevant monitoring procedures and give reliable results on a specific test when it is carried out regularly on numerous samples.

The skills of the operating technicians, just like the measurement devices, also have to be proved and regularly checked. The versatility of the staff must be ensured in case of absence or resignation.

**A laboratory with a small team cannot be certified for a large set of parameters.** At the beginning, it is wiser to aim at the certification for a small number of well-targeted tests which are strategic.

**If the CIL want to be certified ISO 17025, specific funds will have to be awarded for that purpose,** mainly for specific staff devoted to quality system implementation and enforcement plus training courses and supplemented minor equipment in order to conform to certain mandatory specifications.

The certification confers on the laboratory its credibility and strengthens its authority. It is all the more essential since BAHA is an official agricultural health authority. It is also a vital condition for sustainable activity after economic profitability.

This issue must be considered as a priority when the laboratory is fully operational.

It is essential to build up a sustainable laboratory.

A constant effort could lead to accreditation within three years, not before.

### 3.2 Soil and Plant Testing

**Analytical methods and Interpretation framework**

Various analytical methods exist for quantifying the nutrients that plants extract from a soil.

- Some laboratories use a unique ‘extractant’, which cannot be fully adapted to the whole set of nutrients. In this case, regular check-ups are required on a same parcel (at least once a year).

- Other laboratories use one ‘extractant’ for each family of nutrients: exchangeable cations, available phosphorus, micro-nutrients. In that case, the analysis is considered much more reliable and less analysis are therefore required (once every three to four years) to monitor the parcel, besides leaves analysis or other means such as a ‘fluorometer’ that can detect macro and micro-elements deficiencies.

Whatever method is used by the lab, the equipments proposed in the table will be suitable.

The interpretation of the lab results must be done by a competent agronomist who works permanently with the farmers and the laboratory. The agronomist will have to give the threshold values and the rules of interpretation, allowing the printing of an analytical report with an initial diagnosis. This can be a computerized function. This agronomist may be a sole agronomist attached to the lab (or a private agronomist), interpreting all soil and leaf analysis for all farmers and/or all crops (banana, sugar cane, etc), or it may be an agronomist belonging to a farmer organization (BGA, Sugar Cane Farmers Association, Citrus Farmers Association, etc).
Soil and plant testing cannot be processed without the close cooperation of an agronomist with expert knowledge of plant nutrition.

3.3 Economical approach and prospects

With the existing equipment, the CIL has the means to perform a wide range of analytical methods, either in microbiology or in chemistry. Unfortunately, because of water damage, the analytical chemistry has been suspended.

However, the number of analyses currently performed is limited (550 per year), preventing a reasonable acquirement and upgrading of practical competences.

A new service for soil and plant testing could bring new income and would enable the lab to employ one more technician fulltime. However, an appraisal of the number of analyses that each agricultural sector is ready to order is necessary to make a comprehensive economic study.

According to the practical productivity experienced by similar laboratories in Europe with very efficient equipment (such as in proposal 2), we can make these evaluations:

Presently, the average price farmers pay for soil or plant testing (done in Honduras, Costa Rica or the USA) is about 60 US$ per sample.

For the banana crop in Belize, approximately 300 soil samples and 400 leaf samples are collected every year. That represents a potential income of 42 000 US$ (84 000 BS$) per year for the laboratory. The yearly cost (all the charges included) could not exceed 40 000 BS$ for a chemical analyst.

Supposing the analytical methods are validated and ready to be processed routinely, supposing also the BGA sends soil samples in batches of 50, it would take 30 working days (6 weeks) for a well-trained technician to operate the whole set of analyses in an efficient manner.

If leaf samples are sent in the same way, the labor time would be 25 working days (5 weeks) for the same skilled technician.

This is an ideal schedule, but it may not appear very often. Based on our experience, it seems reasonable to value at 6 months the time required for the treatment of all the samples (300 soil + 400 leaf) for one technician. During the first year, it will take probably longer than that as the analytical protocols will have to be experienced, validated and rationalized and the general organization phased in.

Considering only direct proportional expenses, labor costs amounting to about 50%, the soil and plant testing activity could be easily profitable with a chemical analyst working for 6 months.

- **In term of Proportional costs**
  - Salary 6 months : 10 000 $US
  - Consumables : 10 000 $US
  - Total proportional costs : 20 000 $US

- **Gross margin : 20 000 $US**

But this does not take into account the indirect costs which can be very high depending on the organization and the financial structure of the lab, neither unforeseen expenses (repairs, illness, quality flaws ...), and any reserves for depreciation).

**With luck this** new agronomic testing service will attract some actors from other crop industries (citrus, sugar cane, pepper ...).

With citrus covering 45000 acres and sugar cane about the same, a good analytical prospective could be expected. According to Mr Stephen Williams, research & education director at the Citrus Grower Association, the potential could be as high as 600 soil and 1200 leaf test for the citrus industry alone. So, we estimate a reasonable forecast could be at least 2000 soil and plant tests in Belize.

As a matter of fact, the cost of fertilizers has skyrocketed over the last year. This irreversible trend will force farmers to fertilize their crops with the guidance of soil and plant analysis
The fertilizer suppliers and users also demand to know the content in nutrient elements and heavy metals in the products they sell or buy. Composting and recycling of all types of organic matter as well as fodders, require other types of analytical controls.

Therefore, it could be possible to hire two full-time technicians for soil and plant testing, assuring a constant service on duty throughout the year.

If the laboratory embarks on a soil and plant system, it must be aware of the need for a short delivery time.
Presently, the farmers demand to get their results within two weeks. This cannot be done without well-trained lab staff and versatile personnel.

With the first proposal for equipment configuration and high efficiency, we do not think that a soil and plant testing unit would be profitable with less than 1000 samples per year (taking no account of any reserves for depreciation).

### 3.3.1 Equipments to be Bought for Baha Laboratory

According to the priority of investment, the funding granted for the improvement of BAHA laboratory can be modulated in three different proposals. The proposals 1 and 3 make it possible to share the total investment between laboratory equipment and other types of equipment:

1) Improvement of the equipment for pesticide residue measurements.
   It has been already underlined that the existing equipment is well adapted to perform a wide range of tests on pesticides with very low detection limits. Nevertheless, some supplementary devices could be recommended to complement this spectrum and perfect some technical points (proposal 1).

2) Significant improvement of the equipment to enable the laboratory to carry on soil and plant testing with the best productivity and profitability. New efficient techniques are added and
implemented and the competences of the laboratory are enhanced. So, the new equipment strengthens the ability of the lab to cope with agronomical and environmental analysis (proposal 2)

3) Moderate improvement of the equipment. The present equipment is just completed in a minimalist way to enable the laboratory to perform soil and plant testing. The analytical methods that will be practiced are more manual and time-consuming and the productivity lower (proposal 3)

Proposals 1 and 3 may also be combined. Proposal 2 + one or two items of proposal 1 could be possible.

3.3.2 Proposals for BAHA Laboratory

Proposal 1

Detector NPD to be installed on the gas chromatography
Coupled with gas chromatography, allow detection of pesticide residues including nitrogen.

Shaker for separatory funnel
Needed to conduct proper liquid-liquid extractions in a repeatable way.

Rotary evaporator
A new model with regulated temperature and vacuum gives better organic residue extraction.

Scheduled budget: 15 000 €

Proposal 2

The tables below give the common parameters included in a routine soil or plant analysis, the general description of the methods and the main analytical equipments needed.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description of the method</th>
<th>Analytical technique needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 pH in water</td>
<td>Measurement of [H+] protons in a soil suspension in water</td>
<td>Balance, Stirrer, pH meter</td>
</tr>
<tr>
<td>2 pH in potassium chloride</td>
<td>Measurement of [H+] protons in a soil suspension in molar KCl solution</td>
<td>Balance, Stirrer, pH meter</td>
</tr>
<tr>
<td>3 Conductivity</td>
<td>Measurement of electrical conductivity on a filtered aqueous extract solution</td>
<td>Balance, Stirrer, Conductimeter</td>
</tr>
<tr>
<td>4 Total carbonate</td>
<td>Destruction of carbonates with Chlorhydric acid, volumetric measure of CO2</td>
<td>Balance, Specific glassware system</td>
</tr>
<tr>
<td>5 Total Carbon – Organic matter</td>
<td>Dry ashing with oxygen. Measure of CO2 by Infrared detector</td>
<td>Manual grinder, Balance, Elementary Determinator</td>
</tr>
</tbody>
</table>
6 Total Nitrogen
   Dry ashing with oxygen. Measure of N2 by Catharometric detector
   Manual grinder, Elementary Determinator

7 Nutrients : P K Ca Mg Na Fe Mn Cu Zn B Mo
   Extraction of nutrients by desorption or complexation with different aqueous chemical reagents, spectrometric measurements
   Balance, rotative stirrer, Inductive Coupled Plasma Spectrophotometer
   Colorimeter (for Phosphorus)

8 Cationic Exchange Capacity
   Successive extractions with concentrated cationic solutions
   Balance, rotative stirrer, Centrifuge, Colorimeter

9 Mineral Nitrogen: Nitrate and Ammonia
   Extraction with molar KCl
   Colorimetric measurement
   Balance, rotative stirrer, Colorimeter

Table 22: Proposal 2, parameters of a routine Soil Testing

<table>
<thead>
<tr>
<th>PLANT TESTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drying and grinding</td>
</tr>
<tr>
<td>1 Total Carbon</td>
</tr>
<tr>
<td>2 Total Nitrogen</td>
</tr>
<tr>
<td>3 Nutrients : P K Ca Mg Na Fe Mn Cu Zn B Mo</td>
</tr>
</tbody>
</table>

Table 23: Proposal 2, parameters of a routine Plant Testing

Regarding the equipment already owned by the CIL, the list of new equipments as follows would be ideally required:
The BGA agronomic department owns an oven and a grinder, so the BGA agronomic technicians in charge of collection of samples carry out drying and fine crushing of the leaf samples.

ICP (Inductively Coupled Plasma) spectrophotometer

Inductively coupled plasma atomic emission spectroscopy (ICP-AES), also referred to as Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), is an analytical technique used for the detection of trace metals. It is a type of emission typical spectrometry that uses the inductively coupled plasma to produce excited atoms and ions that emit electromagnetic radiation at wavelengths characteristic of a particular element. The intensity of this emission is indicative of the concentration of the element within the sample.
The technique allows a quick simultaneous measurement of several atomic elements such as macro or micro nutrients in liquid solution such as water or resulting from soil extract or acid attack of any solid matrices (food, plant, animal, sediment …). Also, many trace metals can be quantified with lower detection limits than flame atomic absorption.

Hydride generator

This device coupled with ICP allows a radical decrease of the detection limit on certain elements like mercury, arsenic and selenium.

**Elementary determinator CN**
This is the fastest and most accurate way to measure total carbon and nitrogen in solid samples whatever they may be. Furthermore, it is a very low time-consuming method because no pretreatment is needed except ensure the homogeneity of the sample.

**Ashing furnace**
It will be used for a prior dry ashing of tissue (leaves) before acid attack

**Centrifuge**
**pH meter**
**Conductivity meter**
**Bottle top dispenser of solution 50 & 100 ml (Optifix)**
Basic needs of any laboratory, requirement for soil testing

**Mortar + pestle + 2 mm sieve**
Requirement for the preparation of soil samples

Scheduled budget: 150,000 €

**Proposal 3**

Items 5, 6 and 7 differ from the previous soil testing table.

<table>
<thead>
<tr>
<th></th>
<th>Total Carbon – Organic matter</th>
<th>Chemical oxydation with potassium dichromate + sulfuric acid. Colorimetric measurement</th>
<th>Manual grinder, Balance, Mineralisation bench Colorimeter</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Total Nitrogen</td>
<td>Kjeldahl attack, Measure by distillation + titration or flow injection Colorimetry</td>
<td>Manual grinder, Flow injection Colorimeter</td>
</tr>
<tr>
<td>7</td>
<td>Nutrients : P K Ca Mg Na Fe Mn Cu Zn B Mo</td>
<td>Extraction of nutrients by desorption or complexation with different aqueous chemical reagents, spectrometric measurements</td>
<td>Balance, rotative stirrer, Flame Absorption Spectrophotometer Colorimeter (for Phosphorus)</td>
</tr>
</tbody>
</table>

**Table 24: Proposal 3, parameters for soil testing**

The items number 1, 2 and 3 change in the former plant testing table.

<table>
<thead>
<tr>
<th></th>
<th>Total Carbon – Organic matter</th>
<th>Dry ashing</th>
<th>Balance, furnace</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Total Nitrogen</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 25: Proposal 3, parameters for plant testing

In this case, the list is more oriented to manual methods.

**Continuous Flow Injection colorimeter**

One of the best ways to measure nitrate, ammonia or phosphorus by automated colorimetric chemistry plus many others compounds.

**Automatic Dilutor Dispenser**

For diluting the extracts before measurements by atomic absorption spectrometry.

**Kjeldahl digester**

The purpose of this device is to ease the classic Kjeldahl attack with sulfuric acid conducted for total nitrogen.

**Block Digester for carbon**

The chemical method for organic carbon is processed by a hot oxidation with potassium dichromate and sulfuric acid. This attack is run in glass tube warmed with a block digester.

**centrifuge**

**pH meter**

**Conductivity meter**

**Bottle top dispenser of solution 50 & 100 ml (Optifix)**

Classic needs of any laboratory, requirement for soil testing

**Ashing furnace**

It will be used for a prior dry ashing of tissue (leaves) before acid attack (dry ashing is more convenient and less acid consuming than wet attack)

Scheduled budget : 75 000 €

**Equipment eventually chosen**
Following a very short deadline to deliver the specifications for the tenders, we had to decide quickly which equipment would be the most strategic to perform soil and plant testing and enlarge the capability of the laboratory for others types of analysis as well. This list includes the most crucial devices:

**ICP (Inductively Coupled Plasma) spectrophotometer**
**Hydride generator**
**Elementary determinator CN**
**Ashing furnace**
**pH meter**
**Conductivity meter**
**Centrifuge**
**Rotary evaporator**

Unfortunately, additional items will have to be purchased:

**Bottle top dispenser of solution 50 & 100 ml (Optifix)**
**Mortar + pestle + 2 mm sieve**
**Rotary shaker (40r/mn) able to contain one hundred 200 ml bottles at least. It may have to be home made.**
**Rotary shaker for decanter funnels (11)**

Budget: 5000 euros

**Grinder for leaf samples** (BGA grind their leaf samples, required if extension of the demand to other crops.)

The BAHA must commit to achieving in the very short term the pre-installation requirements needed by the ICP spectrophotometer equipment (gas supply, power supply, exhaust system).

### 3.4 Sustainable Commercial Agreement between the Banana Industry and the Baha Laboratory

As already said, the BAHA laboratory will have to work closely with the various agricultural sectors of Belize: Banana, Sugar Cane, Citrus, and Vegetable for the most important ones. Whatever types of analysis the lab will make, one or several agronomists will have to read the results of these analysis and interpret them in a proper way in order to give the right advice to the farmers. The agronomist is therefore placed at the interface Lab-Farmers, to which we could even add Research since research activities may be carried out on various plant nutrition subjects. The agronomist must therefore have a good background in soil sciences, a fair knowledge of the analysis performed by the lab (the extraction methods used, their meanings, etc) and the experience of the terrain in order to give appropriate advice.
Two solutions exist at this level of interpretation, which will lead to specific working relationships:

- **Solution 1:** The laboratory integrates a ‘Department of Agronomy’, composed of at least one agronomist. A technician could second the agronomist, for the samplings, but considering the size of the country and the long distances to cover, it might be easier for the lab to simply collect or receive the samples that would have been taken by regional or crop officers.
  However, when soil (or leaf or water) samples are made, the same protocol must be followed for each sample and a same set of information must be registered (to be followed by the scheduled nutritionist missions).

  We consider that this system is the best because the agronomist will rapidly gain a fair experience in the job and he or she will be able to set up interpretation norms by analyzing all the data from the lab. This is all the more true in a country where agronomists are not numerous.

  If this solution is chosen, the price at which the analysis will be proposed must therefore include the costs of this service.

- **Solution 2:** Each agricultural sector (or each main farmer organizations) has an agronomist who is capable to interpret the lab results and give the advice to the farmers. It may be a short term solution for the banana industry.

Whatever solution is chosen (which might even be a third one where the agronomist would work on a private basis), we do not see any reason to propose a specific agreement between the BAHA and the BGA: These sorts of relationships are common commercial relationships as in any other industry.

It is far more important that each banana farmer adopts the system that will be chosen by the BGA, instead of continuing the present situation where some growers deal with the BGA to have their soil and leaf analyses done, while others are doing them on their own. This is actually the worse solution.

### 3.5 Outline of a Possible Study on Pesticides Contamination

We present here the outline of a proposal for a study to estimate pesticide contamination levels in the banana area:
1) Gathering for each river and farm area, the amounts of active ingredients spread every year and dates of application (since 2000) (data from sigatoka unit control and farms),

2) According to the chemical features of each active ingredients (solubility, soil absorption coefficient, rate of degradation), estimation of the half life of each molecule and calculation of its propensity to move out of the soil or to bio-accumulate,

3) Estimation of the different flows out of the cultivated area (underground flow, surface run off flow for water and suspended particles, volatilization flow) related to climatic events, soil features, and cropping system (excess water generated by rainfall or irrigation, drainage conditions, cover crop, organic matter …

4) Building up of a model that can be run at the scale of different watersheds (plot, group of farms, river),

5) Calculation with real data of the amount of bio-accumulation and lixiviation for each molecule,

6) Regular residue analysis in some specific spots of soils (different depth), underground water, water and suspended particles in the drains… This would make it possible to check the model and the rate of pesticide,

7) Pesticides also have to be analyzed in well-targeted coastal marine organisms prone to bio-accumulate residues (fish, coral…) and marine sediments in the main stable settle down areas.

The evaluation of the various contamination risks require monitoring and surveillance programmes that have to be implemented by a multidisciplinary team (including hydrologists, geologists, agronomists, analysts, nurses and doctors, etc).

This is transversal work which involves the Ministry of the Environment, the Pesticide Control Board, the Ministry of Health, the Belize Agricultural Health Authority, the Public Health Bureau and the Pan American Health Organization.