BRDP Call for Proposal No. 7

AGRICULTURE ENTERPRISE DEVELOPMENT
FOR RURAL BELIZE (AED)

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Contract No. 002/09

A Manual on Integrated Farming Systems (IFS)

Prepared by

Caribbean Agricultural Research and Development Institute (CARDI)

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This Integrated Farming Systems (IFS) training manual is one output of the Agriculture Enterprise Development for Rural Belize (AED) project Agreement between the United Nations Development Programme (UNDP) and the Caribbean Agricultural Research and Development Institute (CARDI) entered into on March 2009. The major objectives of this Agreement were:

1. To establish an integrated farming system in southern Belize for two groups
2. To develop five demonstration sites in Belize
3. To conduct capacity building with farmers’ groups on and off farm
4. To design and construct post harvest models
5. To enhance capacity of farmers in appropriate produce-specific post harvest practices

The other outputs of this Agreement were (a) Integrated community farms, (b) Sustainable farming manuals, (c) 20 Training workshops, (d) Demonstration sites, (e) Localized information materials.

The Goals of this Integrated Farming Systems Manual (IFS) are to:

- provide a steady and stable income rejuvenation/amelioration of the system’s productivity; and
- achieve agro-ecological equilibrium through the reduction in the build-up of pests and diseases, through natural cropping system management and the reduction in the use of chemicals (in-organic fertilizers and pesticides).

The Manual also covers six (6) modules giving detailed explanations on:

1. Integrated Farming Systems (IFS) concepts and components
2. Sources for animal feeds
3. Methods for silage/ensilage
4. Biodigester advantages and installations
5. Composting processes
6. Vermiculture & vermicomposting

The IFS Manual would provide a significant tool for use by farmers, farming groups/communities, development agencies and governments. It would thus be a critical element in the Government of Belize’s efforts to reposition the agriculture sector, introducing the concept of agriculture as a business which can increase the income of its actors, particularly the farmer, within the agricultural community. This would enhance the quality of life and the rural environment and consequently, contribute to Belize’s achievement of the Millennium Development Goals with respect to the reduction of hunger and poverty by 50% by 2015. It will also contribute to the Food and Agriculture Organization of the United Nations’ (FAO) drive to reduce hunger.

The IFS Manual is designed for the farming and rural communities in Belize. However, we believe that it could be useful to continental countries in CARICOM and Central America.

We thank the United Nations Development Programme (UNDP) and the Government of Belize for giving CARDI the opportunity to participate in this Project.
INTRODUCTION

All over the world, farmers work hard but do not make money, especially small farmers because there is very little left after they pay for all inputs (seeds, livestock breeds, fertilizers, pesticides, energy, feed, labour, etc.). The emergence of Integrated Farming Systems (IFS) has enabled us to develop a framework for an alternative development model to improve the feasibility of small sized farming operations in relation to larger ones. Integrated farming system (or integrated agriculture) is a commonly and broadly used word to explain a more integrated approach to farming as compared to monoculture approaches. It refers to agricultural systems that integrate livestock and crop production or integrate fish and livestock and may sometimes be known as Integrated Biosystems. In this system an inter-related set of enterprises used so that the “waste” from one component becomes an input for another part of the system, which reduces cost and improves production and/or income (Paper on Integrated Biosystems by Paul Harris Quoted in a Paper entitled “A Primer on Integrated Farming Systems – One Village Foundation, USA, www.onevillagefoundation.org). IFS works as a system of systems. IFS ensure that wastes from one form of agriculture become a resource for another form. Since it utilizes wastes as resources, we not only eliminate wastes but we also ensure overall increase in productivity for the whole agricultural systems. We avoid the environmental impacts caused by wastes from intensive activities such as pig farming.

The Manual has been divided into six modules:

Module 1 - Integrated Farming Systems – Concept and Components
- What is IFS?
- Goals and Advantages
- Components in IFS
- Models

Module 2 - Animal Feed Sources
- Major energy sources
- Major protein sources

Module 3 - Silage/Ensilage
- What is silage?
- Silage production process
- Principles for good silage
- Advantages of silage
- What can be used for silage?

Module 4 - Biodigester
- What is biodigester
- Advantages of using a biodigester
- Installation of Polyethylene biodigester
Module 5 - **Composting**
- What is compost?
- Why compost?
- How composting works
- Composting process

Module 6 - **Vermiculture and Vermicomposting**
- What is humus?
- Advantages of vermiculture
- Vermi-compost worms
- Process of vermicomposting
- Method of collecting humus
MODULE 1

INTEGRATED FARMING SYSTEMS - CONCEPT AND COMPONENTS

Prof. George Chan working with a network of poly-culture farming pioneers began refining Integrated Farming practices that had already been developed in south-east Asia in the 1960 through the 1980s, building on traditional night soil farming practice (“A Primer on Integrated Farming Systems – One Village Foundation, USA, www.onevillagefoundation.org”). In China, programs embracing this form of integrated farming have been successful in demonstrating how intensive growing systems can use organic and sustainable farming practices, while providing high agriculture yields.

“Integrated Food and Waste Management Systems” (IF&WMS) which was developed by Prof. Chan and is one version of an IFS. He introduced this concept at the Montfort Boy Farm in Fiji, a vocational school that now serves as a model for the students to replicate in their villages (A Primer on Integrated Farming Systems). Today there are numerous IF&WMS or IFS models. These systems combine livestock, aquaculture, agriculture and agro-industry in an expanded symbiotic or synergistic system, so that the wastes of one process become the input for other processes, with or without treatment to provide the means of production, such as energy, fertilizer, and feed for optimum productivity at minimum costs. The concepts associated with IFS are practiced by numerous farmers throughout the globe. A common characteristic of these systems is that they have a combination of crop and livestock enterprises and in some cases may include combinations of aquaculture and trees. It is a component of farming systems which takes into account the concepts of minimizing risk, increasing total production and profits by lowering external inputs through recycling and improving the utilization of organic wastes and crop residues. In this respect integration usually occurs when outputs (usually by-products) of one enterprise are used as inputs by another within the context of the farming systems. The difference between mixed farming and integrated farming is that enterprises in the integrated farming systems interact eco-biologically, in space and time, are mutually supportive and depend on each other.

Examples include:

- "pig tractor" systems where the animals are confined in crop fields well prior to planting and "plow" the field by digging for roots
- "chicken tractor"
- poultry used in orchards or vineyards after harvest to clear rotten fruit and weeds while fertilizing the soil
- cattle or other livestock allowed to graze cover crop between crops on farms that contain both cropland and pasture
- Water-based agricultural systems that provide way for effective and efficient recycling of farm nutrients producing fuel, fertilizer and a compost tea/mineralized irrigation water in the process
• Construction of animal houses over a pond so that animal waste fell directly into water fueling pond where the fish feed on

The advantages of IFS include pooling and sharing of resources/inputs, efficient use of family labor, conservation, preservation and utilization of farm biomass including non-conventional feed and fodder resources, effective use manure/animal waste, regulation of soil fertility and health, income and employment generation for many people and increase economic resources. The IFS is part of the strategy to ensure sustainable use of the natural resources for the benefit of present and future generations (Preston 1995).

Goals of IFS

The Goals of this Integrated Farming Systems Manual (IFS) are to:

• provide a steady and stable income rejuvenation/amelioration of the system’s productivity and
• achieve agro-ecological equilibrium through the reduction in the build-up of pests and diseases, through natural cropping system management and the reduction in the use of chemicals (in-organic fertilizers and pesticides).

Advantages of IFS

• It improves space utilization and increase productivity per unit area
• It provides diversified products
• Improves soil fertility and soil physical structure from appropriate crop rotation and using cover crop and organic compost
• Reduce weeds, insect pests and diseases from appropriate crop rotation
• Utilization of crop residues and livestock wastes
• Less reliance to outside inputs – fertilizers, agrochemicals, feeds, energy, etc
• Higher net returns to land and labour resources of the farming family

Scope of farming system

Farming enterprises include crop, livestock, poultry, fish, tree crops, plantation crops, etc. A combination of one or more enterprises with cropping, when carefully chosen, planned and executed, gives greater dividends than a single enterprise, especially for small and marginal farmers. Farm as a unit is to be considered and planned for effective integration of the enterprises to be combined with crop production activity. Integration of farm enterprises to be combined on many factors such as:

1. Soil and climatic features of the selected area.
2. Availability of resources, land, labour and capital.
3. Present level of utilization of resources.
4. Economics of proposed integrated farming system.
5. Managerial skill of the farmer

In the context of Belize there are a number of situations and conditions that can be alleviated by an Integrated Farming System. The following situations are ideal for the introduction of IFS:

- The farmer wishes to improve the soil quality
- The farm household is struggling to buy food or below the poverty line
- Water is stored on-farm in ponds or river-charged overflow areas
- Fertilizers are expensive or the recommended blend is unavailable
- Soil salinity has increased as a result of inorganic fertilizer use
- The farmer is seeking to maximize profits on existing holding
- The farm is being eroded by wind or water
- The farmer is looking to reduce chemical control methods
- The farmer wants to reduce pollution or waste disposal costs

The practitioner can use IFS to

- Improve productivity
- Regulate nutrient and material flows
- Increase on-farm biodiversity
- Limit disease
- Reduce the smell of some livestock operations

Integration of Enterprises

In agriculture, crop production is the main activity. The income obtained from crops may hardly be sufficient to sustain the farm family throughout the year. Assured regular cash flow is possible when the crop is combined with other enterprises. Judicious combination of enterprises, keeping in view of the environmental conditions of a locality will pay greater dividends. At the same time, it will also promote effective recycling of residues/wastes.

Choice of Enterprise

Livestock is the best complimentary enterprise with cropping. Installation of biodigester in crop-livestock system will make use of the wastes, at the same time provides valuable gas for cooking and lighting.

Components in IFS

The components of IFS include crops, fish farming, poultry, pigs, cattle, sheep and goat, fodder production, kitchen gardening.
The feeds derived from “alternative” crops (sugarcane, roots and leaves of cassava, leaves of nacedero, mulberry, chaya, grasses) require “alternative” farming systems. These are on small-scale and are highly productive. These are diversified and integrated and the role of animals in these systems is synergistic rather than as primary producers. Emphasis is on “small” livestock. External inputs can be minimized through waste recycling, and growing of nitrogen-fixing and pest-resistant plants in the farming system.

The model provided in Figures 1 and 2 are integrated farming system that combines cash crop/tree crop/livestock mix which is functionally sustainable and profitable. Many of its components e.g., corn/Mucuna, Pigs on cassava, Rhode Island Red chicken on coconut/corn/crop leaves, sheep on pasture, were individually tried and proven in various projects in Belize. Figures 1 and 2 shows the basic components and interaction used in actual integrated farming systems. IFS models could be developed based on existing production system using concepts and components. The farm has subsystems:

1. Crop production including vegetables
2. Fodder production
3. Pig production
4. Poultry Production (Dual purpose)
5. Cattle production (Dairy/Beef)
6. Biogas production
7. Compost/Humus production

Each can stand-alone system but with the addition of biodigester unit and introduction of earthworms as a means of producing organic fertilizer the farm becomes one large efficient unit.

**Crops**

The crop activities in the IFS consist of grain crops (corn, sorghum, rice, beans and soybeans), vegetable crops, plantation crops (coconut, banana, and plantain), root crops (cassava, cocoyam, and sweet potato), sugarcane, tree crops (moringa, mulberry, nacedero, leucaena) and fodder crops. The selection of crops is dependent on preferences based on family consumption, market, soil type, rainfall and type(s) animals raised.

**Livestock**

The livestock activities in IFS consist of poultry, pigs, cattle and small ruminants. The selection of livestock is also dependent on preference based on family consumption, potential market, and availability of resources.
Integrated Small Farm Model using 10 acre (4.0 ha) land

Following is a model (Figure 1) which could be used in Belize. This model comprises seven subsystems:

1. Crops production (grains, root crops, coconut, fruit trees, vegetables)
2. Fodder crops and trees production
3. Livestock – Pigs, cattle, poultry, small ruminant
4. Biodigester
5. Compost/vermiculture
6. Aquaculture
7. Organic fertilizer production

Each subsystem could stand alone but it has to be supported by any livestock component with biodigester for the use of manure as fertilizers.

1. Corn/Beans/Cash crops: Two acres (0.8 ha) twice per year would be required to produce adequate corn and beans (Red Kidney Beans, Black beans) for farm use as well as for sale. The corn will feed the family, the chicken, and along with residues from the root crops and fodder tree leaves can fatten the pigs
2. Plantain and Root crops: One acre (0.4 ha) would be planted to a mixture of plantain, cocoyam, cassava for sale and use in the home and rejects could be fed to fattening pigs.
3. Coconut: One acre would be planted to improved grass and coconut. A plant density of 60 hybrid coconut plants per acre and 100 nuts per year will give 6000 nuts. Some nuts would be used by the chicken and rest would be available for sale, to use as additional feed or to use in the production of coconut oil. The latter would produce oil for sale and retain the residues for feed to poultry, pigs or cattle
4. Permanent/Semi-permanent crop: One acre would be planted with a mixture of fruit trees – West Indian Cherry, Mango, Carambola, Sour soup, Lime, Guava, Breadfruit, Local papaya, and others for use in the home and for sale as fresh fruit/processed
5. Fodder crops: All areas planted to permanent crops would be separated by fodder trees like Leucaena, Moringa, Mulberry, and Naceder and hedges. These would be sources of feed for livestock. Neem trees would also be inter-planted in the hedges to supply leaves for extraction of natural insecticide
SOLAR ENERGY

RAIN
+/- Alternative water source

SOIL
Mapped for proper land use

CROPS
Corn/Beans
Root crops
Coconut
Fruit trees
Vegetables

BEE
Hives

AGROFORESTRY
AS FENCE & ON CONTOUR

FODDER TREES
Mulberry
Nacedero
Chaya

OTHER CROPS
FODDER

COMPOST
VERMICUL TURE

LIVESTOCK
Pigs
Cattle

FERTLIZERS

AQUACULTURE
Tilapia

BIODIGESTER
Cooking gas

ANNUAL INCOME/FOOD FROM: Pigs, Poultry, Cattle, Corn/Beans, Fruits,
Coconut, Plantain, Root crops, Vegetables, Coconut oil, Honey, etc.

Figure 1: Integrated farming systems model
6. Poultry: The family would maintain a dual purpose flock (Rhode Island Red – RIR) of 12 adult layers, 2 adult roosters, 12 young pullets and a young rooster and 20 chicks and 2 hens – A total of 49 birds. Feed consumption each day would be 4.5 lbs. of corn, 4 coconut and supplementary Moringa and other leguminous leaves. The two local hens would be used mainly as brood to set the eggs. Twenty-four eggs would be set every 3 months. This would allow farm family to produce an average of 17 eggs per day and at least 4 lb. bird per week while maintaining the flock at no cost. This would also allow at least one dozen eggs per day to sell.

7. Pigs: The farm family would fatten 8 pigs per year. If reared on a commercial basis these would consume approximately 650 lbs of feed per pig – amounting to 5,200 lbs of feed for 8 pigs. The farmer can replace commercial feed with various crops grown on the farm. From weaning to market weight a pig can be fattened on 10 Leucaena trees, 30 Moringa trees, 0.2 acres of cassava and 1 lbs of soybean protein. These could also be fed on well balanced silage.

8. Tilapia: If the subsoil permits a pond could be dug to serve as a water catchment area. This could supply irrigation water in the dry season. Fish culture at the start of the wet season with harvesting at the end of the dry season when the water reserve would be reduced. Commercial Tilapia production would be based on commercially prepared feed used to fatten 4,000 to 6,000 fishes in acre pond over 5 to 6 month period.

9. Biodigester: Biodigester will be very important input where animal wastes would be converted into organic fertilizer for crops and cooking gas would be used home use and other farm activities.

10. Compost/Vermicompost: These will provide organic fertilizer by utilizing farm wastes.

In this plan a minimum of 8-9 acres would be under constant cultivation by fifth year which would comprise:

- 1 acre in coconut and pasture
- 2 acres in plantain and root crops
- 1 acre in fruit trees intercropped with fodder trees (apiary could also be used between trees)
- 1 acre cash crop (vegetables)
- 2 acres in corn/beans
- 2 acres in fallow with Mucuna/Canavalia
- 1 acre with pond

**Integrated Farming System Model: Finca La Esperanza, Costa Rica**

In early 2009 a team comprised of technical personnel from IICA and a few farmers made a visit to Finca La Esperanza, Costa Rica to learn about Integrated Farming System Model used at this farm. Mr. Maximiliano Ortega (IICA, Belize) presented a report on the visit at a workshop on Integrated Farming Systems held at Central Farm, Cayo District, Belize on 27 February 2009 (Ortega, 2009a). The farm has about 15 acres of land and began to develop as IFS in 1985. After 25 years of establishment and constant innovations on adoption of various components of IFS,
the farm has reached as a successful IFS model in Costa Rica. There are following six subsystems:

1. Dairy production
2. Pig production
3. Organic vegetable production
4. Forage production
5. Humus (Vermiculture)
6. Biogas production

Each subsystem could stand alone but with the addition of a biodigester unit and introduction of earthworms as a means of producing organic fertilizer the farm became one large efficient unit. The livestock unit comprised of 60 pigs, 30 dairy cows and 6 million earthworms all working in synergy to make farm as efficient and effective as possible. Each morning the milking process starts around 3 AM and yields about 118 gallons of milk and about 440 lbs of manure. The milk is processed into cheese, butter and some sold as milk. Whey is also produced which is fed to the pigs. The Jersey cows eat an average of 35 kg of forage per day and are fed a mixture of crops such as mulberry, corn, sugarcane, elephant grass and silage. Every so often a mixture of medicinal plants is also included into the diet to keep the animals healthy.
The manure collected during the milking and feeding process in the unit is collected in tanks and put to drain out using metal mesh. Water is added to the manure and stirred to properly rinse it out the fecal matter from the fibers. The slurry is let into the biodigester for conversion to methane and fibers left behind are kept for an additional time to drain out, collected and put in the earthworm room for conversion into humus. These are placed in shelves for easy access and manipulation. Humus is normally ready after 45 days. Humus is used on the farm and also packaged, labeled and sold as organic fertilizer.

There are approximately 60 pigs in the piggery unit, and are fed a total of 10 kg mulberry, 2.5 kg of sugarcane, 80 kg of whey and 64.8 kg of concentrate per day. The meat produced is lower in fat content and has wide acceptance in the market as a healthier meat.

The pigs produce about 440 lbs of manure which also goes to the biodigester, but due to the lower quality of the manure it is double strained to reduce the amount of solids going into the biodigester unit. With an approximate total of 800 lbs of manure produced by both, dairy animals and pigs, the biogas unit has a potential of producing 9 m$^3$ of methane per day. This is equivalent to having 7 burners working 8 hours a day.

The production of organic vegetables is an enterprise done both under the cover structure to protect from pests and diseases and in the open air. If there is a need to control pests then it is done using plant products such as garlic, hot pepper, neem and other medicinal plants. Honey or molasses is also sprayed to give some level of control. Weed control is kept to a minimum and in most cases is left with plants and just “mowed”. Fertilization is done thru drip irrigation. Liquid fertilizer is obtained from the biogas plants and compost is used from the earthworm shed.

About 5 acres is dedicated to the production of forage to feed the dairy cattle, pigs and other animals on the farm. The forage bank produces the following: elephant grass, corn, mulberry, sugarcane, Bohemeria nivea, wild peanut, Thitoina sp. and other plants used for medicinal purposes. These are usually chopped and mixed in certain proportions depending on the animals to be fed. The animals are fed either chopped forage material or silage material.

In about 25 years of development the farm became a model using various components. The farm is being used by students as a training station on IFS. Tourists are visiting the farm as Agro-tourism. Now the farm is almost self-contained. Belize could benefit from this experience by adopting all components and/or adopt single component and grow as get more experience. This will also need to have constant innovations based on local and individual production and marketing systems.
Module 2

Animal Feed Sources

As living standards rise, so does consumption of livestock products. But the feeding systems to produce these products, especially in the industrial countries, use the same feed sources as are eaten by humans, namely cereal grains and soybean meal. It is estimated that almost 50% of the world grain supply is consumed by livestock. It has been argued that if the entire world’s grain production was reserved for human consumption then there would be enough to feed the 10 billion inhabitants.

It is important that the alternatives feed resources can be grown on the farm as this will: (i) directly benefit the poorer farmers, who do not have cash resources to purchase supplements from outside the farm; and (ii) be an active response to the need to localize the farming system as a defense against the decreasing availability and increasing prices of petroleum-based fuels which will drive up the costs of transport.

**Alternatives sources of energy in animal feed:** The examples of alternative energy-rich crops are sugarcane, cassava, coconut.

**Alternative sources of protein in animal feed:** Leaves of many trees and shrubs

**Major energy sources**

**Corn (Zea mays):** Corn grain is probably the most extensively used energy source. It is very palatable and has a high energy value.

**Bananas and Plantains (Musa spp.):** Although bananas and plantains are mainly used as human food, a considerable amount of rejects fruit could be fed to livestock, particularly to pigs. The vegetative part of the plant, the pseudo-stem and leaves, contain more than 60% of the dry matter of the whole plant and could be used as meals for pigs in concentrate ration. Ripe bananas are very palatable to the pigs, and studies have shown that the growing pigs will consume up to 16 lbs per day.
Pumpkin and melons: Pumpkins and melons grow well in Belize and often fed to pigs on small-scale systems. The nutritive value is low and they contain virtually no protein, but they can provide some energy and succulence.

Cassava (*Manihot esculenta*): The role of cassava in integrated farming systems is very important. It is an important crop in the small farm. Cassava roots contain on average 2.0% crude protein whereas cassava leaves can have protein contents between 20 to 26%. Also, when compared with some grains, the nutritional value of cassava leaves in terms of protein content and digestible energy content are higher, thus making it a very attractive option for animal feeding. It can provide all the protein and fiber in a cattle fattening diet based on ad labium molasses-urea. It is readily available product at the time of harvesting of roots. However, in the rainy season, it is difficult to sun-dry and extending the drying period diminishes the nutritional quality of the product. Ensiling is an attractive alternative way to conserve the product.
Cassava has one important characteristic, namely that it can be managed to maximize production of carbohydrate (in the form of the roots), or protein, by harvesting the leaves. For root production the growth cycle is from 6 to 12 months at the end of which the entire plant is harvested. When maximum protein production is the aim, the foliage is harvested at 2 to 3 month intervals by cutting the stems at 20” to 28” above the ground thereby encouraging the plant to re-grow. In this case the roots act as a nutrient reserve to facilitate the re-growth of the aerial part. This process can continue for 2 to 3 years if the nutrients exported in the leaves are supplemented with fertilizer (organic/inorganic). Dual-purpose production systems are also possible whereby one or two harvests of the leaves are taken before the plant is allowed to continue the normal development of the roots. Cassava can produce very high yields, especially of protein (up to 3,563 lbs/acre/year), which makes it an ideal element for taking advantage of recycled livestock wastes.

**Table 1: Chemical composition of the dry and ensiled cassava leaves**

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<tr>
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<th>Ensiled</th>
<th>Sun-dried</th>
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<tr>
<td>% of dry matter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Protein</td>
<td>27.6</td>
<td>26.0</td>
</tr>
<tr>
<td>- Fibre</td>
<td>17.1</td>
<td>16.1</td>
</tr>
<tr>
<td>- Ether extract</td>
<td>13.9</td>
<td>9.9</td>
</tr>
<tr>
<td>- Ash</td>
<td>10.3</td>
<td>10.9</td>
</tr>
<tr>
<td>Mg/kg dry matter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- HCN</td>
<td>147</td>
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This high yield potential is complemented by the high nutritive value of the leaves for cattle, sheep and goats and pigs. The presence of cyanogenic glucosides (HCN) does not appear to be a problem in ruminants and can be neutralized by ensiling or drying which converts the toxic cyanide into non-toxic cyanides the leaves before feeding to pigs (Table 1). Cassava leaves have anthelmic properties in goats and cattle and gives further advantages on this crop as a component of integrated farming systems.

**Sweet potato (Ipomoea batatas):** Sweet potatoes are often grown on small farms. In the fresh state, the tubers contain approximately 32% dry matter and are best used as a feed for pigs. When dried and ground, the meal is similar in energy content to corn but very low in protein.

**Cocoyam (Xanthosoma sagittifloium):** Leaves of cocoyam is highly palatable to pigs.

**Sugarcane (Saccharum officinarum):** There is a long practice in the feeding of sugarcane to all classes of livestock, especially for cattle during the dry season when availability of conventional forage resources is scarce. Nevertheless, the techniques used have been mostly rudimentary and there has been little appreciation of the critical role of supplements as a means of improving the efficiency of utilization of the sugarcane plant as animal feed. The dry matter content of mature sugarcane averages 30 percent which exceeds that of most other forage grasses (the average for
Elephant and King grasses is closer to 17 percent). Thus harvest, transport and processing costs per unit dry matter are less for sugarcane than for most other forages.

The growth characteristics of sugarcane are such as to make it unnecessary to ensile this crop, since its nutritive value is highest in the dry season when other forages are in scarce supply, and it can be left in the field as a standing crop until required. A possible advantage from ensiling appeared to be indicated by the finding that young actively growing cane was inferior in feed value to mature cane, apparently because of the higher sugar content of the latter. It was argued that if sugarcane was to be used as the basis of a year-round confinement feeding system, then there could be advantages in certain climatic situations of ensiling cane in the dry season, when its nutritive value was high, and feeding the ensiled material in the wet season when the standing cane was of low nutritive value.

Plate 3: Sugarcane plant

Citrus pulp: This is available as an energy source in citrus-producing areas. It has around 47% of the feeding value of corn when used at low levels in the diet. It is not recommended more than 10% of the ration.

Major Protein Sources

Soybean (Glycine max): Soybean meal is one of the most widely used protein sources for poultry and pigs. It possesses the highest biological value of the vegetable protein. Anti-nutritional factors in the raw soybean are destroyed by the heat of the oil extraction process. Similarly raw soybean can be dry-roasted to destroy anti-nutritional factor and can be fed to poultry and pigs as full-fat soybean in ration (Tables 2 and 3).
Table 2: Composition of broiler ration using full-fat roasted soybean

<table>
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<th>Ingredients</th>
<th>Starter ration (kg)</th>
<th>Finisher ration (kg)</th>
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<tbody>
<tr>
<td>Corn</td>
<td>6.3200</td>
<td>6.8100</td>
</tr>
<tr>
<td>Roasted soybean</td>
<td>1.1150</td>
<td>1.0760</td>
</tr>
<tr>
<td>48% soybean concentrate</td>
<td>2.4160</td>
<td>1.9750</td>
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<tr>
<td>Dicalcium phosphate</td>
<td>0.0742</td>
<td>0.0742</td>
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<tr>
<td>Broiler Vitamin mix</td>
<td>0.0034</td>
<td>0.0034</td>
</tr>
<tr>
<td>Poultry trace minerals</td>
<td>0.0043</td>
<td>0.0043</td>
</tr>
<tr>
<td>Choline chloride</td>
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<td>0.0015</td>
</tr>
<tr>
<td>DL-methionine</td>
<td>0.0063</td>
<td>0.0063</td>
</tr>
<tr>
<td>Lime stone</td>
<td>0.0436</td>
<td>1.0436</td>
</tr>
<tr>
<td>Mineral salt</td>
<td>1.0126</td>
<td>0.0126</td>
</tr>
<tr>
<td>Total</td>
<td>9.9969</td>
<td>10.0069</td>
</tr>
<tr>
<td>Percent protein in feed</td>
<td>21.3</td>
<td>19.5</td>
</tr>
<tr>
<td>Percent fat in feed</td>
<td>5.4</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Source: Annual Technical Report 1988/89 Belize Unit

Table 3: Composition of swine ration using full-fat roasted soybean (kg)

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>10-20</th>
<th>20-50</th>
<th>50-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>15.400</td>
<td>17.893</td>
<td>19.767</td>
</tr>
<tr>
<td>Roasted soybean</td>
<td>8.750</td>
<td>6.274</td>
<td>4.409</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>0.375</td>
<td>0.375</td>
<td>0.375</td>
</tr>
<tr>
<td>Salt</td>
<td>0.090</td>
<td>0.090</td>
<td>0.090</td>
</tr>
<tr>
<td>Lime stone</td>
<td>0.250</td>
<td>0.25</td>
<td>0.250</td>
</tr>
<tr>
<td>Swine micro mixture</td>
<td>0.125</td>
<td>0.125</td>
<td>0.125</td>
</tr>
<tr>
<td>Total</td>
<td>24.990</td>
<td>25.007</td>
<td>25.016</td>
</tr>
<tr>
<td>Percent protein in feed</td>
<td>19.9</td>
<td>15.9</td>
<td>13.6</td>
</tr>
<tr>
<td>Percent fat in feed</td>
<td>9.9</td>
<td>8.1</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Source: Annual Technical Report 1988/89 Belize Unit
**Mulberry (Morus spp.):** The nutritive value of mulberry is one of the highest found in products of plant origin. It has high levels of crude protein and high levels of digestible energy. It has also good mineral content and has low fiber content. From Costa Rica there are reports of 25-32% dry matter in leaves; 23-29% in young stems; and 24-45% in woody stems.

![Plate 5: Mulberry plant](image)

Even if it is true that with the use of forage trees the seasonality of production is attenuated, in order to guarantee feeding in dry periods, it is indispensable that the ratio of production to unit of land be established on the basis of the periods with less yield.

In the case of mulberry, which has a cutting interval of three months, there is a surplus in the rainy season. If this additional forage is not harvested, there is an imbalance in the nutritional quality of the shoot through ageing, a decrease in edible biomass and a waste of productive potential.

**Nacedero (Trichanthers gigantean):** It is a very promising fodder tree for a wide range of ecosystems. It is well adapted to the humid tropics with an annual rainfall between 1,000 to 2,800 mm and also well adapted to the steep slopes. It also contributes to water preservation and soil fertility. The crude protein content of the leaves varies from 15 to 22% and can produce, annually, from 40 to 60 t/ha of fresh foliage. The calcium content has been found to be high compared to other fodder trees (Table 4). Its foliage ideally balances ingredients with cassava or sugarcane molasses for feeding to pigs. Cassava and sugarcane molasses are, indeed, good sources of energy, whereas nacedero leaves provide proteins and mineral required by the animal.
Table 4: Composition and nutritional value of some tree leaves (g/kg dry matter)

<table>
<thead>
<tr>
<th></th>
<th>Nacedero</th>
<th>Mulberry</th>
<th>Cocoyam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>155</td>
<td>118</td>
<td>128</td>
</tr>
<tr>
<td>Crude protein</td>
<td>210</td>
<td>182</td>
<td>235</td>
</tr>
<tr>
<td>Digestible protein</td>
<td>84</td>
<td>69</td>
<td>82</td>
</tr>
<tr>
<td>Total fiber</td>
<td>400</td>
<td>248</td>
<td>275</td>
</tr>
<tr>
<td>Calcium</td>
<td>60</td>
<td>22</td>
<td>22</td>
</tr>
</tbody>
</table>

**Moringa (Moringa oleifera):** All parts of the moringa tree are used for food, oil, fiber, and/or medicine, the most important products are pods and leaves. Leaves are readily eaten by cattle, small ruminants, pigs and poultry and can also be used as food for fish. Protein content of leaves is 20-30% on a dry weight basis. Most important is that the protein is of high quality having significant quantities of all the essential amino acids. Leaf fresh weight yield is 2.2-22 lb per tree/year. Cattle feed consisting of 40-50% moringa leaves is mixed with molasses, sugarcane, and grass.
Chaya (*Cnidoscolus chayamansa*): The main challenge for tilapia culture in rural areas of Mexico is low producer income and difficulty in acquiring inputs (fingerlings and balanced feed). In response, some rural producers feed tilapia with locally available vegetal inputs such as chaya, *Cnidoscolus chayamansa*. This plant is a bush endemic to the Yucatan Peninsula, Mexico, that is traditionally used for human and animal nutrition. In these rural culture systems, chaya is provided *ad labium* as fresh leaves. Its use to date is empirical, and therefore, little is known about optimum substitution levels. A bioeconomic model was developed using experimental data. The von Bertalanffy model was parameterized using chaya/balanced feed combinations that produced growth not statistically different than a diet with sole use of balanced feed. This model included biological, economic, and management components. The results indicate that balanced feed can be substituted by chaya leaves at up to 50% and that this substitution level provides the lowest production costs during the warm season. Maintenance of this production level requires 2.23 units of chaya per unit of balanced feed, with the restriction that only 50% of the ration can be substituted by chaya leaves.

Plate 8: Chaya plant rich in protein

**Coconut:** Two principal feeds can be produced from coconut. One is the byproduct of the extraction of the oil from copra, known as coconut oil meal, coconut cake or copra meal and which represent approximately 34 to 42% of the weight of the nut. The other is the broken kernel, usually known as raw copra.
**Canavalia beans:** Canavalia is a good example of an alternative legume for pigs. It can produce an annual yield of up to 6 t/ha of shelled beans and 10 t/ha of residues that could mean an annual yield of 3.6 t/ha of protein. However, because of anti-nutritional factors, the general use of this legume for pigs is best limited to no more than 5% of the diet.
Fodder Grasses: *Pennisetum purpureum* (Napier Grass or Uganda Grass) It is a cane-like species of grass, brought from Africa at least a century ago and used as cattle fodder. Interest in its possible energy uses was sparked by its high productivity.

Plate 12: Taiwan grass
MODULE 3

SILAGE / ENSILAGE

Silage: Simple / appropriate method of conservation

Effective way to improve feed resources using locally available feed stuff

What is Silage?

• Silage consists of green forage preserved by fermentation in a silo for use as succulent fodder during periods of feed scarcity
• Silage is the product of controlled fermentation of green fodder retaining high moisture content. The material is normally stored in pits under anaerobic conditions. Naturally produced organic acids, mainly lactic acid, preserves the fodder

Ensilaging is a method of feed preservation which is based on removal of oxygen to promote fermentation of sugars into lactic acid by lactic-acid bacteria causing an increase in acidity (a decrease in pH) which inhibits further silage degradation by plant enzymes, undesirable bacterial species (clostridia yeast and mold).

Factors to take into account before considering a silage making program
**Silage Production Process**

It can divided into four stages

1. Forage harvesting
2. Transportation to the silo (tank)
3. Compaction, and
4. Sealing (air tightness)

**Principles for good Silage**

- The material to be conserved must have a high nutritive value
- The forage must not be contaminated with soil
- The forage should be chopped into pieces no longer than about 2 cm in length to facilitate good compaction and reduce the amount of air in the silage
- It is necessary to expel the maximum amount of air within the forage before closing the silo, or sealing the bag, to avoid its re-entry and prevent water penetration
- Collection and processing of the forage and sealing the silage in containers should be done in the shortest possible time
- During the feeding of the silage, the area exposed to air should be as small as possible and the time between opening and finishing the silo as short as possible

**Advantage of Silage**

- Use for off-season feeding
- Means of increasing feed resources availability
• Reduce pressure on pasture
• Inexpensive home-made feed
• Improves palatability
• Reduces toxic substances to safe levels: cassava

What can be used for Silage?

• Sugarcane
• Mulberry – Nacedero – Taiwan grass
• Lab lab – Hay molasses – Madre cacao
• Leucaena- Rejected banana – Cassava
• Leaves – Napier grass – Elephant grass

Plate 13: Mechanical chopping of sugarcane plant to be utilized in silage preparation
Four-stage fermentation process:

1. Aerobic fermentation (pre-seal and days following post-seal)
2. Anaerobic fermentation
3. Storage (stable phase)
4. Feed out (ready after ~ 30 days)

Importance of correct moisture:

- Too wet (<70% moisture)
  - Seepage
  - Clostridial fermentation
  - Higher pH and greater dry matter losses

- Too dry
  - Results in poor packing
  - Poor fermentation and heating
  - Greater spoilage and poor life
  - Lower starch and fiber

For a successful ensiling

- Chop / grind: the finer the better: compaction / storage
- Fill & seal silo quickly: slow/delayed = feed loss
- Sprinkle molasses every 6” layer: mix with water
- Dissolve molasses in equal amount water if moist
• Dry crop: mix with twice its volume
• Approx 30 – 40 lbs molasses per ton of crop
• At least 50% moisture to easily compress it tightly
• Judgment left to man on spot
• Cover over with plastic, add a good layer of soil: 3”

Choosing site for silo

• Near feed troughs
• Under a barn to avoid thatching: permanent roof
• Concrete: space to allow cart to go around it
• Slope to drain any moisture settled at bottom
• A hole in middle
• A foot of straw at bottom to act as an absorbent
• Feed straw to animals

When is the silage ready to feed?

• As early as 6 weeks
• Airtight silo can last for more than 6 months
• Cover ensiled material well after every opening
• May need to discard 3” – 6” from top

   Good silage is pale yellowish brown in color
   If dark brown or black: spilled: slow filling, too dry crop or insufficient treading

Plate 15: Locally designed silage press
Plate 16: Demonstration on Silage Preparation using manual silage press
Biodigesters can play a pivotal role in integrated farming systems by reducing health risks, facilitating control of pollution and at the same time adding value to livestock excreta through production of biogas and improved nutrient status of the effluent as fertilizer for fish ponds and crop land.

What is biodigester?

Biodigesters convert organic wastes, mainly manure, into a nutrient rich liquid fertilizer and biogas (methane), a renewal source of electrical and heat energy. In addition to providing fuel, it offers an environmentally friendly way of treating waste. As waste is processed in a biodigester, it is sterilized by methane-producing bacteria and the high-methane environment; over 90% of protozoa, cysts and disease-causing bacteria, such as E. coli, are killed. The effluent that remains after gas production is a high quality organic fertilizer that can be safely used on food crops. Liquid fertilizer has a higher nutritional value than feedstock initially put in. Quality of crops improves dramatically after one year of using biodigester fertilizer. A biodigester is normally made out of concrete, metal or any other material that permits the anaerobic fermentation of organic materials.

Advantages of using a biodigester

The bio-gas technology has several advantages under crop-livestock integrated farming system and in protecting the environment in a particular area.

Biodigesters:

- Provide clean and renewal energy. Families use less firewood, decreasing deforestation, save money and have accessible fuel
- Reduce greenhouse gas emission. The combustion of biogas produces lower greenhouse gas emission than typical methane emission from a waste
- Reduce contamination of surface water, groundwater and other resources
- Reduce odours and pathogens
- Convert waste into high quality organic fertilizer. Families can obtain improved crop yields and save money
Polyethylene biodigester

The use of tubular plastic biodigesters for anaerobic digestion to convert organic matter to biogas and effluent (Botero and Preston 1995) is a very simple and practical system that is flexible and use-low-cost materials when compare to other types of biodigester. The polyethylene tube biodigester has become increasing popular in developing countries, due to its low cost and ease of manufacture and installation. A polyethylene biodigester unit is a sealed tubular structure made of polyethylene “plastic” bags that has an inlet for organic material (manure) and an outlet for expelling decomposed material (effluent). The fermentation unit is one open area consisting of two parts, a liquid and gas phase. The liquid phase is a mixture of water and manure at a ratio of 4:1 respectively. This phase makes up 75% of the total volume of the unit. The gas phase which is composed of methane produced by the liquid phase makes up of the remaining 25% of the total volume. The gas phase forms a “bell” on the top portion of the biodigester unit where a gas outlet is placed to facilitate the transfer of the methane out of the unit. A family of 6, digester system of liquid capacity of 4 to 6 m$^3$ can meet the daily biogas requirements.

Location of the biodigester

Identify the most appropriate location
- Close to the area of the source material
- Avoid using areas with flooding problems
- The pit should be located on the lower side of the pen

Calculating the biodigester size

It is normally calculated based on the amount of manure produced per day and the retention time. It must be noted that different animals produce different amount of manure as can be seen in Table 5.

Table 5: Manure produced per animal species (daily)

<table>
<thead>
<tr>
<th>Species</th>
<th>Manure produced* (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef or dual purpose cattle</td>
<td>6</td>
</tr>
<tr>
<td>Dairy cattle</td>
<td>8</td>
</tr>
<tr>
<td>Horse, Mules and Donkeys</td>
<td>7</td>
</tr>
<tr>
<td>Sheep and Goats</td>
<td>4</td>
</tr>
<tr>
<td>Pigs</td>
<td>4</td>
</tr>
<tr>
<td>Rabbits</td>
<td>3</td>
</tr>
</tbody>
</table>

* Manure produced per 100 lbs of live weight
• First you need to know the animal species and number of them
• Then you need to know that the ratio for daily feeding of the biodigester unit is 1 part of manure and 4 parts of water
• The retention time is at least 50 days. This is the time period required for the manure to be in the biodigester unit before it is completely decomposed and maximum gas is produced

Size of pits and length of polyethylene tube required has been calculated based on number of pigs used for feeding the biodigester and presented in Table 6.

Table 6: Size of pits and length of polyethylene required when using pigs as the source of manure

<table>
<thead>
<tr>
<th>No. of pigs</th>
<th>Unit No.</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure produced/day lbs.</td>
<td>80</td>
<td>120</td>
<td>160</td>
<td>200</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td>Total volume of the Unit Metres³</td>
<td>10.7</td>
<td>16.0</td>
<td>21.3</td>
<td>26.7</td>
<td>32.0</td>
<td></td>
</tr>
<tr>
<td>Length of pit needed ft</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Length of polyethylene tube required ft</td>
<td>14</td>
<td>19</td>
<td>24</td>
<td>29</td>
<td>34</td>
<td></td>
</tr>
</tbody>
</table>

Polyethylene plastic tube can be obtained at different sizes, but a circumference of 19.6 ft is most common. As a general the depth and width of the trench should be around 90% of the diameter. In this case, the width would be 5.5 ft and 5 ft at the base to give it an incline (Figure 3). The depth would be 5 ft.

![Figure 3: Three dimensional diagram of the trench](image)
The pit

When preparing for the pit, it is important to observe the following:

- The sides and floor should be smooth with no protruding stones or roots which could damage the plastic.
- The floor should have a slope of about 25% from the inlet to exit.
- The soil that is excavated should be moved away from the edges of the pit so that movement around the biodigester during or after installation, or subsequent heavy rains, does not cause soil to fall onto the plastic.

Materials required: Apart from Polyethylene tube materials required for construction of biodigester are provided in Table 7. The length of polyethylene would be depended on size of biodigester needed.

Table 7: Material used in a Biodigester

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1” PVC pipe</td>
<td>3 ft</td>
</tr>
<tr>
<td>5 gallon plastic bucket</td>
<td>8</td>
</tr>
<tr>
<td>1” transparent plastic hose</td>
<td>8 ft</td>
</tr>
<tr>
<td>1” PVC male adapter</td>
<td>1</td>
</tr>
<tr>
<td>1” PVC female adapter</td>
<td>1</td>
</tr>
<tr>
<td>1” PVC Elbow</td>
<td>1</td>
</tr>
<tr>
<td>1” PVC Tee</td>
<td>1</td>
</tr>
<tr>
<td>1” PVC End cap</td>
<td>1</td>
</tr>
<tr>
<td>Small can of PVC Glue</td>
<td>1</td>
</tr>
<tr>
<td>Bicycle tube</td>
<td>4</td>
</tr>
<tr>
<td>Empty sack/Bags</td>
<td>4</td>
</tr>
<tr>
<td>Rubber seals of used tyres</td>
<td>2</td>
</tr>
<tr>
<td>Rigid washers</td>
<td>2</td>
</tr>
<tr>
<td>1” Hose clamp</td>
<td>2</td>
</tr>
<tr>
<td>Pot washer</td>
<td>1</td>
</tr>
<tr>
<td>Hacksaw blade</td>
<td>1</td>
</tr>
<tr>
<td>Plastic bottle</td>
<td>1</td>
</tr>
</tbody>
</table>

Preparations of materials

Before you start assembling the biodigester unit, you need to prepare various parts. The following steps will guide you the process of preparing each component of the unit.
Polyethylene tube

- The polyethylene tube normally comes in rolls of 164 ft (50 metres) or 328 ft (100 metres)
- The rolls should be protected, especially the edges, and should be stored and manipulated in a horizontal position
- Find an open area such as football field, basket ball court where the plastic can be spread out without being pierced by sharp objects lying around (Plate 17)
- Two equal length of plastic should then be cut as one will be placed inside the other to make a double layer bag for additional strength

When the second length of tube is inserted inside the first length, care should be taken to ensure that the two films fit snugly together and there are no folds or creases (Plate 18).

- Fold the plastics lengthwise in accordion form to facilitate easy opening when taking to the pit. After it has been folded, roll the plastic for easy transportation

Inlet and outlet buckets

- 8 buckets needed for inlet and outlet
- Cut the bottom of all buckets using a hacksaw blade and then insert into one another to form one hollow cylinder
- A fertilizer bag is then cut at the base and put thru the set of 4 buckets to form culvert like tube (Plate 19)
Fixing the gas outlet

- The first step is to mark the place where the gas outlet will be placed. This should be at least 1.5 m from the end of the plastic tube and in the centre of what will be the top of the Biodigester.
- The size of the hole is determined by the external diameter of the PVC male adapter.

- The rubber washer circles are cut from a length of "used" motor cycle or car inner tube, using the plastic (Perspex) circles as a guide (Plate 20).
The components are then assembled to ensure the male and female adapters fit together smoothly (Plate 21).

The female adapter, with the rubber and plastic circles attached, is screwed tightly on the protruding male adapter (Plate 22).

The male adapter, complete with plastic circle and above it the rubber circle, is inserted from within the plastic tube (Plate 23).

The female adapter, with the rubber and plastic circles attached, is screwed tightly on the protruding male adapter (Plate 24).
Fixing the inlet pipe

- Rubber bands 5cm wide are cut from "used" inner tubes (from bicycle, motor cycle or motor car)
- Fold the ends of the polyethylene and thread them through the buckets. Fold the ends over the sides of the buckets and fix in place wrapping around with the rubber bands
- Make sure that the plastic is smoothly and evenly set inside the bucket so as to ensure easy flow in either direction (Plate 25)

- Tie another piece of rubber tube or rope to the bucket and secure it to a stake previously placed at both ends of the pit, to hold it firmly in place
• It is necessary to dig a small trench (groove) into the heads of the pit to place the inlet and outlet buckets (Plate 26)

Fixing the pressure release valve

• A "T" is prepared from three pieces of PVC pipe, two short pieces and a longer one which will fit into a "used" plastic bottle
• Cut the upper part of the bottle, just below the neck, through which water will be added to form the gas seal
• Small holes are made either side of the neck to take a length of thin wire which will be used to attach the bottle to some support structure
• The PVC "T" is inserted in the bottle and water is added to a depth of 4-5 cm above the lower point of the "T"
• Small holes are punched into the sides of the bottle at a point 2 cm above the lower end of the "T". This ensures that if the gas pressure inside the system exceeds 2cm water column the gas can escape to relieve the pressure
• The "water trap" is now suspended in a convenient place so that the water level can be easily observed and replenished when necessary
• A flexible plastic pipe is attached to the gas outlet and joined to one arm of the "T". The other arm links with another plastic pipe which goes to the kitchen (Plate 27)
Filling the plastic tube with air and water

- Before filling the plastic tube, you must ensure that it sits snuggly in the pit without folds or wrinkles
- Seal one end of the digester to make sure that air will not come out
- At the other end, place a tube or pipe connected to a motorized knapsack/blower and seal so that air doesn’t escape. Then proceed to blow air into the unit (Plate 28)

- After filling the digester with air, the next step is to remove the tube used to fill the bag and replace it with a hose for filling with water

Plate 27: Gas outlet connection

Plate 28: Blowing air to the plastic tube using motorized mist blower
• The digester should be filled to a 60 – 75% of its capacity with water. Normally this occurs when the water has surpassed the bottom of the buckets. At this level air will no longer escape and is trapped in the bell above the water level.
• The ends of the bag can be opened and tied back, making sure that both sides are freely opened.
• It is necessary to reposition the angles of the inlet and the outlet buckets so bottoms are well below water level and fluid can easily flow out of the biodigester. The mouth of the inlet bucket should be at least 6 – 8 inches higher than the mouth of the outlet. This is to ensure water flow in one direction.

Feeding the unit

• It should be fed on a regular basis.
• The mixture should be at a ratio of one part of manure to 4 parts of water.
• The biodigester usually takes 45 to 60 days to begin producing gas regularly and if properly maintained can last up to 10 years.
• It is important to build a roof over the unit as sun degrades polyethylene plastic.
• A fence should also be constructed around the unit.

Daily maintenance

• Charge your biodigester with the necessary mixture at a ratio of one part of manure to four parts of water.
• Check the inlet and outlet buckets to ensure that the level of water is adequate.
• Check the pressure release valve to ensure that the bottle has water.
• Check for damage to the bag.
• Clean off any mud, stones, or foreign material on the bag.

Periodic maintenance

• The pot washer that is inside the PVC in the release valve should be replaced at least every 3 months or when necessary.
• Check pipes and hoses for cracks and leakage.
• Do not divert the effluent from the unit directly into the lakes or streams.
THE COMPLETED BIODIGESTER

Plate 29: Biodigester installed in Stann Creek and Corozal

- What was once a polluted area is now dry soil
- There are no bad odors as twice daily the pig excreta are washed directly into the biodigester
- The farm family no longer needs to buy liquid gas for cooking
- The savings will help the cost of the biodigester in less than 12 months

Detailed Manual on installation process has been prepared by Mr. Max Ortega of IICA in 2009 (Ortega, 2009b). Installation of low cost polyethylene biodigester. (27p). Electronic (PDF) format is available from IICA website at http://www.iica.int.
 MODULE 5

COMPOSTING

Compost is an organic fertilizer that can be made on the farm at very low cost. The most important input is the farmer’s labor. Compost is decomposed organic matter, such as crop residues and/or animal manure. Most of these ingredients can be easily found around the farm.

What is compost?

Compost is a nutrient rich soil-like material created by the biological decomposition of organic materials such as vegetative debris and livestock manures. Compost can improve soil fertility, extend fertilizers, save water, suppress plant diseases, and boost soil tilth. Composting manures can improve manure handling and help to reduce their environmental impacts.

Composting is the decomposition of plant remains and other once-living materials to make an earthy, dark, crumbly substance that is excellent for adding to plants or enriching soil.

It is a technique of stabilization and treatment of organic residues. It is an aerobic process, that under good conditions of air flow, moisture and controlled temperature convert the degradable organic residues to a healthy and stable product that can be used as fertilizer.

Why compost?

Because farming itself involves the efficient management of a variety of natural processes, in many ways, composting is a natural fit for the farmer. Composting is the efficient management of the biological decomposition of organic matter. Ideally, the basics required for compost are readily available on the farm: feed stocks to be composted, such as livestock manure or crop residues; readily available bulking materials to thicken feed stocks, such as sawdust; and air, water, space and time. Microorganisms already present in the feedstock break down the material to a stable, beneficial product, free of pathogens and plant seeds.

How composting works?

Composting depends on providing the right conditions to support the growth of tiny living creatures – micro-organisms (bacteria and fungi which can be seen only by using a microscope). As these micro-organisms break down the plant and animal waste materials, heat is produced. After a few days compost heap will be hot and when opened up it will even give off steam. As the waste materials break down they release nutrients in a form that can be used by crops.
What are advantages of composting?

- Compost increases the level of organic matter in the soil, which has a positive effect on the soil organisms, soil structure, infiltration, water retention capacity and aggregate stability. Compost is rich in nutrients that are readily available to plants.
- Through composting, diseases and pests, as well as weeds seeds are destroyed because the temperature in the compost heap is so high that they cannot survive.

What are disadvantages and limitations of composting?

- Composting is labour intensive. If labour is in short supply, this can be an important limiting factor. On the other hand, compost is such a valuable fertilizer that it makes the invested labour very cost-effective.
- Another limitation can be that organic material is scarce. Composting without manure is very difficult, but it is possible.
- A compost heap can attract vermin, especially if kitchen scrapes are also used. It can also stink. This need not be a problem if the heap is kept in the field instead of home yard.

The composting process

The composting process happens due to the activity of micro-organisms (bacteria) and other larger organisms like worms and insects. These need certain conditions to live. These include moisture and air.

To make the best possible compost, the micro-organisms must be able to work optimally. This can be achieved if the following four factors are combined to the best advantage:

1. Type of organic material
2. Air
3. Moisture
4. Temperature

The acidity (ph) is also considered to be an important factor. Acidity depends on the air and moisture flow. A compost heap that is properly composed will seldom get too acid.

The composting process will be optimal when:

- Various materials of different decomposition rates are combined
- The different materials are well mixed
- The size of heap varies from 1 x 1 yard to 3 x 3 yard. This makes it possible for the temperature to stay constant within the heap
A good composting process passes through three consecutive stages, these are as follows:

1. **A heating phase (fermentation)** – During the first of composting heap starts to heat up considerably. This effect is known as fermentation and is the result of the breaking down of the complex and tough fibrous material of the organic matter. This fermentation process (decomposition) is strongest in the centre of the heap. In this phase pH reaches to its highest value of 8.5. During fermentation the micro-organisms multiply and change at a rapid rate, which adds to the heating up process. Maximum fermentation takes place at a temperature of 60-70°C in the compost heap. Due to its temperature, fermentation also has a hygienic effect.

2. **A cooling down phase** – The fermentation phase gradually changes into a cooling down phase. Decomposition occurs without much generation of heat and temperature drops slowly.

3. **A maturation phase** – In this end of decomposition, the temperature drops to soil temperature, depending on the climate. In this phase pH decreases between 7 and 8 and moisture should be between 35 to 40%.

It is not easy to draw the line between these stages. The process takes place very gradually and with the help of continuously changing micro-organisms the organic material is converted into compost.

**What are the basic parameters to evaluate the quality of the compost?**

- Moisture content should be between 40 to 60%
- Carbon/Nitrogen ratio should be between 20 and 25 to 1
- Organic content should 50% or more

**What are the materials to be used for compost?**

In general, any type of organic material of plants and animals can be used. It includes any kind of crop residues, residues obtained after chopping, lawn mowing and pruning, residues from grains (beans, rice, peanut, soybean, corn, etc.), residues from sugar industry (bagasse, leaves, etc.), residues obtained from fruit and vegetables, residues from restaurants and other biodegradable trashes (paper, card board), animal manure, sawdust and shavings, residues from slaughter house of chicken, cattle and others. It is essential to mix old and tough materials (crop residues, small twigs), which are difficult to decompose with young and sappy materials, which are easily decomposable (fruits, vegetable skins, young leaves).
What are factors that influence in the compost process?

1. Air
2. Moisture
3. Temperature
4. Ph
5. Nutritional factors
6. Carbon/nitrogen ratio
7. Size of materials used

Steps to follow to make compost

1. Start with a layer of resistant material of approximately 8” (20 cm) thick and moisten uniformly
2. Add a layer of animal residues (manure) approximately 2” (5 cm) thick
3. Add a base material (ashes, lime or others). Ash adds potassium to the compost
4. Place some stick so as to facilitate aeration and place them 1 to 2 yard separate. These should be removed at 3-4 days after
5. Additional layers may be added using residues of rice, sweet potato vines, and residues obtained from chopping, lawn mowing and pruning, residues of plantain. These layers are placed until the compost reaches a height of approximately 1 to 1.5 yard. Remember to wet the compost after each layer
6. The compost pile should be left without wetting. Then the temperature should be measured with a steel rod. If it has the normal temperature it means that the fermentation process has not initiated. If it is warm then process has started and if burns when touched then the temperature is between 55 to 60°C. This can happen 2-3 days after establishing the heap
7. First turning of the heap is done after 9 to 10 days. The layers should be inverted in such a way that those materials were outer side must be inside after turning
8. While turning the layers it should be moistened, mainly the upper level. Avoid excessive of moisture and keep the height of the heap between 1 to 1.5 yard
9. The compost should be left for a while, but the temperature must be checked because it should again get into fermentation phase
10. The temperature should come down before doing the next turn
11. After the second turn, the compost heap should be moistened again, measure the temperature and if this has not increased then it means that the material has become humus. It should have appearance of dark soil and a smell of humus, but if the temperature rises up, you must wait for the temperature to come down and make sure that it does not go up again
12. Turn the compost heap every 2 days without adding water and do not increase the height of the compost heap. When the moisture is between 35 to 40% the compost is ready
Plate 30: Preparation of compost pile

Plate 31: Composting units constructed in five beneficiaries farms
MODULE 6

VERMICULTURE AND VERMICOMPOSTING

Vermiculture is the culture of earthworms. It is a simple and cheap way to produce a continuous supply of organic compost of high quality. Vermiculture is the intensive exploitation of earthworm for the production of humus and animal protein. The humus is a result of the decomposition of organic matter by the action of microorganisms and the process of transformation done by earthworm. The earthworm eats the equivalent of their own weight on a daily basis. Of all the material that they eat, around 60% is transformed to humus and other 40% is used for the earthworm’s metabolism.

Vermicomposting is the process by which earthworms are used to convert organic materials (usually wastes) into humus-like material known as vermicompost. The goal is to process the material as quickly and efficiently as possible.

These two processes are similar but different. If your goal is to vermicompost, you will want to have your maximum worm population density at all time. If your goal is to produce worms, you will want to keep the population density low enough that reproductive rates are optimized.

What exactly is humus?

Humus is the main substance responsible for the fertility of the soil since it is an organic fertilizer that has a high content of microorganisms and enzyme activity that act to improve the soil increasing its productivity.

Humus is rich in organic matter and mineral salts that are easily absorbed by plants.

It is an organic product that is stable, uniform and is dark in color.

The quality of the earthworm humus depends on its chemical, physical, and biological characteristics and also on the material used as feed for the worms as well as the management process of the vermiculture.

If it is too much water is added to the vermiculture, nutrients are lost by leaching and if the humus is collected before time, it will have unstable properties and will organic matter of very low quality.
Advantages of vermiculture

1. Permits the recycling of organic matter, returning to the soil part of the elements that are extracted from it with the harvest
2. It is a mechanism of decontamination
3. It is a source of animal protein
4. The worm protein can be used in the production of substrates
5. The worms can be used as bait for fishing
6. Permits the continuity of crops without necessity of getting more earthworms
7. It is a biological fertilizer that acts as soil improvement agent improving its physical, chemical and biological properties
8. It is 6-7 times more effective than any other fertilizer.
9. It protects plants, improve their defences because of its balanced contribution of natural phytoregulating vitamins, auxins, enzymes, micro and macro elements humic and fulvic acids
10. It is a source of income from selling the humus, worms, and worm flour as animal feed
11. As it is organic matter rich in nutrients it can be used in smaller dosages compared to other organic matter to increase fertility of soil

The vermi-compost worm

There are an estimated 1800 species of earthworm worldwide. In Belize, the Ministry of Agriculture has imported and introduced *Eisenia fetida*, which is commonly known as the “compost worm”, “manure worm”, “redworm”, and “red wiggler” (Plate 29). This extremely tough and adaptable worm is indigenous to most parts of the world.

Plate 32: Compost redworm
Potential benefits

Why should a farmer be interested in vermiculture and/or vermicomposting? The answers are several and may not apply to all producers. In summary, they are as follows:

- Vermicompost appears to be generally superior to conventionally produced compost in a number of important ways
- Vermicompost is superior to most compost as inoculants in the production of compost teas
- Worms have a number of other possible uses on farms, including value as a high-quality animal feed
- Vermicomposting and vermiculture offer potential to organic farmers as sources of supplemental income

Constraints

- It can be quicker, but to make it so generally requires more labor
- It requires more space because worms are surface feeders and won’t operate in material more than a meter in depth
- It is more vulnerable to environmental pressures, such as freezing conditions and drought
- Perhaps most importantly, it requires more start-up resources, either in cash (to buy the worms) or in time and labor (to grow them)

What worms need (five essentials needs)

1. An hospitable living environment, usually called “bedding”
2. A food source
3. Adequate moisture (greater than 50% water content by weight)
4. Adequate aeration
5. Protection from temperature extremes.

Initial population of worms

To initiate the initial population of worm it is necessary to prepare an area for this purpose which can be any container, separated from soil with holes for drainage and shade that when initial population is received the container is prepared with irrigation and food available.
The box test

This test consist in placing 50 earthworms in a box with food that will be used for the worms, after 24 hours, the live worms must be counted and if there are more than 49 then the food can be used, but if the number of worms is less then food cannot be used. If this is not done, you run the risk of losing all the worms since it is not only necessary that the pH is adequate but there are chemical substances that are harmful to the worms.

Worm food

Compost worms are big eaters. Under ideal conditions, they are able to consume in excess of their body weight each day. They will eat almost anything organic (that is, of plant or animal origin), but they definitely prefer some foods to others. Manures are the most commonly used worm feedstock, with dairy and beef manures generally considered the best natural food for Redworms, with the possible exception of rabbit manure. Table 6 summarizes the most important attributes of some of the more common foods that could be used in an on-farm vermicomposting or vermiculture operation.
<table>
<thead>
<tr>
<th>Food</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle manure</td>
<td>Good nutrition; natural food, therefore little adaptation required</td>
<td>Weed seeds make pre-composting necessary</td>
<td>All manures are partially decomposed and thus ready for consumption by worms</td>
</tr>
<tr>
<td>Poultry manure</td>
<td>High N content results in good nutrition and a high-value product</td>
<td>High protein levels can be dangerous to worms, so must be used in small quantities; major adaptation required for worms not used to this feedstock. May be pre-composted but not necessary if used cautiously.</td>
<td>Some have suggest that poultry manure is not suitable for worms because it is so “hot”; however, research done has shown that worms can adapt if initial proportion of Poultry manure to bedding is 10% by volume or less.</td>
</tr>
<tr>
<td>Sheep/Goat manure</td>
<td>Good nutrition</td>
<td>Require pre-composting (weed seeds); small particle size can lead to packing, necessitating extra bulking material</td>
<td>With right additives to increase C:N ratio, these manures are also good beddings</td>
</tr>
<tr>
<td>Pig manure</td>
<td>Good nutrition; produces excellent vermicompost</td>
<td>Usually in liquid form, therefore must be dewatered or used with large quantities of highly absorbent bedding</td>
<td>Scientists found that vermicompost made with hog manure outperformed all other vermicomposts, as well as commercial fertilizer.</td>
</tr>
<tr>
<td>Rabbit manure</td>
<td>N content second only to poultry manure, there-fore good nutrition; contains very good mix of vitamins &amp; minerals; ideal earth-worm feed</td>
<td>Must be leached prior to use because of high urine content; can overheat if quantities too large; availability usually not good</td>
<td>Many rabbit growers place earthworm beds under their rabbit hutches to catch the pellets as they drop through the wire mesh cage floors.</td>
</tr>
<tr>
<td>Fresh food scraps</td>
<td>Excellent nutrition, good moisture content, possibility of revenues from waste tipping fees</td>
<td>Extremely variable (depending on source); high N can result in overheating; meat &amp; high-fat wastes can create anaerobic conditions and odors, attract pests, so should NOT be included without pre-composting</td>
<td>Some food wastes are much better than others: coffee grounds are excellent, as they are high in N, not greasy or smelly, and are attractive to worms; alternatively, root vegetables (e.g., potato culls) resist degradation and require a long time to be consumed.</td>
</tr>
<tr>
<td>Grains</td>
<td>Higher N content makes these good feed as well as reasonable bedding.</td>
<td>Moisture levels not as high as other feeds, requires more input and monitoring</td>
<td>Probably best to mix this feed with others, such as manures</td>
</tr>
<tr>
<td>Legume hays/crop</td>
<td>Excellent, balanced nutrition, easy to handle, no odor, can use organic grains for certified organic product</td>
<td>Higher value than most feeds, therefore expensive to use; low moisture content; some larger seeds hard to digest and slow to break down</td>
<td>Danger: Worms consume grains but cannot digest larger, tougher kernels; these are passed in castings and build up in bedding, resulting in sudden overheating.</td>
</tr>
<tr>
<td>Fresh food scraps</td>
<td>Excellent nutrition (due to high-protein glue used to hold layers together); worms like this material.</td>
<td>Must be shredded (waxed variety) and/or soaked (non-waxed) prior to feeding</td>
<td>Some worm growers claim that corrugated cardboard stimulates worm reproduction</td>
</tr>
</tbody>
</table>
Worm food should be:

- Neutral in pH
- Level of moisture that permits ingestion of food
- Well disintegrated
- Does not contain any toxic or harmful substances

**Moisture**

The bedding used must be able to hold sufficient moisture if the worms are to have a livable environment. They breathe through their skins and moisture content in the bedding of less than 50% is dangerous. With the exception of extreme heat or cold, nothing will kill worms faster than a lack of adequate moisture. The ideal moisture-content range for materials in conventional composting systems is 45-60%. In contrast, the ideal moisture-content range for vermicomposting or vermiculture processes is 70-90%.

**Aeration**

Worms are oxygen breathers and cannot survive anaerobic conditions (defined as the absence of oxygen). When factors such as high levels of grease in the feedstock or excessive moisture combined with poor aeration conspire to cut off oxygen supplies, areas of the worm bed, or even the entire system, can become anaerobic. This will kill the worms very quickly. Not only are the worms deprived of oxygen, they are also killed by toxic substances (e.g., ammonia) created by different sets of microbes that bloom under these conditions. This is one of the main reasons for not including meat or other greasy wastes in worm feedstock unless they have been pre-composted to break down the oils and fats. Although composting worm’s oxygen requirements are essential, however, they are also relatively modest.

**Methods of Collecting Humus**

- **Collection using screen**: It consist of placing a mesh on top of the Humus with fresh food and in 24 hours time a number of worms have already on the top of the mesh. Keep this mesh for 3 days and then move it to another box. This operation is done for at least three times. The earthworms will move up on the mesh, leaving underneath the humus. About 5% of eggs and earthworms can stay within the humus.
- **Collection using the scraping method**: This method consists of placing a layer of food directly over the box, wait at least for three days. At this time some of the worms have already moved to the new layer. Then proceed to remove the new layer with all those worms place them in another box. This operation is done for three times.
- **Collection using pyramid method**: This method consist placing the humus with worms over a small layer of fresh food in pyramid form, if possible a light be placed over the pyramid with the objective to make the worms move to the middle of pyramid and towards the fresh food. Worms are attracted to light. Then you can proceed to remove the
top part and the sides of the pyramid as the worms have moved to the centre of the pyramid

- **Collection by sifting**: This method consists of placing humus with worms over a sieve, humus will pass through the sieve and earthworms will remain on the top of the sieve.
CITED REFERENCES AND FURTHER READING


