Ministry of Agriculture, Animal Husbandry and Fisheries

A Manual for Cassava Production in Suriname

Produced under the project Cassava Industry Development
– Market Assessment and Technology Validation and Dissemination

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Ministry of Agriculture, Animal Husbandry and Fisheries

Government of Suriname

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Table of Contents

List of Figures

List of Tables

Foreword

This manual is a guide for cassava production in Suriname and was produced under the project titled “Cassava Industry Development Market Assessment and Technology Validation and Dissemination” (GCP/SLC/010/CDB), funded by the Caribbean Development (CDB, under a Grant Agreement – GA 174/REG) and the Food and Agriculture Organization of the United Nations (FAO), and executed and by the FAO in close collaboration with the Ministry of Agriculture, Animal Husbandry and Fisheries (MAAHF) in Suriname. The objective of the project is to enhance the capacity for evidence-based decision making regarding the development of the cassava industry in three beneficiary countries – Dominica, Suriname and Trinidad and Tobago.

The information used in this manual is based on national, regional and global literature, the results from field demonstrations conducted under the project and information provided by the MAAHF. It is anticipated that this Manual (as well as the eight technical fact sheets derived from the manual) will prove to be useful to the MAAHF Extension and Technical personnel as well as to cassava farmers across Suriname for the continued and sustainable development of this sector.

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All other persons who contributed to the preparation of this manual are also acknowledged.

Abbreviations and Acronyms

°C	-	Degrees Celsius
%	-	Percentage
AESA	-	Agro-Ecological System Analysis
BP	-	Best practice
CaO_3	-	Lime (Calcium carbonate)
CaO	-	Calcium oxide
CDB	-	Caribbean Development Bank
cm	-	centimeter / centimetre
e.g.	-	for example
FAO	-	Food and Agriculture Organization of the United Nations
FFS	-	Farmer Field School
FP	-	Farmers practice
GCP/SLC/010/CDB	-	Cassava Industry Development Market Assessment and Technology Validation and Dissemination project
i.e.	-	id est / that is
K	-	Potassium
Kg	-	kilogram
m	-	meter / metre
MAAHF	-	Ministry of Agriculture, Animal Husbandry and Fisheries
N	-	Nitrogen
NaClO	-	Sodium hypochlorite
P	-	Phosphorous
pH	-	Acidity
PP	-	polypropylene plastic
ppm	-	part per million
T	-	Troeli (cassava variety)
TOT	-	Training of Trainers
UWI	-	The University of the West Indies
WZ	-	Weg naar Zee (cassava variety)

Introduction

Cassava (*Manihot esculenta*) is the fourth most important staple food in Suriname after rice, wheat and plantain and the most cultivated crop among the roots and tubers (Johnson, 2018). According to the statistical data of the Ministry of Agriculture, Animal Husbandry and Fisheries (MAAHF), the total cassava production area in 2019 was approximately 282 ha with a total production of 7.8 tons (Soil Structure and its benefits, 2020). Cassava is an excellent source of carbohydrates, proteins, vitamins and minerals.

In Suriname, cassava has been eaten for centuries by the Maroon and indigenous populations and continues to be a popular staple food in local diets. Cassava is consumed in various ways (savoury and sweet) by the populace. Freshly harvested sweet cassava is boiled and eaten as the main starch at a meal, added to soups, used as base for other dishes or fried as chips or snack crisps. Grated cassava is used in sweet desert items. The bitter cassava varieties are cultivated in the interior of Suriname and are used after they have been processed to farine, compressed flour (loloksaba), etc.

The names and other characteristics of the many traditionally cultivated varieties are not known. Tillage operations used prior to planting the crop are minimal, mainly restricted to hand hoes and forks and there is little or no mechanization. During cultivation, fertilizers are either infrequently or not used at all, and there is minimal pesticide use. The yields from this type of farming system are generally low and are found to provide meagre returns to the farmer (Johnson, 2018).

In 2016, the Caribbean Development Bank (CDB) signed a Grant Agreement (GA 174/REG) with the Food and Agriculture Organization of the United Nations (FAO) to implement the project *Cassava Industry Development Market Assessment and Technology Validation and Dissemination* (GCP/SLC/010/CDB). Suriname was one of the three targeted countries engaged in the project, because cassava was identified as a priority industry for significant development to address issues relating to rising food import bills, food security, employment and rural development efforts. Cassava is found to have the potential to contribute to the reduction of the high food import bill and improved food security in the region through import substitution of wheat flour, animal feed ingredients and malted barley (Johnson, 2018). One of the components of the project was to conduct adaptive research to identify, validate and demonstrate improved varieties of cassava and production systems (Johnson, 2018), and furthermore to communicate these to the farmers.

Therefore, this manual has been prepared to provide information on the sustainable production, harvesting and post-harvest handling of cassava as well as the various known usages in Suriname that add value to the raw product. A case study is also provided, based on the farmer field schools (FFS) conducted in two agro-ecological zones that served as a training ground for farmer groups to demonstrate the applications of known ‘best practices’ for improved production and productivity of cassava.

Chapter 1. The Cassava Plant

Cassava belongs to the Euphorbiaceae family of flowering plants and the genus *Manihot*. Cassava is a perennial shrub and is monoecious; a single plant carries both male and female flowers, but these are separated from each other. The plant has sympodial branching and can grow to a height of 5 m (Ospina & Ceballos, 2012).

Plant parts

The leaves of the cassava plant produce starches and protein, which are the building blocks for growth and development. The amount and health of the leaves are therefore important because these factors affect the eventual yield of the plant. The stems are an important part of the plant, because these are used for propagation and serve as transport organs of the proteins and starches produced in the leaves. The cassava plant has three type of roots: fine, white roots, which absorb water and nutrients; thick roots, which anchor the plant to the ground; and tuberous roots, which store carbohydrates (Titus, Lawrence & Seesahal, 2011). The tuberous roots contain more than 60% water. The dry matter content is very rich in carbohydrates, amounting to about 250-300 kg for every ton of fresh roots. The best time to harvest cassava roots for food is between 8 and 10 months after planting; a longer growing period generally produces higher starch yield (Howeler, Lutaladio & Thomas, 2013).

Growth and development

The cassava plant has two recognizable growth phases:

1. The first growth phase is from planting to about 8 weeks, which involves the growth of stems, leaves and the roots systems. During this phase, the cassava tubers begin to form.
2. The second phase is from beyond 8 weeks, which involves a rapid growth of the vegetative parts and the roots.

Growing conditions

Cassava grows best in full sunlight between temperatures of 25 ℃ and 32 ℃. Maximum root production occurs when cassava is planted in well-drained sandy clay loamy soils, with a pH ranging from 5.5 - 6.5 and the rainfall is well distributed throughout the growth season.

Chapter 2. Cassava varieties and various uses

Cassava is an important tuberous crop in Suriname and it is used for different purposes throughout the food chain, from fresh tubers to processed form. The different varieties are not known, but based on the local characteristics and knowledge, specific varieties are used for specific products. For the production of standardized quality products, the varieties and their characteristics must be known.

2.1. Cassava varieties in Suriname

Over the past decade, numerous varieties of cassava have been provided to the farmers in Suriname. Correct identification of these varieties is a challenge not only for the farmers but also for the service providers in the national extension system. Although there is a list of varieties that were introduced in Suriname, the characteristics to identify specific varieties are not commonly known (Bernardo, et al., 2016). The basic understanding in Suriname is that there are two types of cassava, namely sweet cassava and bitter cassava.

Sweet cassava, based on the colour and taste of tubers, is classified into two types: White cassava and Yellow cassava (Botro cassava).

Bitter cassava are the varieties that have a high cyanide content. These varieties cannot be consumed fresh but have to be processed. They are mostly cultivated in the interior and have a growing period of up to 12 months.

2.2. Varieties introduced to Suriname

During 2018 and 2019, six cassava varieties were introduced to Suriname to be used for different purposes[1]. These varieties are listed below:

	Varieties
1	PER 183
2	COL 1468
3	CM 2766
4	CM 4484
5	CM 6119
6	CM 3064

[1] The varieties were introduced as tissue cultured plantlets (under the project "Cassava Industry Development Market Assessment and Technology Validation and Dissemination") from the cassava Gene Bank held by the International Centre for Tropical Agriculture (CIAT, Colombia. For more information, contact the Ministry of Agriculture, Animal Husbandry and Fisheries, Suriname.

The MAAHF is evaluating the growth, development and production / productivity of these cassava varieties under Surinamese conditions. The first generation (F1) plants, obtained from the weaning and hardening of the tissue cultured materials received from CIAT, have been planted out in two agro-ecological zones (Wanica and Saramacca district). Plans are in place for further testing of the second (F2) generation plants in order to select the better-adapted and better-performing varieties, followed by a final evaluation (F3) of these varieties in farmers' fields. After concluding this research, the intention is to multiply and distribute the planting material of the best performing varieties to farmers.

2.3. Various uses of cassava

The uses of cassava are based on the type of cassava. The sweet cassava types are used for:

i. Fresh Market

The fresh tubers (Figure 1[2]) are mainly sold in the market for use in households, restaurants and hotels. This cassava needs to be a tuber with loose skin, which boils easily, is soft and keeps its shape (Figure 2). The tubers should have a shelf life of at least one week.

Figure 1. Fresh cassava tubers.

Figure 2. Surinamese dish with cassava, called Teloh.

ii. Processing

The sweet cassava is processed to develop various products (Figure 3):

- Cassava bread
- Cassava chips
- Cassava flour
- Cassava fries - produced mostly from the 'botro' or yellow cassava for its slightly sweet taste and softness.
- Cassava porridge mixture
- Cassava snacks (krupuk, kroket, etc.)
- Cassava sweets (different kinds of sweets, e.g. cassava cake)
- Frozen cassava chunks
- Frozen cassava mash

[2] Unless otherwise cited, the pictures in this manual have been kindly provided by Mr. Chanderdew Kesharie, Ministry of Agriculture, Animal Husbandry and Fisheries, Suriname.

Figure 3. A variety of cassava products: (1) Cassava bread (40% cassava); (2) Cassava chips; (3) Cassava fries; (4) Cassava snack (Krupuk); (5) Frozen cassava mash; (6) Cassava cake (bojo); (7) Cassava sweets (Dokoe or Lemet); (8) Frozen cassava chunks.

The bitter cassava can only be used after it has been processed. During the processing, the high cyanide content is extracted. Although less research has been done on the processing of bitter cassava in Suriname, this type of cassava is used for making some additional products (Figure 4) (Idoe, 2010) (Johnson, 2018):

- Farine
- Kasirie (traditional alcoholic drink)
- Compressed cassava flour (Loloksaba)
- Traditional cassava bread

Figure 4. Bitter cassava products: (A) Farine; (B) Compressed cassava flour (Loloksaba); (C) Traditional cassava bread.

If a farmer is planting cassava for a processor, it is very important that both the farmer and the processor agree in advance which type of cassava is needed, in order to avoid unpleasant surprises at harvest time.

Conclusion

Various products are prepared from cassava in Suriname. To further develop the market for cassava, it is very important to know the varieties that can be used for various products, in order to ensure quality consistency in these products.

Chapter 3. Selection and preparation of cassava planting material

Appropriate selection of cassava planting material is very important since cassava is propagated vegetatively. Different problems such as root rot at harvest, difference in production between plants, difference in plant vigour and fewer mature plants at harvest can be prevented just by carefully selecting the planting material. The quality of cuttings depends on the sanitary conditions and agronomic characteristics of the plants from which they originated.

The quality of cassava planting material depends on several factors; these are necessary for the sprouting of vigorous plants capable of producing a good number of roots with the desired diameter and rendering robust yields. These factors are:

1. <u>Age of the plant</u>

To obtain good cuttings, 8- to 18-month-old plants should be used. Plants should not be older than 18 months, because two-thirds of the stems of these plants are highly lignified and cuttings of this material would germinate slowly and produce non-vigorous shoots. When the stems are old, cuttings are difficult to cut (Dipotaroeno & Romero, 2015) (Lozano, Toro, Castro & Bellotti, 1984).

The plants should also not be younger than 8 months, because these green, immature stems are extremely susceptible to attack by soil-borne pathogens and sucking insects. Moreover, these cuttings cannot be stored for longer periods, because they have high water content and tend to dehydrate much rapidly. Their succulence makes it easy for many microorganisms (bacteria and fungi) to infect them and cause severe rotting shortly after planting (Lozano, Toro, Castro & Bellotti, 1984).

For the production of good quality roots, the age of the plant is very important. If the field has not yet reached the preferred age, but the farmer is ready to harvest, he needs to ensure that a part of the field is retained for planting material for the next crop (Dipotaroeno & Romero, 2015).

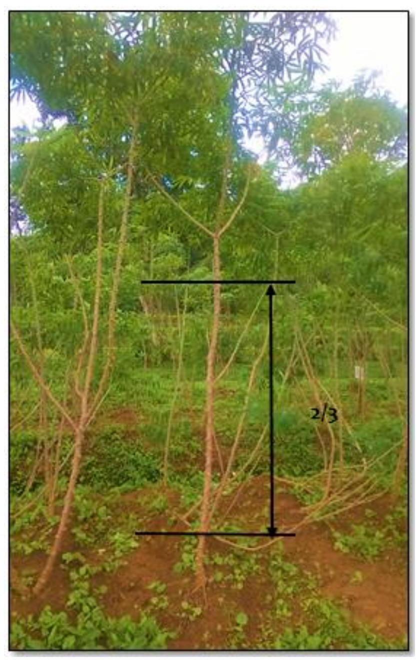

Figure 5. Approximately the middle 2/3 of a cassava plant.

2. <u>Plant part selected for preparing cuttings</u>

This is strictly related to the age of the plant. For an 8-month old plant, the middle third (2/3) must be used (Figure 5). As the plant becomes older, the stem accumulates greater reserves which enables the use of the upper part for cuttings. So for an

18-month-old plant, the upper third of the plant can be used and the basal third must be discarded.

This clearly indicates that the age of the stem should be taken into account, rather than the age of the plant, since the age of the stem depends basically on the plant section where the stem piece is located (Lozano, Toro, Castro & Bellotti, 1984).

3. <u>Cutting diameter</u>

Any part of the stem can be used as propagation material. Thin stems have poor nutrition reserves and the shoots developing from such stems are weak and produce fewer, smaller tuberous roots (Lozano, Toro, Castro & Bellotti, 1984) (Titus, Lawrence & Seesahal, 2011).

To determine the appropriate diameter of a cutting, a relationship between the total cutting diameter and that of the pith (central part of the stem) has been established. If the diameter of the pith is equal to or less than 50% of the cutting diameter, the material is adequate for planting (Figure 6) (Dipotaroeno & Romero, 2015) (Lozano, Toro, Castro & Bellotti, 1984).

Figure 6. Measurement of the diameter of the pith(left) and the total diameter of the stem(right).

In general, it is recommended that the diameter of the cutting selected must not be less than one and a half times (1.5x) the diameter of the thickest part of the stem being used for planting (Lozano, Toro, Castro & Bellotti, 1984).

4. <u>Cutting length and number of nodes per stem cutting</u>

It is possible to obtain a cassava plant from a very short cutting with, for example, just –2-3 buds, but the possibility that it will germinate and root under field conditions is very low. On the other hand, longer cuttings (e.g. 60 cm) have a higher probability of germinating and rooting, but one plant will produce fewer cuttings, which will make it more expensive for the farmer to obtain planting material (Lozano, Toro, Castro & Bellotti, 1984).

Nodes of a cassava cutting are the axillary buds from which the shoots sprout above ground, and when buried roots develop in the soil. The number of nodes per cutting depends on the variety used, because different varieties have different internode lengths.

Ideally, the cuttings should have a length of 15-20 cm, with up to seven (7) to nine (9) nodes (Figures 7) (Dipotaroeno & Romero, 2015) (Howeler, Lutaladio & Thomas, 2013) (Lozano, Toro, Castro & Bellotti, 1984).

Figure 7. Stem cuttings with the appropriate length and number of nodes for planting.

5. <u>Cutting the stem and the cutting angle</u>

The stem should cut with a sharp machete or hacksaw (Dipotaroeno & Romero, 2015) (Lozano, Toro, Castro & Bellotti, 1984). When using a machete, the stem should be placed on a piece of wood and a single, firm stroke should be applied to make a cutting. Keep in mind that only the part that will be cut will touch the angle of wood (Figure 8). Avoid tearing the bark or splintering the woody piece of the cutting. When using a hacksaw, the stem should be held on both sides of the blade with the hands (Figure 8). The stem should never be placed directly on the ground to make cuttings, because this causes bruising of the tissues and damages the cuttings (Lozano, Toro, Castro & Bellotti, 1984). It is recommended to make the cuttings transversely with a hacksaw, so the cutting is able to root uniformly around the perimeter, giving better root distribution.

Figure 8. Cutting made with a machete (left) and a hacksaw (right).

6. Physical damage to cuttings

Physical damage can decrease the quality of the cutting. Physical damage may occur from striking, or friction to the cuttings during preparation, transporting, storage or transplanting. Each injury of the cutting, on the epidermis or to the buds, is a new entry point for microorganisms that cause rotting (Lozano, Toro, Castro & Bellotti, 1984).

7. Storage of cuttings

Cuttings can be stored upright in cool, shaded and covered conditions, with the base of the stem resting on soil that has been loosened with a hoe and watered regularly (Howeler, Lutaladio & Thomas, 2013) (James, et al., 2000) (Lozano, Toro, Castro & Bellotti, 1984) (Titus, Lawrence & Seesahal, 2011). Before transplanting, the cut surface of stored cuttings should be checked for exudation of latex. If the latex appears slowly, it means that the cutting has dried out and the material should be discarded (Lozano, Toro, Castro & Bellotti, 1984). It is recommended that cuttings should be used within three (3) days after harvesting, to transplant in the field (Dipotaroeno & Romero, 2015). Do not use cuttings which have dried out or are already sprouting buds.

8. Treating the cuttings

After the cuttings are transplanted in the field, they are subject to attack from pathogens and insects, which live in the soil and generally attack the buds of the cutting and also penetrate through wounds or through the base of the sprout or rootlets. In Suriname, no research has been done on this topic, but it is recommended that cuttings should be treated as follows before planting:

- For prevention against fungi and insects, treat chemically with a solution of an appropriate fungicide / insecticide that is registered for use in Suriname, using recommended dosage and application methods, i.e., soaking the stems for about 10 minutes in a one litre solution of fungicide / insecticide (James, et al., 2000) (Lozano, Toro, Castro & Bellotti, 1984) (Titus, Lawrence & Seesahal, 2011); or
- Soak the cuttings for 5-10 minutes in hot water to kill the pest- or disease-causing organisms that might be present (Howeler, Lutaladio, & Thomas, 2013).

Remember, always disinfect the machete or hacksaw before using, with a solution of sodium hypochlorite (NaClO, 5%), at a dosage of one (1) litre of the product in one (1) litre of water (Howeler, Lutaladio & Thomas, 2013).

Chapter 4. Soil and water management

Soils provide a wide range of benefits to human society, including producing food, providing clean water and reducing the risk of flooding. Good soil management is the key to maintain these benefits. Water management, on the other hand, is the use of water in a way that provides crops and animals the amount of water they need that enhances productivity, and conserves natural resources for the benefit of downstream users and ecosystem services. For good, sustainable crop production, the management of both soil and water needs to be taken into consideration.

4.1. Soil management

Soil is the uppermost layer of the earth's crust, consisting of a mixture of organic matter, minerals, gases and water. Soil develops in layers, which are different from each other in color and texture (Figure 9).

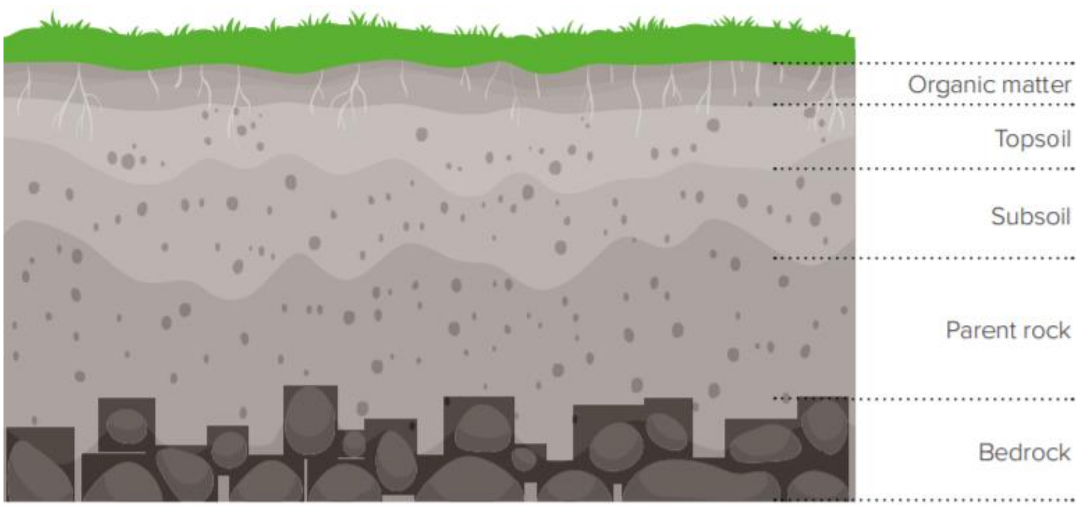

Figure 9. Example of a mineral soil profile (Soil Structure and its benefits, 2020).

The topmost layer (upper top layer) of an untouched soil is made up of organic matter, including leaf litter, at various stages of decomposing. Below this is the surface soil (also topsoil) which is 10-25 cm deep; it is a combination of organic matter and mineral components and has the highest biodiversity and the most available nutrients for plants (Soil Structure and its benefits, 2020.

There are three main types of soil particles: clay, sand and silt. The combination of these determines the soil type that is important to consider in the fields (Soil Structure and its benefits, 2020:

- To assess the risk of drought or flooding;
- To determine the vulnerability of the soil to compaction;
- To measure the characteristics of soil degradation, which differ between soils.

A. <u>Soil regions in Suriname</u>

Based on the geography of Suriname, there are four (4) different ecological and physiological regions (Figures 10 and 11) (Idoe, 2010):

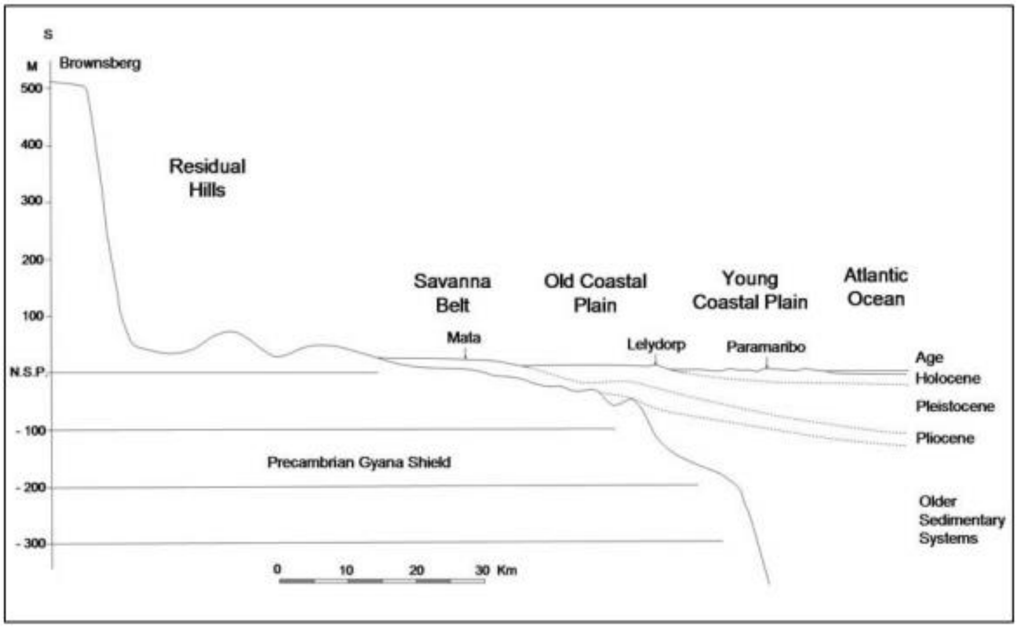

Figure 10. North – South profile of Suriname (Idoe, 2010).

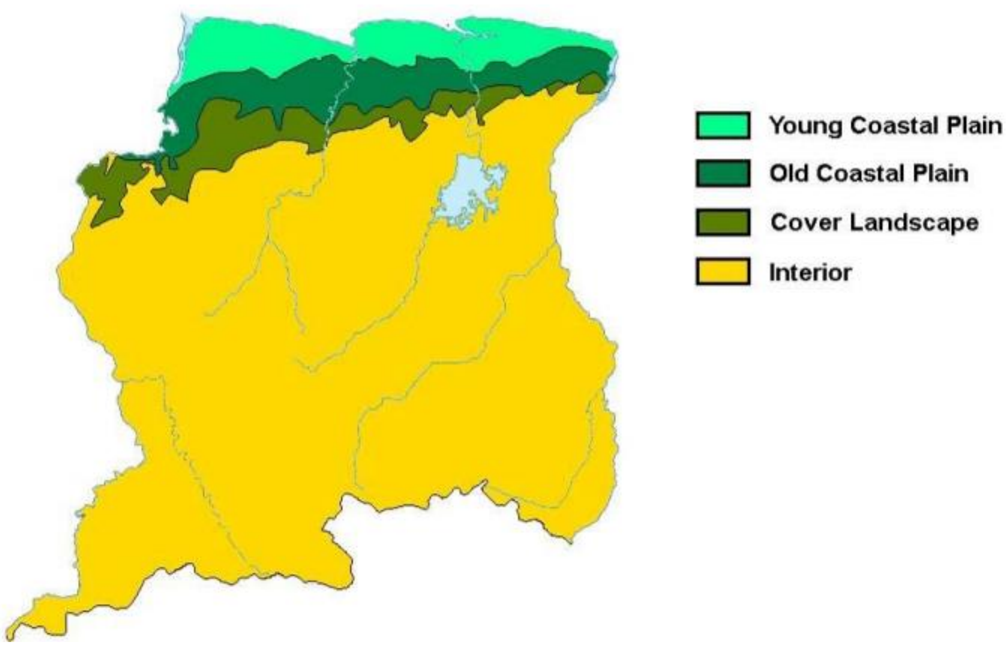

Figure 11. Geographic zone of Suriname (Bouterse, et al., 2017).

1. **Young Coastal plain**: Over 80% of Suriname's population lives in this region. Most of the permanent large-scale agriculture takes place in this region due to the landscape, which is characterized by brackish and freshwater swamps, sand and shell ridges and peat swamp. The soil is mostly characterized by heavy clay, with over 60% of clay-sized particles in different stages of maturity. It is at a thickness of 25 metres (m) near the coast, where lateral sedimentation is still taking place, fed by longshore currents transporting clay and sand from the Amazon River.

2. **Old Coastal plain**: This region consists of marine clay deposits and sand ridges, which are oriented in an east to west direction. The soil of this region is composed of clay, sandy-clay or clayey-sand, which is good for agriculture and is 4-10 m above sea level, on average.

3. **Savannah belt (cover landscape)**: This region consists of sediments of coarse bleached white sand and yellowish-brown sands to clay loams, ranging from 10-100 m above sea level. This area has a high infiltration and percolation rate and is less fertile; therefore, agricultural activities are limited to the cultivation of small-scale dry-area crops (example, pineapple). However, this area is very important for the maintenance of drinking water reserves, because the greatest amount of rainfall percolates into the ground, recharging freshwater aquifers, which are the main source of potable water in coastal areas.

4. **Residual hills (interior highlands)**: This area consists mainly of the deeply weathered pre -Cambrian crystalline basement complex of the Guyana shield. These soils are old and highly leached, making them very poor in plant nutrients and cation exchange capacity. The area covers over 80% of the country with tropical rain forest. The agricultural activities in this area are mostly limited to shifting cultivation.

B. Soil management for the cassava crop

Generally, cassava is cultivated in all regions of Suriname. However, 80% of the annual commercial cassava cultivation is limited to the young and old coastal regions (Johnson, 2018).

Cassava requires adequate space for tuber formation and is therefore best cultivated in loose (friable), well-aerated, well-drained soils with an abundance of available nutrients and good water holding capacity for healthy plant growth. The arrangement of solids and pore spaces within the soil refers to the structure of the soil. Pores in the soil structure are the gaps between the aggregates that are formed by organic matter and mineral ions (Soil Structure and its benefits, 2020). A well-structured soil has a continuous network of pore spaces, which allows drainage of water, free movement of air and unrestricted growth of roots.

This soil typically consists of 50% solid material, 25% air spaces and 25% water spaces, but varies according to soil type (Soil Structure and its benefits, 2020). To enhance the structure of the soil, farmers plough the land, which breaks up the solid clods and increases the number of air and water spaces. Ploughing should be done under dry conditions because under wet conditions the machinery causes compaction of the soil, which makes it less permeable to water (Figures 12 and 13) and increases the likelihood of soil erosion and flooding.

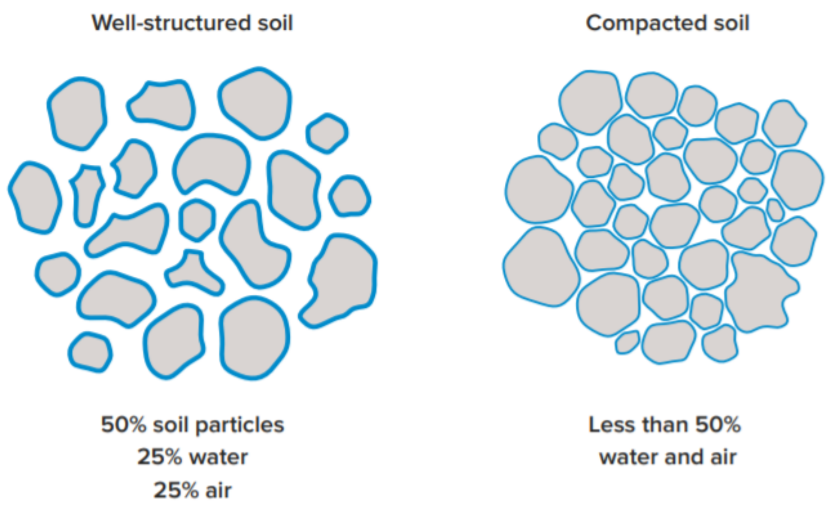

Figure 12. Graphical representation of well-structured soil vs compact soil (Soil Structure and its benefits, 2020).

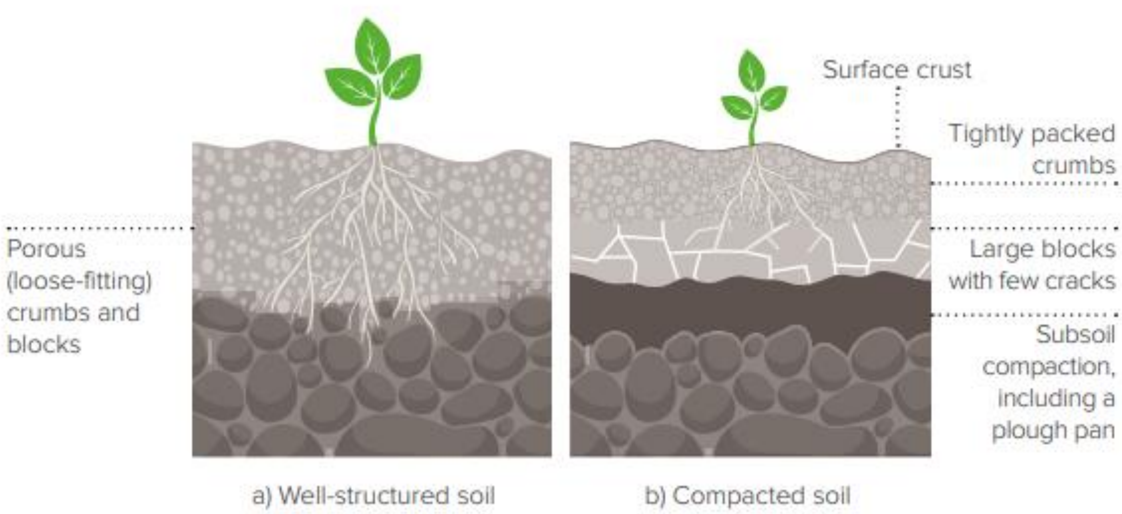

Figure 13. Graphical representation of a plant growing in well-structured soil vs compact soil (Soil Structure and its benefits, 2020).

C. Organic matter content

Figure 14. Humus layer in the upper top soil.

Generally, the soils in Suriname which are not yet in agriculture, have a high organic matter (humus) in the upper top layer (Figure 14). This layer has disappeared from areas that have been cultivated for several years, due to poor soil management practices. However, organic matter is linked to important functions in the soil and is critical to maximizing biological activity within the soil.

Organic matter is consumed by microorganisms as a food source; this promotes aggregation of soil particles, resulting in improved soil structure, soil water infiltration and water holding capacity. High organic matter in the upper top layer of the soil results in favourable soil temperature, improved plant root growth, healthy microbial population and moderate pH ranges.

To keep the soil healthy with a good structure, it is important to add organic matter to the soil after every planting cycle (Kalwar, 2017).

D. Soil pH

Although cassava can tolerate soil acidity, with pH ranging from 4.0 to 8.0, it grows best in a pH range of 5.5 to 6.5 (Titus, Lawrence & Seesahal, 2011). Acidic soils, have a three-fold negative effect on crop cultivation (Soil Structure and its benefits, 2020:

1. The availability of major nutrients such as nitrogen, phosphorus, potassium, sulphur, calcium, magnesium and trace element molybdenum are reduced and may be insufficient, resulting in poor root growth (Figure 15).

   Poor root growth restricts the ability of plants to explore sufficient soil volume to compensate for the reduced nutrient availability.

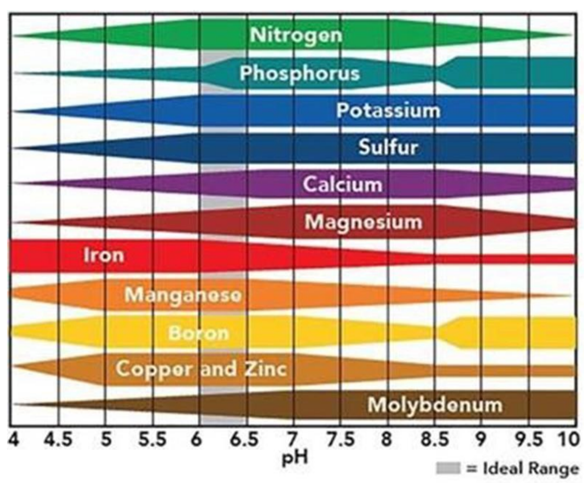

Figure 15. Nutrient availability in the soil based on pH (El Hadrami, 2019).

2. In highly acid soils (pH below 4.5), aluminum, which is toxic, becomes more soluble and is more available for the plant. Toxicity in the soil solution affects root cell division and the ability of the root to elongate. This results in deformed and brittle root tips and reduced root growth and branching.

3. In acidic soils, soil microbial activity is weakened. This affects the mineralization of the nutrients in plant-available forms, which limits plant nutrition uptake.

If the soil is acidic, it is very important to buffer the soil with lime ($CaCO_3$). Lime should ideally be added 3-4 months (minimum 2 weeks) before planting (Figure 16). The amount of lime is highly dependent on the soil type and the pH change that is required. To determine the amount of lime that should be added, the conduct of a soil test is highly recommended.

Figure 16. Applying lime to the soil, prior to rotovating the soil.

E. Crop production and maintenance practices

Crop production and maintenance practices that can enhance the soil structure and the organic matter are:

1. Crop rotation, including:
    - cover crops to provide soil cover to reduce evaporation, erosion, and water runoff;
    - perennial grasses to add above-ground as well as below-ground biomass;
    - legumes for green manure purposes; and
    - crops/plants that produce greater biomass.
2. Incorporate straw / crop residues.
3. Reduce tillage to minimize soil carbon losses and to slow organic matter decomposition processes.
4. Apply fertilizers (manure and sludge) on cover crops and legumes to produce more biomass.
5. Apply manure, plant material, or other carbon-rich waste.
6. Graze, rather than harvest forage.

4.2. Climatic conditions

Suriname has a tropical climate with abundant rainfall, uniform air temperature and a high humidity. The daily average temperature in coastal regions is 27 ℃. December and January are the coldest months, with average temperature of 26 ℃ while September and October are the warmest, with average temperature of 31 ℃. The overall variation in annual temperatures is very low (Bouterse, et al., 2017) (Idoe, 2010).

The tropical climate is dominated by the migration of the Inter-Tropical Convergence Zone (ITCZ). Therefore, four (4) seasons are observed (Bouterse, et al., 2017):

- Major wet season: May to July.
- Major dry season: August to October.
- Minor wet season: November to January.
- Minor dry season: February to April.

The El Niño and the La Niña phenomena also influence the climate, which causes inter-annual variations. El Niño is associated with dry conditions throughout the year, bringing warmer temperatures between June and August, while La Niña is associated with wetter conditions throughout the year, bringing cooler temperatures between June and August (Bouterse, et al., 2017).

Despite the known normal climatic conditions, Suriname is also impacted by climate change. Therefore, the known seasonal variation throughout the year is not 100% the same as past decades.

4.3. Water management

In Suriname, cassava is exclusively a rainfed crop, which can withstand drought periods during the later growing period. However, water requirement in the first three months after planting is critical. Insufficient water in this period has a negative effect on sprouting and reduces the growth of shoots and roots, which affects the eventual yield (Howeler, Lutaladio & Thomas, 2013).

To optimize the rainfed cassava production, careful attention to planting dates, use of planting methods and planting positions are required (Howeler, Lutaladio & Thomas, 2013). It is recommended that cassava should be planted at the beginning or middle of a rainy season. Once the plants are established, the roots will grow deeper as the topsoil begins to dry out with the arrival of the dry season and produce good yields.

Figure 17. Waterlogging in cassava field.

Planting towards the end of the rainy season results in lower yield, due to lack of water (Howeler, Lutaladio & Thomas, 2013). However, soil moisture content under rainfed conditions and planting methods need to be taken in consideration, because if the soil is not well drained and holds too much water due to heavy rains, the roots can rot and plants can die (Figure 17). In this case, it is recommended to plant stakes on top of ridges or mounds to keep the roots above the standing water, which will reduce the possibility of root rot (Howeler, Lutaladio & Thomas, 2013). It is also important to keep in mind that when planting in heavy and wet soils, stakes should be planted at a shallow depth of 5 to 10 cm and slightly deeper (> 15 cm) in light–textured and dry soils to avoid surface heat and lack of water (Howeler, Lutaladio & Thomas, 2013).

If a decision is made to plant at the end of the rainy season, or the minor rainy season is shorter due to climate change or in an off-season (dry), it is very important to irrigate the plants in the first three months after planting. In this case, the use of drip irrigation is recommended (Figure 18). Drip irrigation is more effective, in terms of its efficiency of water use, by providing small and frequent amounts of water, thus saving water while maintaining the soil moisture at a level that is highly favourable for plant growth (Howeler, Lutaladio & Thomas, 2013).

It should be noted that after the critical period, the cassava plant can still be watered, if necessary. This is found to have a positive effect on the root growth, achieving higher yields than fully rainfed production (Howeler, Lutaladio & Thomas, 2013).

Figure 18. Using drip irrigation in cassava field (Niphon, 2021).

Chapter 5. Cultural Practices

Cultural practices are an important part of the production of good quality cassava. Based on this, there are three key recommendations:

1. *Protect the soil structure, soil organic matter and overall soil health by limiting mechanical disturbance of the soil.*
2. *Maintain a protective organic cover on the soil surface, i.e. using crops and mulches to reduce soil erosion, conserve soil water and nutrients and suppress weeds.*
3. *Cultivate a wider range of plant species in association, sequences and rotations.*

Incorporating improved levels of soil organic matter and biotic activity, reducing pest and disease pressure, reducing erosion and increasing availability of crop water and nutrients, all serve to sustainably increase the yields while lowering the production cost.

5.1. Selection of land

Cassava can be cultivated on most soil types. However, the best soils for cassava cultivation are sandy clay loams that are well drained (James, et al., 2000). When identifying a location for sustainable cultivation of a crop, it is always important to consider the agricultural and socio-economic aspects. Some of these are (Teeltprotocol cassave: Para, 2014):

- Accessibility of the field in the wet and dry seasons;
- Soil type (well drained, good moisture-holding capacity and fertile);
- Irrigation opportunities;
- Water management of the area;
- Agricultural infrastructure of the area.

5.2. Land preparation

Land preparation is the first step in growing a successful crop. To allow optimal tuber development which can reach a depth of up to 20 cm, good soil preparation is required (soil for cassava production therefore needs to be prepared to a depth of at least 30 cm). This involves:

- Loosening of the soil – to allow infiltration / circulation of air and water and
- Decomposition of organic matter in the soil.

Land preparation should be done as follows:

i. Clear the field from grass, bushes and trees.
ii. Plough up to a depth of 25 - 30 cm. Ploughing breaks up the clods and exposes pest and diseases and weed seeds to direct sunlight. Ploughing should be done under dry conditions.
iii. After ploughing, the field can be rotovated to further break up the soil into a fine tilth (Figure 19). This makes it easier for the growing cassava roots to move through the soil. A fine tilth also encourages percolation of irrigation water and dissolved nutrients into the root room of the growing crop. At this stage, based on the soil results, lime and fertilizers can be applied (James, et al., 2000).

Figure 19. Rotovating the soil.

5.3. Prepare the seedbed

Depending on the soil type, there are three seedbed options:

a. *Flat plant beds and furrows*:

When planting on plant beds (Figure 20), the furrows should be 40-60 cm deep, for good drainage. The bed width differs depending on the soil type as follows (Teeltprotocol cassave: Para, 2014):

- Clay soil: maximum 6 meters
- Sandy soil: smaller than 10 meters
- Loamy soil: smaller than 8 meters

Figure 20. Flat plant beds.

b. *Ridges and furrows*:

For cassava production, it is recommended that the ridges are 25-40 cm high and 100 cm apart (Figures 21 and 22) (Teeltprotocol cassave: Para, 2014). This allows for easy drainage of excess water from the field as well as elevating the tubers, making harvesting significantly easier.

Figure 21. Plant bed preparation; making of the ridges.

Figure 22. Ridges formed 25 cm high and 1 meter apart.

c. Mounds

Mounds can be made in areas where waterlogging occurs or when planting in clay (Figure 23) (James, et al., 2000).

The level of tillage and type of seedbed required for cassava cultivation depends on the soil texture of the field (James, et al., 2000).

Figure 23. Planting cassava on mounds.

- For deep loamy soils, tillage is essential, and any seedbed type can be used. However, if the loamy soil is shallow and the cassava is planted on plant beds, the roots will reach the hard or rocky ground very quickly, which will result in poor yield.

- In sandy soils, minimum tillage is needed and planting cassava on the flat is appropriate, because the soil is sufficiently loose to allow drainage and good root development. When planted on ridges, the plants are not stable and can overturn. However, if the field tends to get waterlogged, then it is better to plant on ridges or mounds.

- In clay and poorly drained soils, tillage and planting on ridges or mounds is required, to limit the effects of waterlogging.

Considerations for mechanical planting

Mechanical planting is mostly used for large-scale operations. When mechanical planting is to be used, the field should be flat and oriented in such a manner that the tractor towing the planter / harvester can turn at the ends of the rows. The steepest acceptable gradient is seven degrees. Land preparation includes only ploughing and rotovating; there is no ridge and furrow formation. This will then necessitate the establishment of drains. It is important that the width of the planter / harvester is factored into the distance between drains, this will prevent wastage of arable space.

A mechanical planter buries the cuttings horizontally from 5 to 20 cm deep (Figure 24) (Titus, Lawrence & Seesahal, 2011). Depending on the type of planter, one (1) and to up to ten (10) rows can be planted at the same time and some planters also deliver chemical fertilizers during planting.

Figure 24. Two-row cassava planter.

5.4. Planting

To get the best sprouting and growth from cassava cuttings, it is important to plant the cuttings properly. There are three ways of planting cassava cuttings: vertically, horizontally, or at an angle (Figure 25) (James, et al., 2000).

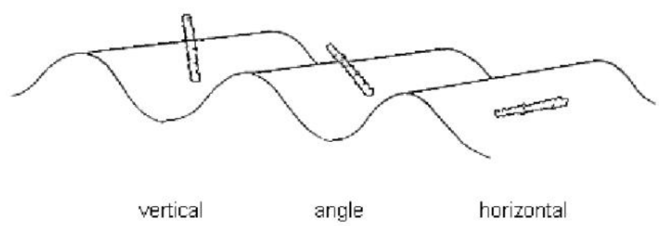

Figure 25. Illustration of cassava planting method.

Vertical planting should be done in sandy soils with 2/3 of the length of the cutting below the soil. In other soil types, the storage roots develop deeper in the soil, close together and are very difficult to harvest by pulling (James, et al., 2000).

The storage roots of horizontally planted cuttings develop closer to the surface and are more likely to be exposed and attacked by rodents and birds. Also, several weak stems develop from the cuttings and the cuttings can rot in wet conditions (James, et al., 2000). It is therefore recommended that cuttings are planted at an angle of 45^{o}, with only 2-3 nodes above the ground (Figure 26).

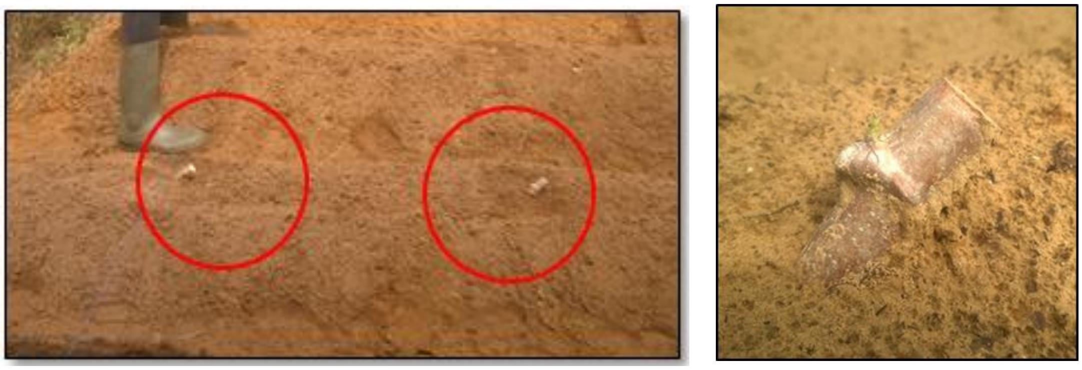

Figure 26. Cuttings planted at an angle of 45^o.

Cassava cuttings should be planted with a spacing of 1 m apart (James, et al., 2000). When planting on ridges, the plant spacing should be 0.9 - 1 m between the plants and 1 m between the ridges (Figure 27). For mounds, the same plant spacing as on flat land should be used.

Figure 27. Plant spacing of 1 m between the plants and 1 m between the ridges.

5.5. Supplement cuttings

In order to maximize the desired yields and minimize losses from the failure of establishment of cuttings, it is necessary to replace or supplement lost cuttings within three (3) weeks after planting the field (Dipotaroeno & Romero, 2015) (Teeltprotocol cassave: Para, 2014). After 3 weeks, it is too late to supplement the cuttings, because the new cuttings will be behind in growth and will need to be treated separately for observations and routine crop maintenance activities. This is not desirable.

5.6. Crop rotation

Research has shown that growing cassava as a monoculture crop year in and year out, reduces the soil fertility, water holding capacity and other soil properties, while intercropping or crop rotation in cassava cultivation system can improve soil fertility (Howeler, Lutaladio & Thomas, 2013).

Crop rotation is the practice of planting different crops sequentially on the same plot of land to improve soil health, optimize nutrients in the soil, and combat pest, diseases and weed pressure (Wijanarko & Purwanto, 2018). Crop rotation can take two forms:

- Crop rotation under continuous cropping. This involves continued use of the same parcel of land while alternating the crops grown from one season to the next or from one year to the next.
- Crop rotation nested in fallow. Fallow involves leaving the field unused for some time to enable soil fertility to build back up before reuse.

A farmer with just one field cannot do the latter form of crop rotation. So crop rotation is recommended under continuous cropping. Crop rotation under continuous cropping can consist of sequences from two to four different crops, keeping in mind that crops with the same pest and disease problems should not be planted in rotation (Ameu, et al., 2013) (Wijanarko & Purwanto, 2018).

A good rotation would be nutrient-demanding crops with soil-enriching legumes, and shallow-rooting crops with deep-rooting ones (Ameu, et al., 2013) (Figure 28)

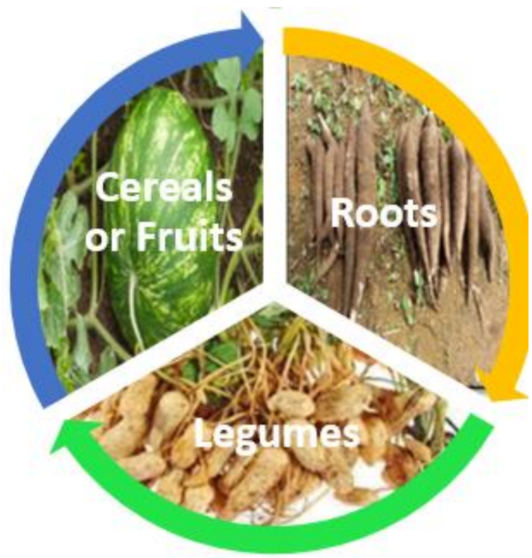

Figure 28. Example of Crop rotation.

Crop rotation can consist of:

- Two sequences : e.g. Cassava and maize or cassava and groundnut.
- Three sequences : e.g. Cassava, maize and groundnut.
- Four sequences : e.g. Cassava, maize, groundnut and melon or a vegetable.

Although no research has been done on this topic in Suriname, the changes in the soil's chemical and physical properties due to different cropping systems can have a positive effect on cassava yields. Research has shown that crop rotation of cassava had a higher yield than intercropping (Wijanarko & Purwanto, 2018). In Suriname, seasonal crop rotation with an appropriate alternate crop that has a better market price is recommended, because cassava does not fetch the same price every season.

Chapter 6. Agronomic practices during planting

Agronomic practices are very important during a cropping season. These are practices that farmers incorporate to improve soil quality, enhance water usage, manage crops and improve the environment.

Agronomic practices during a cassava crop cycle focus on better fertilizer management, weed management, irrigation / drainage and regular monitoring of the field.

6.1. Fertilizer requirement/application

Like any other crop, cassava plants require adequate amounts of the major nutrients – nitrogen (N), phosphorus (P), potassium (K) and magnesium – as well as other nutrients particularly, boron, manganese, zinc and calcium at specific times in the life cycle (Titus, Lawrence & Seesahal, 2011).

The requirement of the specific fertilizers is closely related to the growth phases of the cassava plant. There are two critical phases during the life cycle of the plant. The first phase is at 6-8 weeks after planting, when the thin and thick roots are being rapidly produced and can absorb the nutrients from the soil. The second phase is at 12-16 weeks after planting, when the tubers begin to bulk up and there is a high demand for sucrose, which is stored in the tubers. At this time, potassium is the most important fertilizer, because it helps in mobilizing the sucrose in the tubers where it is converted to starch (Titus, Lawrence & Seesahal, 2011). Decisions on the amount and fertilizers should be made using the following guidelines:

- Conduct a soil test on the nutrients and pH of the soil.
- Determine the amount of nutrients the cassava crop requires to produce high yields.
- Based on the results of the soil test and the required amount of nutrients for the crop, calculate the amount and type of fertilizer to add to the soil.

A soil test laboratory can usually provide details on crop nutrient / fertilizer needs, once it is informed of the crop that is to be planted. Or advice on the fertilizer application regime can be obtained from soil experts at research institutes and universities.

In general, the cassava plant grows best at a pH of 5.5 to 6.5, because at this pH nutrients become available for plant growth (Titus, Lawrence & Seesahal, 2011). When the pH is below 5.5, lime should be applied at least two weeks before planting (ideally 2-3 months before planting). The rate of application is dependent on the level of soil acidity.

Cassava is known to extract large amounts of nutrients from the soil. A general recommendation for soils that are moderately deficient in phosphorus and potassium is the use of a fertilizer with an NPK ratio of roughly 1:1:2 (Titus, Lawrence & Seesahal, 2011).

Excessive fertilizing of the cassava crop with nitrogen will cause excessive vegetative or leafy growth that will produce small tubers. Excessive nitrogen application may also lead to high cyanide content, which will result in bitter tubers. On the other hand, inadequate potassium also leads to excessive vegetative production at the expense of tuber growth (Titus, Lawrence & Seesahal, 2011).

Some key points to remember when fertilizing cassava are:

- Fertilizers should be applied 15-20 cm from the stem base in holes of 10-15 cm deep (Figure 29).
- The choice of fertilizer type and amount must always be calculated from the soil test results.

Figure 29. Applying fertilizer, prior to planting.

For example, the soil test of the Farmer Field School plot at Lelydorp showed that the pH was 5.2, with total N 0.12 parts per million (ppm), total P 188 ppm and total K 688 ppm. The dosage recommended by Dr. Gaius Eudoxie, Soil Specialist from The University of West Indies, Trinidad and Tobago, was as follows (Gajadien, Report of the Farmer Field Schools (FFS) to improve Cassava Production and Productivity in Suriname, 2019):

- Use lime (CaO_3) 1500 – 2000 kg/ha two weeks before planting;
- On the day of planting, apply the fertilizer NPK 12-24-12 (70 gram per stick);
- One month and three months after planting, apply the fertilizer N & K, in quantities of 15 grams of N per stick and 15 grams of K per stick.

The effects of the application of the recommended amount of fertilizer can be seen in in Figure 30.

Figure 30. Cassava plants fertilized (1) with no fertilizer vs (2) with the required amount of fertilizer based on recommendations from the soil test results.

6.2. Weed management

It is well known that weeds have a negative impact on the growth and development of the crop, because they compete with the cassava plants for water and nutrients. Therefore, weeds must be managed even before planting (Figure 31).

Figure 31. Manually removing weeds from cassava beds.

For this reason, land preparation should be done 2-4 weeks before planting, allowing the heat of the sun to kill the weed seeds (Titus, Lawrence & Seesahal, 2011).

The first three months after planting is the critical time to manage the weeds (Figure 32), because this is the period before the canopy closes over the soil surface (Titus, Lawrence & Seesahal, 2011). Also, some pests that live and feed on weeds can attack the young plants, which can have a negative impact in the sprouting and growth of the cassava cuttings.

Figure 32. Cassava plants about 2 ½ months old, which require weed management.

After this period, there are less weeds in the direct zone of the plant during the remaining crop cycle (Figure 33). For weed management, herbicides can be used, but are not recommended in order to meet the consumer demand for healthy, pesticide-free food.

Figure 33. Cassava leaf canopy closing over the soil.

The use of a combination of manual and mechanical methods is therefore recommended. Another method to prevent weeds from growing is the use of mulch.

6.3. Irrigation

In Suriname, cassava is a rain-fed crop. The cuttings are planted at the beginning of a rainy season and the tubers are harvested in the dry season. However, the critical water requirement period is the first three months after planting (Howeler, Lutaladio & Thomas, 2013). Insufficient water in this period has a negative effect on sprouting and reduces the growth of shoots and roots, which effects the eventual yield (Howeler, Lutaladio & Thomas, 2013). So the best period for planting cassava as a rainfed crop is at the beginning or the middle of a rainy season.

Planting towards the end of the rainy season results in lower yield, due to lack of water. In this case, drip irrigation can be used (Figure 34).

Figure 34. Using drip irrigation in cassava field (Niphon, 2021).

6.4. Regular crop monitoring

Regular monitoring is essential throughout the crop cycle. In the first two (2) months after planting, field visits should be conducted at least 2-3 times per week to check the following:

- Germination rate of the cassava cuttings.
- Whether any cuttings need to be substituted / supplemented.
- Whether the plants are being attacked by pests and diseases. In this case, the rate of attack is important, so that the plants can be treated accordingly.
- Whether irrigation is required.

After two months, the cassava field can be visited every week or every two weeks to monitor the growth of the plants, and the incidences of pest and diseases.

Chapter 7. Pest and Disease Management

Cassava fields in Suriname are relatively free from pests and diseases. However, no research has been conducted on this topic, because no severe incidences have been reported. Pest and disease management depends on the type and severity of infestation. Many cassava pests and diseases can be spread by distribution and planting of infested or diseased stem cuttings. The first management strategy should always be prevention. The prevention measurements are:

- *Assure phytosanitary quality of the planting material: use disease-free cuttings;*
- *Sanitize field tools;*
- *Conduct crop rotation;*
- *Control weeds.*

In general, several pests (insects and diseases) are known to attack cassava, these are summarized in Table 1.

Table 1.*Pest (insect and diseases), which can attack cassava (Dowlath, 2014).*

Insects	Diseases
Thrips	Cassava bacterial blight
Chinch Bug	Super elongation
Cassava shoot fly	African mosaic disease
Mites	Bacterial stem rot
Cassava hornworm	Tuber rot
Whiteflies	Anthracnose
Mealy bugs	Brown leaf spots
Grasshoppers	Cassava brown streak disease
Termites	Witches broom
Fruit flies	Cassava ash
Leaf cutting ants	Rust
Lace bugs	Concentric ring leaf spot
Cutworms	Root smallpox disease
Scale insects	Bacterial stem gall
Gall midges	White leaf spot
White grubs	Frog skin disease

Although no incidences of pest and diseases that can have a severe impact on the yield are reported (with the exception of the cassava frog skin disease), there are a few pests that are seen infrequently in the fields. These are described below.

7.1. Insect pests of cassava

1. Thrips

There are several species of thrips, of which two are of economic importance (Dowlath, 2014):

- *Corynothrips;*
- *Frankliniella*.

Thrips are found on the growing points of the plant (Figure 35). The species *Frankliniella* and *Corynothrips* are yellow in color and about 1.1 mm to 1.5 mm in size. They deposit their eggs on the underside of the leaves on the midrib (Titus, Lawrence & Seesahal, 2011).

Figure 35. Thrip species Frankliniella (Jagroep & Matau , 2020).

Thrips damage the crop mostly in the dry season. Because they feed on the veins of the leaves, the young leaves become deformed and irregular yellow spots are visible. Brown wound tissue appears on stems, and petioles and parts of leaf lobes are missing due to cell damage. The internodes become shorter, the growing points may die and lateral buds start to grow, giving rise to a "Witches Broom" appearance (Dowlath, 2014) (Titus, Lawrence, & Seesahal, 2011).

The pest can cause a reduction in the yield from 5 – 30% (Dowlath, 2014) (Titus, Lawrence & Seesahal, 2011).

2. Cassava shoot fly

Shoot fly affects the shoots in young cassava plants, thereby affecting the growth. The female flies lay their eggs in the terminal shoots. The larvae hatch and penetrate the stem and settle in the first 5 cm of the shoot tissue. The larvae chew into the soft tissue of the plant and kill the growing tip. Whitish larvae present in the affected shoots often kill the apical buds, retard the normal growth of young plants and induce the production of lateral buds (Figures 36 and 37) (Alavez, et al., 2012) (Gisloti & Prado, 2011).

Figure 36. Cassava shoot fly infestation.

Figure 37. Cassava shoot fly infestation.

Shoot fly damage seems to be restricted to stem production, without impairing tuber yield. Heavy infestations occur in the beginning of the rainy season on young plants. Mature plants do not suffer as much, because the shoot fly females select soft, malleable buds in which to oviposit, so as to enable their larvae to pierce the plant tissue more successfully (Alavez, et al., 2012) (Gisloti & Prado, 2011).

Generally, the adult shoot flies live in and feed on weeds, so weed control is the most important step in managing the pest.

3. Leaf cutting ants

Figure 38. Damage caused by leaf-cutter ants (Alavez, et al., 2012).

The ants cut semi-circular pieces of leaves and sometimes remove the buds and carry these back to their nest (Figure 38). They leave tracks marking their pathway to easily find the way back to their nest holes that can be far away from the site where they cause the damage (Alavez, et al., 2012).

Outbreaks usually occur during the first month of crop growth. In severe cases, the plants may be completely defoliated. Incidences of this pest have been reported in the interior of Suriname. Toxic insecticide baits are the most effective means of control.

4. Cassava hornworm

Figure 39. Cassava hornworm (1) larvae, (2) pre-pupa and (3) adult.

The cassava hornworm, *Erinnyis ello* is a pest that eats and destroys the cassava leaf (Figure 39). The first signs of an infestation usually are many holes on the young leaves, followed by damage on more mature leaves.

In severe situations, the complete fields are defoliated in a short time. This may not be serious once the cassava crop has matured. But if young, growing plants are attacked, the yield can be reduced and the plants can even die (Alavez, et al., 2012).

To control this pest, the use of formulations containing *Bacillus thuringiensis* (BT) and the pyrethroid Lambda-cyhalothrin has been recommended.

5. Gall mites

Small midge flies usually induce galls on cassava leaves. The galls are generally found in the upper surface of the leaf where the flies lay their eggs. Feeding by the larvae causes abnormal cell growth, forming galls. The galls are yellowish green to red in color (Figure 40). When opened, a cylindrical tunnel can be seen inside, surrounding a small yellow larva. Severe outbreaks usually retard growth (Alavez, et al., 2012). In Suriname, no severe outbreak has yet been reported.

Figure 40. Gall mites on cassava leaf.

7.2. Diseases of cassava

1. Cassava bacterial blight

Cassava bacterial blight is caused by the probacterium *Xanthamonas axonopodis* pv manihotis (Howeler, Lutaladio & Thomas, 2013). Yield loss due to this disease ranges from 20-100% (Dowlath, 2014).

Figure 41. Cassava bacterial blight (Celos, 2016).

Symptoms

The bacterium infects the leaves first, causing them to turn brown in large patches and eventually die (Figure 41). Later stages affect the vascular tissue of the petioles and the woody stem. Heavy attack causes defoliation and the stems and roots show brownish discoloration (Alavez, et al., 2012) (Howeler, Lutaladio & Thomas, 2013).

Transmission of the infection takes place (Alavez, et al., 2012)

- from the use of infected planting material or farm tools
- from plant to plant by rain splash
- by movement of people, machines or animals from infected fields to healthy fields

Management (Howeler, Lutaladio & Thomas, 2013)

- Obtain healthy planting material
- Plant varieties of cassava that are resistant / tolerant to bacterial blight disease
- Carefully check for the presence / absence of the disease in the roots at harvest time
- Carefully select the planting material that will be used for the next crop
- Assure phytosanitary quality of the planting material during storage and at planting
- Induce tolerance through optimum fertilizer management
- Manage waste and residue by eliminating all infected material

2. Cassava Frog Skin Disease

The presence of this disease is confirmed in some production areas in Suriname. Studies suggest that cassava frog skin disease is associated with a phytoplasma (Bacteria Gram without cell wall and restricted to the phloem). The disease can cause losses of up to 100% of the production, because it directly affects the accumulation of starch, the quality of roots and consequently, the yields obtained from the cassava crop by farmers (Alvarez & Ospina, 2020).

Symptoms

The symptoms of the disease are only visible at harvest time. The tuberous roots have a corky corrugation, while the peel becomes thicker, breakable, and more difficult to peel off from the roots (Figure 42 and 43).

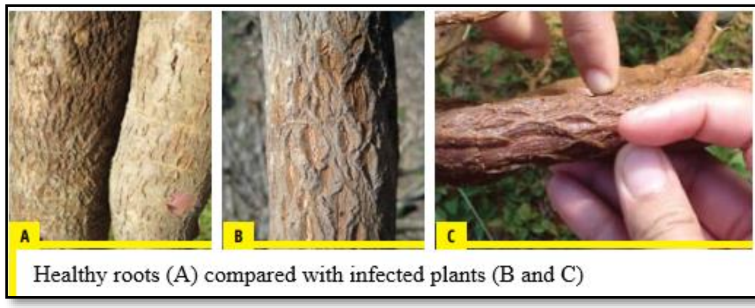

Figure 42. Cassava frog skin disease (Alvarez & Ospina, 2020).

The peel of the roots presents lip-like slits that joined together, create a honeycomb pattern. On the tuberous roots, deep lesions are visible, which reduce their diameter (Alvarez & Ospina, 2020).

Stems of cassava plants infected with frog skin disease tend to be thicker, due to the accumulation of the products of photosynthesis in the leaves and stems of the plants, rather than being translocated to the roots (Alvarez & Ospina, 2020).

Figure 43. Infected roots with frog skin disease.

Dissemination of the disease

Disease dissemination is very rapid when cuttings are taken from infected plants. The disease is not transmitted through the soil, but through vectors from some leafhopper insect families such as *Scaphytopius marginelineatus* (Cicadellidae). These insects acquire the disease from infected plants and successfully transmit it to healthy plants (Alvarez & Ospina, 2020).

Management (Alvarez & Ospina, 2020)

- Obtain healthy planting material
- Plant cassava varieties resistant / tolerant to cassava frog skin disease – some varieties have recently imported into Suriname and are currently being tested
- Carefully check for the presence / absence of frog skin disease in the cassava roots at harvest time (Figure 44)
- Carefully select the planting material that will be used for the next crop (Figure 45)
- Assure phytosanitary quality of the planting material
- Induce tolerance through optimum fertilizer management
- Manage waste and residue by eliminating all infected material
- Use thermotherapy as a technique for the production of healthy planting material

Figure 44. Careful checking for the presence or absence of the disease at harvest time (Alvarez & Ospina, 2020).

Figure 45. Careful selection of planting material (Alvarez & Ospina, 2020).

7.3. Animals impacting cassava (wild rabbit)

In Suriname, cassava roots can be attacked by wild rabbits, which eat the roots and in severe incidents this may cause a yield reduction of up to 50% (Figure 46). When planting near forested areas, the field can be planted with cassava as edge plants. In this case the rabbits will not attack the middle plants from which the farmer will obtain his crop.

Figure 46. Damage caused by wild rabbits.

Management

- Plant at least two rows of cassava edge plants
- Use rabbit traps

Chapter 8. Harvest and post-harvest practices

Harvest and post-harvest practices are very important in cassava production, because cassava is highly perishable and begins to deteriorate within 1 - 3 days after harvest. When harvesting, care should be exercised to minimize damage to the roots. The key to ease of harvesting is the proper preparation of the land prior to planting. Post-harvest practices, particularly correct handling, play a very important role in improving the quality and shelf life of fresh cassava.

8.1. Harvesting

The most important and critical phase of cassava production is harvesting, because cassava is a highly perishable crop and begins to deteriorate as early as 1-3 days after harvest (Amponsah, Addo & Gangadharan, 2017). Therefore, it is important to harvest cassava at the right time, depending on the variety, between 6 and 18 months (Titus, Lawrence & Seesahal, 2011) and in the appropriate manner. When cassava is harvested too early, it results in low yield and poor quality of fresh tubers, and when the roots are left too long in the soil, they become woody and inedible. Cassava is ready to harvest from 6-7 months, when the roots are large enough. The roots are clustered around the base of the plant and extend about 60 cm on all sides (Amponsah, Addo & Gangadharan, 2017).

A good harvesting practice is to cut back the stems about 2 weeks before harvesting, leaving only 20-25 cm of the stem sticking out from the ground. This practice allows the sugars in the tuberous roots to convert to starches and results in a cassava that will not deteriorate or rot as easily (Titus, Lawrence & Seesahal, 2011).

The problems with harvesting are the shape, distribution and depth of penetration of the tubers in the soil, as well as the type, texture, and water holding capacity of the soil. The key to ease of harvesting is the proper preparation of the soil prior to planting. In general, there are a few cassava-harvesting methods, namely manual, semi-manual and fully mechanized.

1. <u>Manual harvesting</u>

Cassava planted in sandy soils is easy to harvest by hand even in dry conditions, because the soil is loose and the farmer can easily uplift the plant with minimum damage. Cuttings that are planted horizontally, enable the tuberous roots to be produced closer to the soil surface. In this case, the farmer can physically uproot the plant with a minimum of broken roots (Figure 47) (Titus, Lawrence & Seesahal, 2011).

Figure 47. Manual harvesting of cassava.

In sandy loamy to clay soils, the soil must be loosened first with a hayfork. It is suggested to plant at a 45^{o} angle to minimize damage, by sticking in the ground at the proximal end of the plant where the stem emerges from the ground, because the tuberous roots are produced at the distal end, away from the stem (Titus, Lawrence & Seesahal, 2011).

2. Semi- manual harvesting

This type of harvesting utilizes tools that usually adopt the lever principle to ensure that little human effort is used in uprooting the cassava.

A pole about 2 m long is securely attached to the stem, with one end on the ground and the other serving as a lever to pull up the plant and tubers (Figure 48) (Amponsah, Addo & Gangadharan, 2017).

Figure 48. CTCRI (Central Tuber Crops Research Institute, India) harvester (Amponsah, Addo & Gangadharan, 2017).

3. Mechanical harvesting

Mechanized planting and harvesting of cassava tubers are the two major operations that can significantly reduce the cost of production. The cassava harvester (Figure 49)[3], is attached to the back of a tractor, can harvest two rows simultaneously and must be used under dry conditions. Before harvesting, first the stems need to be cut, leaving only 20 – 25 cm of the stem sticking out from the ground (Figure 49) (Amponsah, Addo & Gangadharan, 2017). After harvesting with the harvester, the roots still need to be cut off from the stem with a sharp cutlass and moved out of the field.

Figure 49. Cassava harvester (left) and cassava harvested with the cassava harvester(right).

[3] Introduced to Suriname under the project "Cassava Industry Development - Market Assessment and Technology Validation and Dissemination".

8.2. Post-harvest handling

Proper post-harvest handling of freshly harvested cassava root is essential. Rapid physiological deterioration of the root soon after harvest confers limited shelf life and creates poor utilization of the cassava root (Uchechukwu-Agua, Caleb & Opara, 2015). The mechanical damage or physiological deterioration causes blue–black vascular streaking, which makes the roots unpalatable and unmarketable within a few days after harvest. The presence of wounds also increases respiration, which in turn increases heat; both contribute to the development of vascular streaking (Figure 50) (Titus, Lawrence & Seesahal, 2011).

Figure 50. Example of vascular streaking (Titus, Lawrence & Seesahal, 2011).

Cassava is very sensitive to water loss. Methods used to maintain high relative humidity during storage include moist sawdust and plastic films, which can extend shelf life (Mlingi & Ndunguru, 2007). This means that post-harvest handling process starts the moment cassava is harvested, from uprooting / lifting the roots to transporting the harvested roots to consumers as fresh cassava or to processors for different processing methods and uses.

Overall, in Suriname, cassava is harvested manually and filled in woven polypropylene plastic (PP) sacks to transport for different purposes, without any selection or cleaning of the tuberous roots. Although no research has yet been done on the post–harvest handling of cassava and its impacts in Suriname, some suggestions are made based on the literature to extend the shelf life of fresh cassava.

1. <u>Cleaning of roots</u>

The basic steps for a good post-harvest handling start with handling and cleaning of the roots:

1. Harvest cassava roots carefully with the roots intact to the stem;
2. Remove the roots with a sharp cutlass, without causing any damage;
3. Wash and brush off all soil from the roots;
4. Separate damaged and undamaged roots;
5. Use a sharp knife to make smooth cuts in damaged surfaces and set them aside;
6. Unmarketable tubers must be removed.

Unclean roots have risk of spoilage by microorganisms or pest larvae, which can enter the roots. In addition, decaying tubers can infect healthy tubers, which may result in further, at times total loss.

2. <u>Post-harvest treatment of roots</u>

After the roots are cleaned, several post-harvest treatments can be done (depending on the intended use of the roots) to extend the shelf life (Mlingi & Ndunguru, 2007).

Example 1: Washing and disinfecting

- Dip the roots for about one minute in clean water, allowing them to absorb the water;
- Place the woven PP sacks in a shaded area;
- If using woven PP sacks, wrap with plastic sheets.

When the roots are treated with an appropriate fungicide after the water treatment, the fresh roots can be stored for up to two weeks. The above-mentioned post-harvest treatment also gives processors time to process the roots to the desired product.

Example 2: Waxing

Wax the roots with paraffin or water-based carnauba wax (Figure 51). Storage at a temperature of 0 ºC to 5 ºC can extend the shelf life up to 30 days (Raemakers, et al., 2007).

Cassava tubers can then be cured or waxed, or stored in a simple, modified atmosphere environment. All of these measures are designed to reduce postharvest losses of both quality and quantity.

Figure 51. Waxed cassava.

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Chapter 9. Cassava farmer field school – Suriname case study

Some of the best practices for cassava production that are outlined in the various sections of the Manual were demonstrated to cassava farmers in the two agro-ecological zones of Suriname. This was done through two season-long Farmer Field Schools (FFSs) that were established in Lelydorp (Wanica) and Maho (Saramacca) during 2019 and 2020/21, respectively.

A farmer field school (FFS) is a season-long non-formal education programme conducted on a crop in farmers' fields. The activities follow the different developmental stages of the crop and related management practices. The process is learner-centered and participatory, and relies on an experiential learning approach, which entails the following (Ameu, et al., 2013)*:*

- *Involvement of a group of farmers*
- *Field-based experience*
- *Duration of one cropping season: from land preparation and seeding / transplanting to harvest and at times to post-harvest and marketing in annual crops*
- *Regular meetings among FFS participants during the cropping season*
- *At each session, Agro-ecosystem analysis (AESA) activity conducted in the field*
- *A study (by participants) comparing improved and conventional practices*
- *Other field studies, based on local problems*
- *A 'Topic-of-the-day' dealing with specific issues selected by participants*
- *Group dynamics and team-building exercises to enhance cooperation and collaboration*
- *Guidance from at least one facilitator offering experiential learning opportunities (not delivering top-down instructions)*

9.1. What is the farmer field school?

A farmer field school (FFS) brings together groups of farmers in order to strengthen their skills and knowledge in agro–ecosystems to make informed decisions on crop and field management. It provides a space for hands-on practical learning in the field for the duration of a cropping season (Gajadien, 2019) (Gajadien, 2021).

FFS is a participatory approach to extension, whereby farmers are given the opportunity to make choices in production methods through a discovery-based learning approach. A group of farmers meets regularly throughout the cropping season to experiment with new production options versus their individual, traditional methods. It is anticipated that at the end of the field school, farmers continue to meet regularly to experiment, learn and share information, with less contact with extensionists (Gajadien, 2019) (Gajadien, 2021).

FFS aims to increase the capacity of farmer groups to test new technologies in their own fields and assess the results and the relevance of those results to their specific circumstances.

The FFS encourages farmers to interact on a more demand-driven basis with the researchers and extensionists providing support and possible solutions where they are unable to solve a particular problem among themselves (Gajadien, 2019) (Gajadien, 2021).

9.2. Objective of farmer field school

The overarching objective of the FFS is to bring farmers together to carry out collective and collaborative inquiry with the purpose of initiating community action in solving community problems (Gajadien, 2019) (Gajadien, 2021).

The specific objectives of FFS are (Gajadien, 2019) (Gajadien, 2021):

1. To empower farmers with knowledge and skills to make them experts in their own fields.
2. To sharpen the farmers' ability to make critical and informed decisions that render their farming profitable and sustainable.
3. To sensitize farmers in new ways of thinking and problem solving.
4. To help farmers learn how to organize themselves and their communities.

9.3. Creating capacity for farmer field school

To deliver a quality farmer field school, the skills of the facilitator are very crucial (Ameu, et al., 2013). The skills are:

- Technical,
- Methodological and
- Organizational.

It is therefore necessary to invest in training facilitators in every country where FFS is offered.

9.4. Approach

In Suriname, two sites were selected for hosting the cassava FFS. The first FFS was held from January to November 2019 in the Wanica district (Lelydorp) and the second was held from August 2020 to April 2021 in the Saramacca district (Maho), with 11 and 9 cassava farmers respectively (Gajadien, 2019) (Gajadien, 2021).

Prior to each FFS, intensive 3-week Training-of-Trainer (TOT) sessions were held for Extension and Technical personnel by a local FFS Master Trainer, Mr. Nareen Gajadin (Figure 52 and 53) (Gajadien, 2019) (Gajadien, 2021).

During the TOT, the participants were introduced to use of participatory methods and how to conduct FFS sessions. They received technical knowledge on cassava production as well as the soft skills needed to become FFS facilitators. The number of persons trained in the two sessions was 22 and 14, respectively (Gajadien, 2019) (Gajadien, 2021).

The trained personnel then conducted the two field schools at Wanica (2019) and Saramacca (2020/21) under the expert guidance of the Master Trainer and the National Project Coordinator, Mr. Chanderdew Kesharie, assigned by the MAAHF with administrative support from Ms. Aartie Pachai.

Figure 52. Training of Trainers (2019) – Technical and extension personnel trained in classroom (left) and field (right) sessions.

Figure 53. TOT (2020) – Participants trained in classroom (left) and field (right) sessions, following COVID guidelines.

The FFS training was field-based, from land preparation through to harvest using non-formal adult education methods. Specific aspects of the FFS sessions are as follows (Gajadien, 2019) (Gajadien, 2021):

- Each FFS was carried out at a host farmer's field.
- A soil test was conducted prior to land preparation and results sent to Dr. Gaius Eudoxie, Soil Scientist at The University of the West Indies (UWI), Trinidad and Tobago for recommendations on the fertilizer application regime.
- The FFS was scheduled for two sessions per month until harvest.

- The field was divided into a Best Practice (BP) plot and a Farmer Practice (FP) plot. The BP plot was prepared to demonstrate (i) improved land preparation (Figure 54) with fertilizer applications based on recommendations from soil test results (Figure 55) and (ii) cuttings planted on ridges at a 45° angle (Figure 56).
- The FP plot was prepared based on the method that farmers use and managed according to the cropping calendar compiled by the farmers themselves. In Wanica district no fertilizers were applied to the plants and the cuttings were planted horizontally on a flat plant bed. In Saramacca district the FP plot was fertilized according to the compiled cropping calendar and the cuttings were planted on an angle on a flat plant bed.
- Field maintenance, application of fertilizer (Figures 57 and 58), data collection, analysis and presentation (Figures 59 and 60), and group dynamics activities (Figure 61) took place during the scheduled FFS days. Progress of the crop growth was discussed during the presentations and decisions taken by the group accordingly.
- Some activities like field observations (Figure 62) and pest management were executed as required during non-FFS days.


Figure 54. FFS BP plot preparation – Wanica (left) and Saramacca (right).


Figure 55. Planting at 45° angle in BP plot: Wanica (left) and Saramacca (right).

Figure 56. Fertilizer application at planting in BP plot: Wanica (left) and Saramacca (right).

Figure 57. Maintenance of FFS field plots - Wanica (left) and Saramacca (right).

Figure 58. Fertilizer application in BP plots – Wanica (left) and Saramacca (right).

Figure 59. AESA observations in field plots – Wanica (left) and Saramacca (right).

Figure 60. AESA observations - Wanica – (A1) drawing and (A2) presentation and Saramacca – (B1) presentation (B2) and drawing.

Figure 61. Group dynamics activities.

Figure 62. Field observations – leaf galls caused by a midge fly (left) and root damage caused by an animal (right).

<u>Specific activities conducted at the FFS sessions:</u>

Session 1:

- Introduction;
- Formation of two host teams;
- Levelling of expectations (what is the aim of the FFS and what the farmers expect from it);
- Validation of the baseline survey information in order to prepare the cropping calendar;
- Discussions about the land preparation and field plan (design/layout)

In addition, farmers made some valuable suggestions for the design and layout of the FFS plot. It was agreed that planting would be done on the third FFS day.

Session 2:
The cropping calendar was compiled and preparations were made for planting of the cassava on the third FFS day.

Session 3:
Cassava cuttings were planted on the BP and FP plots.

Session 4:
The method of Agro-ecosystem analysis (AESA) was introduced to the farmers. To collect the AESA data in Wanica district five (5) randomized plants were tagged and in Saramacca district 15.

Data was collected for the plant height, number of leaves, number of branches, number of dry leaves, number of leaves with spots, insects, diseases, pests, weed and damage.

From Session 5 onwards, the following main activities were undertaken – AESA, presentations and discussions, special topics related to crop and post-harvest management, group dynamic activities, field planning and evaluation of the FFS.

At the last session of the FFS the cassava was harvested (Figure 63) and data was collected (see Table 2 and 3 for the measurements).

A Graduation Ceremony was held as the final activity, at which the TOT participants and farmers received certificates of participation. The farmers also received and a small token of appreciation (Figure 64).

Figure 63. Harvesting of cassava at Saramacca.

Figure 64. FFS Graduation ceremony – Wanica (left) and Saramacca (right).

9.5. Results of the cassava farmer field schools

i. Lelydorp, Wanica district (2019)

Data collected at harvest for the two varieties is presented in Table 2 (Gajadien, 2019).

***Table 2**. Performance of two varieties in the FFS at Lelydorp (Wanica) (Gajadien, 2019).*

Measurements (per plant)	Best practice		Farmers practice	
Variety	**WZ**	**T**	**WZ**	**T**
Average number of tubers	8.9	9.2	9.7	7.5
Average weight tubers (kg)	0.29	0.32	0.18	0.15
Average length of the tubers (cm)	12.4	22.7	18.7	17.0
Average circumference of the tubers (cm)	12.5	19.3	8.2	12.1

For the variety Weg naar Zee (WZ), the number of tubers harvested in the BP plots was lower than the FP plots, but the circumference, weight and length of the tubers were higher in the BP plots. For Troeli (T), all measurements in the BP plots had higher values (Gajadien, 2019).

This demonstrated to the farmers that the planting method and fertilizer application had a positive effect on the development of the tubers in the BP plots.

ii. Maho, Saramacca district (2020 / 2021)

A locally popular variety was tested in both FP and BP plots. At harvest, additional data was collected on plant height, number of leaves, canopy width, and number and diameter of branches. Results (Table 3) showed that for nearly all the parameters, performance of the plants in the BP plot was far superior to that of the FP plot. Total marketable yield in BP plots was five sacks, compared to two sacks in the FP plots (Figure 65) (Gajadien, 2021).

***Table 3.** Performance of the local variety in the FFS at Saramacca (2020-21) (Gajadien, 2021).*

Measurements (per plant)	Best practice	Farmers practice
Average plant height (cm)	332.9	270.3
Average number of branches	3	2
Diameter of the branches (cm)	3.6	2.4
Average total number of tubers	10	12
Average weight tubers (kg)	5.9	3.3
Average number of marketable tubers	8	5
Average weight marketable tubers (kg)	5.4	2.2
Average length marketable tubers (cm)	31.3	27.2
Average diameter marketable tubers (cm)	5.9	4.5

Figure 65. Total marketable yield in sacks, five of the BP plot (left) and two of the FP plot(right).

Conclusion

The objectives of demonstrating improved crop management practices to farmers for increasing cassava yields in a sustainable manner and the dissemination of new production technologies using participatory extension methodologies were successfully achieved.

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