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Comparison of raised versus non-raised beds as an alternative agricultural practice for eggplant and cabbage on an agricultural field with water intrusion at the 'Weg Naar Zee' Area

By
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A thesis submitted to the Anton de Kom University of Suriname, Faculty of Technology, Suriname, in fulfillment of the requirements for the degree of
Master of Science (MSc) in Sustainable Management of Natural Resources

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Preface

This thesis concludes my Master of Science Education in Sustainable Management of Natural Resources at the Anton the Kom University of Suriname.

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My deepest gratitude goes to my beloved parents, sister and my husband for their moral support and prayers during my journey in completing this study.

Lastly, I would like to thank everyone who has contributed to this research.

Sarah-Eve D. Renfrum

Paramaribo, 2020

Summary

Every year agricultural land becomes unavailable for agriculture production due to soil salinity. Salt water intrusion is one of the causes of soil salinity. When the salinity in the plant exceeds a certain threshold, it results in negative effects on the plant. This makes agriculture a vulnerable sector to be affected by salt water intrusion. The aim of this research was to investigate the impact raised and non-raised beds have on crop production and plant performance of eggplant and cabbage on an agriculture field with salt water intrusion. At the ‘Weg naar Zee’ area a research investigation was conducted on cabbage and eggplant. These crops were both cultivated on plots of raised and non-raised beds. To study the impact of the raised versus non-raised beds on an agricultural field with water intrusion, descriptive statistics were used. Soil and water samples, plant growth and harvest data were measured and observed. The results indicated that the non-raised beds experienced flooding but the raised beds did not. Both the raised and non-raised beds of eggplant have grown and given fruit. But for cabbage, the crop only grew fully on the raised-beds. The eggplant on the non-raised beds experienced early plant death. From the results can be stated that the crops on the non-raised beds had a lower plant performance in plant growth and in the harvest. At the ‘Weg naar Zee’ area where flooding occurs, cabbage and eggplant are best grown on raised beds. It is recommended that future studies focus on other methods to eliminate or minimize the effects soil salinity and flooding have on vegetable crops. Also studies in which species of crops are best suited to grow in soils with high salinity level and flooding.

Keywords: *soil salinity, raised and non-raised beds, flooding, plant performance, cabbage and eggplant.*

December, 2020.

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List of symbols and abbreviations

NSP	Normaal Surinaams Plein (national reference plane for Suriname)
FAO	Food and Agriculture Organization (of the UN)
SWM	Surinaamsche Waterleiding Maatschappij
pH	pondus Hydrogenium
EC	Electrical Conductivity
CEC	Cation Exchange Capacity
dS/m	deciSiemens per metre
ADEKUS	Anton de Kom Universiteit van Suriname
LVV	Ministerie of Landbouw, Veeteelt en Visserij
CO_2	Carbon dioxide
N	Nitrogen
P	Phosphorous
K	Potassium
SOC	Soil organic carbon
SOM	Soil organic matter

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1. Introduction

1.1 Background information

Soil salinity is one of the major constraints in of crop production in the world because throughout the world thousands of hectares of land becomes unavailable for agriculture production every year. It has been estimated that about 50% of the irrigated area of the world will be salinized or potentially effected by salinity in the year 2050. Salinity problems can be severe if precipitation is not sufficient (Shrivastava & Kumar, 2014). One of the causes of soil salinity is salt water intrusion. Agriculture can be both a contributor and victim of this process when looking at the large water demand for irrigation and the direct relationship between yield and salt concentration, especially in low situated coastal areas. Agriculture is the largest consumer of freshwater and the rate is still increasing. Plant effects of salinity may differ for crops but when the salinity increases to the level above the limit that the plant can bear, the yield will decrease and in worst cases the plant will die. This makes agriculture a vulnerable sector that is prone to be affected by salt water intrusion. Salinity is one of the most significant factors that constrain crop production (Duan, 2016).

Eggplant (*Solanum melongena* L.) is a herbarceous plant[1] from the Solanacae family, with an annual cycle. This crop is cultivated in many tropical, subtropical and Mediterranean countries. However, there is a conflict in the literature on the salinity level that the plant can tolerate. Some literature classifies its salinity tolerance as moderate and others as salt sensitive. This difference in its tolerance can be related to the varieties used and environmental conditions of those studies (Ali, Ahmet, Guluzar, Engin, & Donald, 2008). The type of soil can also have some influence on the sensitivity of the plant (Tanji & Kielen, 2002).

Cabbage (*Brassica oleracea* L.*)* belongs to the mustard family Brassicaceae. Several varieties from the wild cabbage have been developed through cultivation. The variety of cabbage that has been used in this research is the Cannonball cabbage also known as the green cabbage. Because of its adaptability to a wide range of climate conditions, soils, ease of production, storage

[1] Herbarceous plants have non-woody stems. The body of such a plant is mainly made up of cellulose. This makes it relatively flexible and fragile (Keser, 2015)

and its food value it is known throughout the world. Overwatering of cabbage may cause cabbage heads to split (Masarirambi, Oseni, Shongwe, & Mhazo, 2010).

In Suriname these crops are cultivated by farmers throughout the year. Eggplant is known as a very good source of nutrients such as calcium, magnesium, vitamin K, vitamin C potassium and fiber. With a growing cycle of 6-12 months it is cultivated throughout the vegetable growing areas in ‘Saramacca’, ‘Wanica’, ‘Commewijne’ and ‘Weg Naar Zee’. Some of the production is exported to Europe, the Netherlands. On clay soil, eggplant can be susceptible to fungi (Khoesial, 1996). Cabbage cultivation is very intensive and demands a lot of inputs which results in a relatively high price throughout the year. It is cultivated in the ‘Wanica’ and ‘Saramacca’ regions on sandy ridges. Fresh cabbage is marketed and processed locally. Some of the produced cabbage is frequently exported to French Guyana. It is very susceptible to insect damage. Cabbage and eggplant are also cultivated in Suriname at the ‘Weg Naar Zee’ area (Khoesial, 1996).

Lately, an increase in cultivation in the coastal area (‘Weg Naar Zee’) has been observed (Vries, 2012). However, some areas face problems with saltwater intrusion of the rising sea level on the agricultural land. Farmers at the Brantimakaweg and Oedayrajsingh Varmaweg (‘Weg Naar Zee’) are facing flooding of their farmland. Ocean water floods their land which makes cultivation very difficult. The constant flooding of the land can have a negative impact of high salt concentration of the soil. Because of the high salt concentration, some species of plants are very difficult to grow on the land because of their low salt tolerance. Rising of the sea level results in flooding (Vries, 2012). A flood is an overflow of water that submerges land that is usually dry. Flooding can result in insufficient oxygen around the plants. To know the salinity tolerance threshold and the impact on the yield in response to soil salinity is crucial. Plant tolerance to salinity can be determined by identifying the plant responses to different physiological parameters (Negrao, Schmockel, & Tester, 2016). This can be improved by applying techniques to improve drainage. One of the techniques are draining the excess water at the surface or to apply raised beds.

Raised beds are any type of planting surface above ground level. There are different types of raised beds that mostly share the same advantages and disadvantages. Raised beds can differ from very simple soil mounds to framing material used to contain the soil (Edmunds, 2016).

1.2 Statement of the problem

There are several methods to reduce salt water intrusion on an agricultural field including raised beds as a good agricultural practice. However, in Suriname research on raised beds has not been conducted in agricultural fields to evaluate if raised beds can result in a better yield production on agricultural fields with water intrusion.

1.3 Research objective/aim

The purpose of this study is to investigate the impact of raised beds and non-raised beds on the growth performance of eggplant and cabbage on an agricultural field in the coastal area with salt water intrusion.

1.4 Research questions

The central question that arises from the objective is: Are raised beds a good alternative to eliminate the effects of salt intrusion in cabbage and eggplant at the 'Weg Naar Zee' area?

Sub questions:

- Are the measured soil samples of raised and non-raised beds the same in texture and nutrient parameters or do they differ?
- Is there a difference in plant growth parameters on the raised and non-raised beds?
- Which beds have the best drainage?
- Do raised beds have a better plant performance?

1.5 Relevance and justification

The results of this research will provide information on increased production of cabbage and eggplant on raised beds. This information is important for the 'Weg naar Zee' livelihood farmers who cope with flooding and soil salinity problems. The Agricultural Extension Service could promote the results of the raised beds as a good agriculture practice to encourage sustainable farming and to provide a solution on the issue of saltwater intrusion in the agricultural fields in the 'Weg naar Zee' area.

2. Literature review

2.1 Soil and Water Salinity

Worldwide, approximately one billion hectares of agricultural land have been depreciated because they have been salinized. In addition, another trillion hectares have been influenced by salt in the ground (Shrivastava & Kumar, 2014). This means that about one fifth of the cultivated lands are saline. Approximately 2000 hectares are added every day, which are influenced by salt (Shrivastava & Kumar, 2014). According to the national development plan of Suriname 2017-2021, Suriname is recognized as one of the countries most threatened by rising sea levels (Stichting Planbureau Suriname, 2017). Suriname will have to deal with increasing coastal erosion, large scale floods, the loss of fertile land, the reduction of freshwater sources and the decline of biodiversity as a result of salinization (Government of Suriname, 2019). Mitigation measures that are being implemented in Suriname are the planting of mangrove trees and the construction of dams along the coast (Cete, Haage, Hardwarsing, Kalloe, & Ma-ajong, 2018). Soil salinity is the salt content in the soil or the amount of dissolved salts in the soil solution (Hardie & Doyle, 2012). The salt content is the concentration of all salts dissolved in water, expressed in number of parts per thousand, which corresponds approximately to the number of grams of salt per liter of solution. The average salinity of the ocean is 35 promille which is 35 grams of salt per liter of seawater (Murray, 2004). Salt can penetrate the soil in various ways. The easiest way is by rivers. If rivers have a low water level, the sea can enter the riverbeds. Here it becomes salty and through this manner, the salt water can reach parts of the land (Rasel, Hasan, Ahmed, & Miah, 2013). If the salt water overflows these pieces of land, or seeps into them, the salt ends up in the soil. Another possibility is with agricultural land. When irrigation takes place, often only a part of the water is absorbed by the plants. The rest of the water drops into the soil to the groundwater. Salt is dissolved in this groundwater. If the groundwater rises too much, capillary action can occur. This means that the small molecules can creep upwards through a very narrow opening that looks like a tube (Rasel, Hasan, Ahmed, & Miah, 2013). In clay soils, a top layer can be distinguished with a high hydraulic conductivity, below which the hydraulic conductivity is much lower and often decreases with depth. Salt movement is linked with water movement which depends on the hydraulic conductivity of the soil profile and structure (Wallender, et al., 2006). Most of the water is drained off by infiltration into the heavy clay layer and flows through the permeable subsoil to the drains. If the highly permeable subsoil is absent, the water table will rise faster and cause a decrease of the infiltration rate. If there is a surface drainage system, water will first infiltrate into the layer of low permeability causing a rise of the water table to the top layer and afterwards all rainfall will be discharged horizontally through the top layer (Wallender, et al., 2006).

2.2 The influence of salt on plants

The Na+ particles, the sodium, from the salt are toxic for the plant. They achieve this toxic effect in several ways. Plants really need K+, the potassium. The Na+ is incorporated into the plant in the roots, along with other salts (Jouyban, 2012). The sodium is dissolved in water and brought up by the wood vessels to the leaves. Here the water evaporates and the Na+ stays behind and starts to accumulate. The leaves are much more sensitive to Na+. The cells from the leaves die off, but stay there so that their place cannot be taken by other cells (Jouyban, 2012). This can also damage the cells surrounding this dead tissue. One of the problems of the leaves is that the cells must remain turgor. This means that there is much moisture in the vacuole of the cell that the cell is, as it were, so full that the cell membrane is pressed against the cell wall so that the plant remains firm. For this reason, the osmotic value within the cell must be greater than the osmotic value outside the cell (Jouyban, 2012). In order to achieve this, more substances must be dissolved in the cell than in the surrounding moisture. If outside the cell Na+ is dissolved in high concentrations it is very difficult for the cell to remain firm. The intake of Na+ does not go very well either, because this is toxic to cytosol, the main component of the cytoplasm. This makes it likely that the cell will lose its turgor and that plasmolysis will occur. The cell membrane is released from the cell wall and the cell collapses as it were. This eventually leads to cell death. If a cell than manages to retain its turgor, it runs into other problems. Sodium takes in binding sites where potassium is supposed to bind (Hadi & Karimi, 2012). These substances compete with each other, but a plant needs all potassium to grow. More than 50 enzymes are activated because K+ binds to them. In addition, potassium must bind to the RNA to ensure that the ribosomes can read it. If Na+ occupies these K+ binding sites, the plant can no longer produce and activate its proteins and enzymes. Because of this, it can no longer grow. This is the biggest problem that Na+ causes for the plant (Hadi & Karimi, 2012). Soil salinity effects the plant performance of many agricultural crops by reducing the plant growth due to specific-ion toxicities and nutritional imbalances. A high salinization of the soil makes it difficult for plants to acquire water from the soil because of the osmotic or water-deficit effect of salinity. The osmotic effect of salinity induces metabolic changes in the plant. By decreasing CO_2 availability, salinity effects photosynthesis as a result of diffusion limitations and a reduction of the contents of photosynthetic pigments (Machado & Serralheiro, 2017). Salt stress reduces marketable yields giving a decreased productivity and an increased unmarketable yield. Salinity can also affect plant growth indirectly by increasing the soil's pH and by sodium's effect on the degradation of the soil's physical condition. Saline waters enhance the occurrence of blossom-end rot in eggplant. This is a nutritional disorder related to Ca^{2+} deficiency (Machado & Serralheiro, 2017). Salinity also has some favorable effects on the quality of the edible part of the crops. However, salt stress improves the quality of edible part of vegetable crop with the exception of visual appearance (Machado & Serralheiro, 2017).

Salt in the soil may be considered toxic if it is in excess. This term is better applied to those ions that cause characteristic and acute plant injury. Among the fruits such injury is quite widespread. When the leaves of these plants accumulate more than ¼ % of sodium or ½ % of chloride, characteristic leaf-injury symptoms generally appear (Alshareef & Tester, 2019).

Salinity is the accumulation of salt to a level that damages the natural and built environment. High levels of salinity can have detrimental effects on agriculture (Shrivastava & Kumar, 2014). According to the department of Agro-hydrology of 'Landbouw Veeteelt en Visserij' (LVV), soil salinization occurs if the salt content exceeds the limit of 1000 μS /cm. If this is the case, there will be a decline in growth and productivity (Van Reuler & Baltissen, 2016). In Table 1 the influence of soil salinity on crop plants is given (Shahid & Rehman, 2011). The salinity class ranges from non-saline, making the salinity effects negligible, to very strongly saline which only a few crops can tolerate.

Table 1. Soil salinity classes and crop growth.

Soil Salinity Class	Conductivity of the Saturation Extract (dS/m)	Effect on Crop Plants
Non saline	0 – 2	Salinity effects negligible
Slightly saline	2 - 4	Yields of sensitive crops may be restricted
Moderately saline	4 - 8	Yields of many crops are restricted
Strongly saline	8 - 16	Only tolerant crops yield satisfactorily
Very strongly saline	> 16	Only a few very tolerant crops yield satisfactorily

Note. Soil salinity classes and their effect on crop plants. FAO.
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Salinity tolerance of vegetable crops is defined as the ability to endure the effects of excess salt in the root zone (Machado & Serralheiro, 2017). Eggplant is moderately sensitive at a salt tolerance threshold level of 1.1 dS/m (Grieve, Grattan, & Maas, 2012). But in gypsiferous soils[2], plants will tolerate an EC about 2 dS/m higher. Cabbage is moderately sensitive at a salt tolerance threshold level of 1.8 dS/m (Tanji & Kielen, 2002).

2.3 Irrigation and crop requirement

Suriname has for the most part a humid tropical rainforest climate. In addition, it also has areas with low rainfall and other temperature distributions. The coastal area generally has a lower precipitation average than the midlands. The average amount of precipitation of Suriname is 2060 mm per year (Mitro, 2010). The characteristic that the distribution of this shows over a series of years (multi-year average) is the most important principle of the seasonal division in Suriname. There are four seasons in Suriname namely two wet and two dry seasons. The short dry season (February-May), the large rain season (May-August), the large dry season (August-December) and the short rain season (December-February) (Meteorologische dienst, 1968). It has been observed that sometimes the start of the rainy season is delayed and/or it might rain considerably more in some years than others might (Mitro, 2010). Annual variation could be great, for some years, the

[2] Gypsiferous soils are soils that have a sufficient amount of gypsum to interfere with plant growth. Gypsum is calcium sulphate (Al-Barrak & Rowell, 2006)

short dry season and the short rainy season may not occur, but the long dry season and long rainy seasons are always encountered (Mitro, 2010). The amount of irrigation a crop needs mainly depends on the climate, the crop variation and the growth stage of the crop. In sunny and hot climate, crops need more water than in a cloudy climate. Fully grown crops need more water than crops that have just been planted. Irrigation is important because the plant consists for the most part of water. The plant uses a large proportion of the water to keep the leaf temperature below a harmful level (Nagarajan, 2009). Irrigation is mostly used in the dry seasons. Irrigation systems that are used in the agricultural sector include (Brouwer, Prins, Kay, & Heibloem, 2001):

1. Rain-fed irrigation system: Here one is dependent on the short and large rainy season and there is no control over the amount of rainfall that is applied to the cultivated fields.
2. Sprinkler system: Through an installation water is pumped from the water source and a certain area is irrigated through the sprayer. Water quality is important to prevent clogging. Here one can check and automatically irrigate the planting through a timer.
3. Drip irrigation system: The water is pumped from the water source (channel, creek, etc.) through a water pump. The water is pumped to the plant via tubes or hoses at a certain speed. Exactly at the plant a dropper is placed where water drips through the soil. The disadvantage is that blockages often occur when using this system. The advantage is that evaporation of water and washing away of nutrients is minimized.
4. Surface irrigation system: Water is distributed by gravity whereby the water ends up in the ditches that is directed according to the bed system. The area is irrigated.
5. Manual irrigation system: Here garden tools such as a garden hose and watering cans are supplied with water to the plant which is time consuming and labor intensive.

To produce 1 kilo of cabbage, 237 liters of water is required (Fox & Ceng, 2013). The approximate value of the seasonal crop water needs of cabbage is between 350-500 mm per total growing period is the same as 350-500 liters per m^2 (Brouwer & Heibloem, 1986). The water requirement of eggplant in the summer is 2967 m^3 per Feddan is the same as 706.43 liters per m^2 (Hosni, El-gafy, Ibrahim, & Abowarda, 2014). Not only is the amount of irrigation of importance but also the salt concentration of the irrigated water as shown in Table 2 (Hillel, 2000).

Table 2. Classification of water quality according to total salt concentration.

Designation	*Total dissolved salts (ppm)*	*EC (dS/m)*	*Category*
Fresh water	<500	<0.6	Drinking and irrigation
Slightly brackish	500-1,000	0.6-1.5	Irrigation
Brackish	1,000-2,000	1.5-3	Irrigation with caution
Moderately saline	2,000-5,000	3-8	Primary drainage
Saline	5,000-10,000	8-15	Secondary drainage and saline groundwater
Highly saline	10,000-35,000	15-45	Very saline groundwater
Brine	>35,000	>45	seawater

Note. Classification of water quality according to total salt concentration. The International Bank for Reconstruction and Development/THE WORLD BANK. Copyright 2000 by The International Bank for Reconstruction and Development/THE WORLD BANK

2.4 'Weg Naar Zee' area

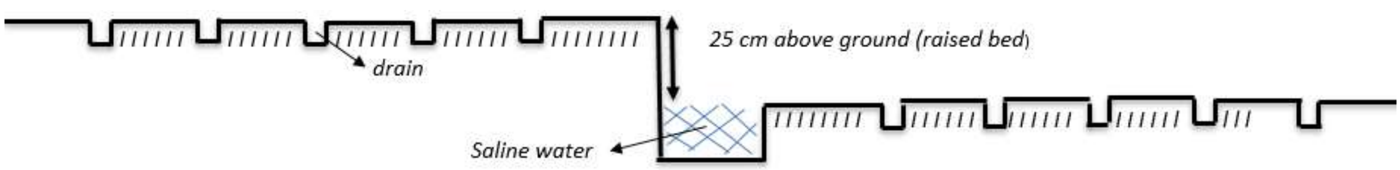
The Weg naar Zee area is currently being used for a variety of activities such as agriculture, animal husbandry and urbanization. In this area the main mean of existence is agriculture, which is intensively practiced and has made the region known to be the largest vegetable producer of the Paramaribo district. The 'Weg naar Zee' area is almost flat and consists of extensive wide clay plates. The 'Weg naar Zee' area has a population of ca. 14000 and a population density of 390 people per km^2 (Cete, Haage, Hardwarsing, Kalloe, & Ma-ajong, 2018). The entire area has a surface of ± 41 square kilometers. The coast of Suriname consists of heavy clay, which consists of more than 50% of clay particles smaller than 2 micrometers (Cete, Haage, Hardwarsing, Kalloe, & Ma-ajong, 2018). Roads have been established coming from the 'Henry Fernanades' road ('Weg naar Zee') on the East and on the West side. Along these roads' horticulture is practiced in most places. Horticulture is interspersed with cattle breeding, while permanent cattle breeding also occurs. The farm lands with dominant clay soils, have an extensive form of animal husbandry and locally grown perennial crops and horticulture on beds (Cete, Haage, Hardwarsing, Kalloe, & Ma-ajong, 2018).

2.5 Raised and non-raised beds

A good way to cultivate crops on soil with a hardy, compact, clay texture is raised beds. Doing this helps to overcome issues with problematic soils like bad drainage. This method can be done by raking the soil several inches higher above ground level into flat-topped mounds (McLaughlin & Hunsberger, 2002). It is a simple technique that can improve the productivity and health of your crops. Raised beds can be either framed or uncontained. In this research, uncontained beds were established. Native soil is used and mounded in a narrow bed (Fritz & Rosen, 2018).

Figure 1 schematically shows the uncontained raised beds on the left which are 25 cm higher and the standard non-raised beds on the right. Care of raised beds is similar to that of a traditional garden. Organic matter and fertilizer are added each year as needed. Raised beds may need more frequent watering. It is difficult to keep up with watering if you have more than one bed. Drip irrigation, soaker hoses, or hand watering are more efficient than sprinklers (Cogger, 2017). During hot or dry weather irrigation may be needed as often as every day. Organic mulching is done to conserve moisture and reduce weed problems. If the soil has a medium to heavy texture and is poorly drained, this technique will help (Cogger, 2017). The raised beds need to be replenished every year or two with more soil or compost to maintain the original height because the settling of fill material and decay of organic matter will reduce the height of the soil. Although they require a little planning and extra effort in the beginning, raised beds can help solve many problems and make planting easier (Edmunds, 2016).

Figure 1. A schematic overview of the raised and non-raised beds



2.6 Cabbage (*Brassica oleracea* L.)

Cabbage is an herbaceous plant and is a well-known and widely consumed vegetable in Suriname (Power, Wijngaarde Iwan, & Wijngaarde, 2015). Wild cabbage originates from the Mediterranean Sea area, South-West Europe and South England. Cabbage varies widely in vegetative growth and in shape. It is cultivated along 'Pad van Wanica' , 'Kwatta' , 'Santo Boma' and 'Alkmaar'. There are many varieties of cabbage. In this research, variety *capitata* L. was used. The species of *Brassica oleracea* variety *capitata* that are grown in Suriname are the American varieties and the Golden Acre and Copenhagen Market varieties. These varieties have been cultivated for many years in Suriname. There are also the Japanese varieties of which the production is high, but the quality is lower than that of the American requirements (Ministerie van landbouw veeteelt en visserij onderdirectoraat landbouwkundig onderzoek, 2005). The leaf stalk is very thick, making the cabbage look coarse. Summer 50, KK Cross and Tropical King are the most known varieties grown in Suriname. Summer 50 is also cultivated in vegetable growing areas like 'Weg Naar Zee'. Cabbage is relatively low in calories and protein content. It is a good source of minerals, in particular potassium and it is relatively high in vitamins A and C. The best soil type for cabbage is light clay soils with a lot of humus and an optimum pH of 6-7. Certain root diseases occur faster if the pH is lower than 6. (Ministerie van landbouw veeteelt en visserij onderdirectoraat landbouwkundig onderzoek, 2005). The best seasons to cultivate cabbage are the end of the long rainy season (July/August), the beginning of the short rainy season (November/December) and the end of the short rainy season (begin of February). Cabbage is mostly cultivated in open field (Power *et.al*, 2015). Cabbage grows best at a pH level of 6.5 - 7 (Ministerie van landbouw veeteelt en visserij onderdirectoraat landbouwkundig onderzoek, 2005) and Electrical Conductivity (EC) level between 0-2 dS/m (Abrol, Yadav, & Massoud, 1988). It is a cool season crop with moderately low optimum temperatures 15 ^{0}C to 20 ^{0}C and requires much water for optimum performance (Muleke, Saidi, Itulya, Thibaud, & Ngouajio, 2014).

2.7 Eggplant (*Solanum melongena* L.)

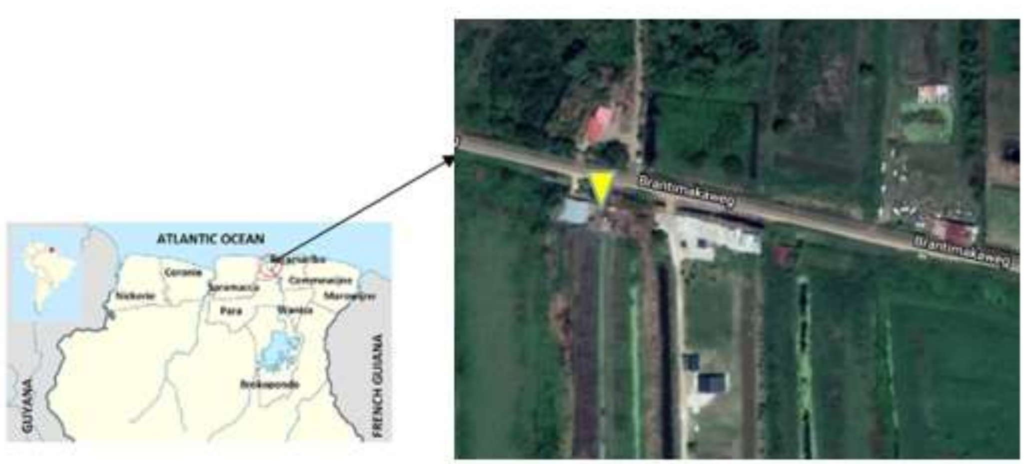
Eggplant is a true people's vegetable, not only for its good taste, but also for its availability all year round. There are different fruit shapes and colors of eggplant. Two indigenous species that are grown the most are the long violet colored and the shorter type. The long variety was used in this research. It has fewer seeds (Power, Wijngaarde Iwan, & Wijngaarde, 2015). This crop grows well on all soil types. It is mainly cultivated in the 'Wanica' district and in particular in 'Mottonshoop', 'Weg naar Zee', 'Middenpad van Kwatta' and 'Garnizoenspad'. The foreign varieties, which have been tried by the Agricultural Experiment Station over the years, turned out to be no better than the established, local varieties. The long variety is mostly cultivated. Both, the farmer and the consumer prefer the elongated variety because it yields more per unit area and contains fewer seeds (Ministerie van landbouw veeteelt en visserij onderdirectoraat landbouwkundig onderzoek, 2005). Eggplant contains water (91.5%), carbohydrates (6.4%) and protein (1.3%). The iron and vitamin content are very low. The best growth and production of eggplant is obtained on well-drained, rich sandy soils. Good production can also be achieved on shell soils and on the flanks of sand and conch fringes (loamy sand, sandy loam). On heavy clay soils with a low pH, the cultivation is not always successful. Wilting symptoms of the plant often appears on these soils, which causes the plant to die completely at a later stage (Ministerie van landbouw veeteelt en visserij onderdirectoraat landbouwkundig onderzoek, 2005). Other than that, it grows very easily in Suriname and it does not have many pests and diseases. The best time to cultivate eggplant is immediately after the long rainy season, the beginning of the short rainy season in November or at the end of the short rainy season in begin of February (Power, Wijngaarde Iwan, & Wijngaarde, 2015)). Eggplant grows best at a pH level between 6- 7 with optimum growing temperature range of 21 ^{0}C – 30 ^{0}C (Ullio, 2003) and at an EC level between 0-2dS/m (Abrol, Yadav, & Massoud, 1988).

3. Methodology

3.1 Location of experimental design

This research was conducted from September 2018 – January 2019 at a farmer's field at the Brantimakkaweg no. 332, at 'Weg Naar Zee' as seen in Figure 2 (5.890016-55.197638, 2018). The geographical coordinates are North 5 89' 19'' and West 55 20' 34''. The farmer's total agricultural land area is about 4 hectares, of which 240 m^2 was used for this research. Over the years, the farmer was only able to cultivate the land in the dry seasons. Prior to the start of this research, the farmer cultivated cucumber, cantaloupe, eggplant, tomato and bitter melon. The entire research plot size was 120 m^2 for eggplant on raised and non-raised beds and 120 m^2 for cabbage on raised and non-raised beds.

Figure 2. Location Brantimakkaweg.

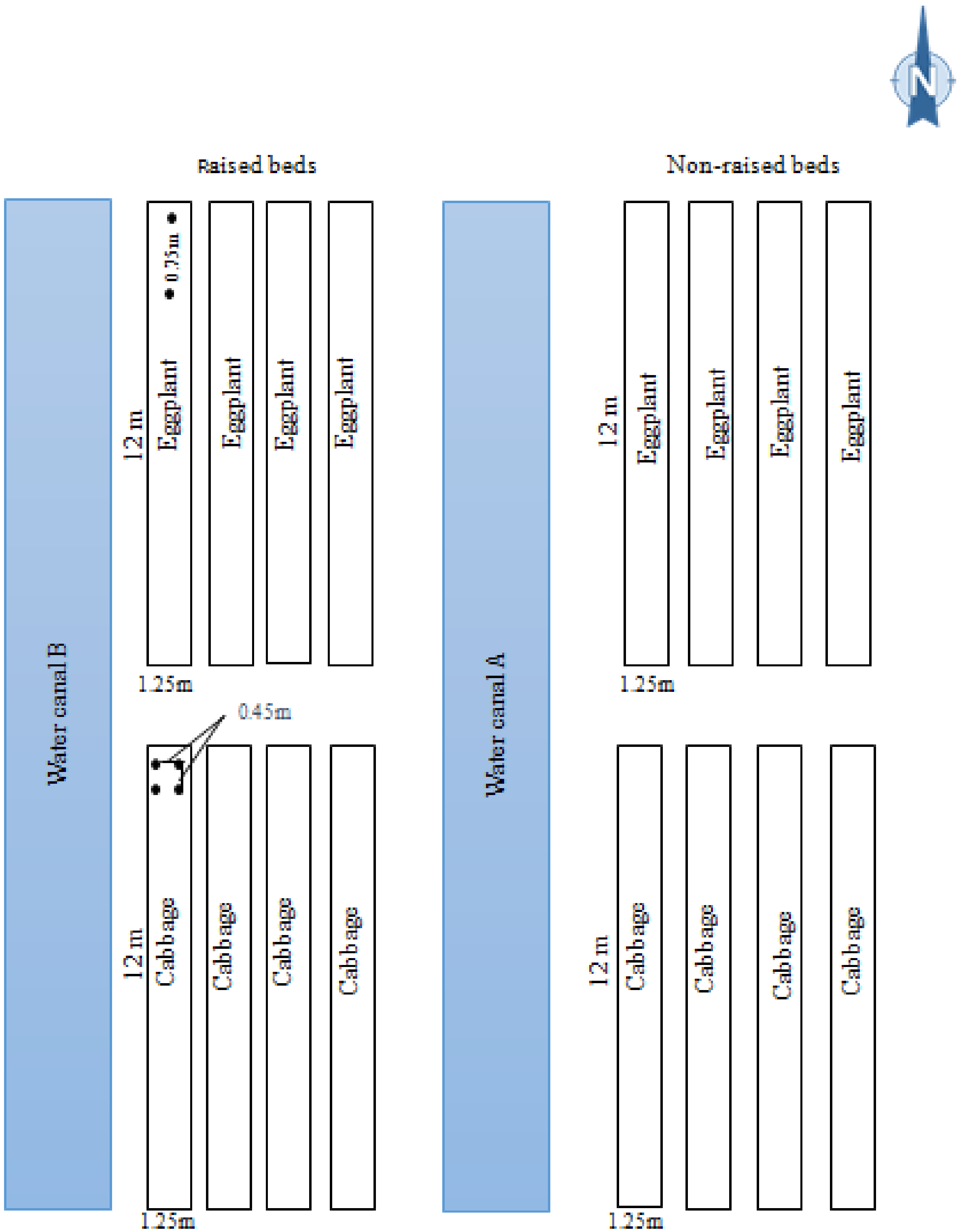


Note. Google map location of the experimental site. Googlemaps. Copyright 2018 by Googlemaps

3.2 Experimental layout

This research was set as a Completely Randomized Design with four replicates. The size of the experimental unit of this research was approximately 240 m^2. For each crop species there were four replicates of 12m x 12m beds on both raised and non-raised beds, with walking spaces between and around the beds. The beds are 1.25 m wide and 12 m long. Figure 3 provides an overview of the experimental layout.

Figure 3. Experimental layout



3.3 Sowing and transplanting

Seeds of one eggplant (*Solanum melongena* L.*)* cultivar and one cabbage (*Brassica oleracea* L.*)* were used for this research. The eggplant cultivar that was used for this research is a typical Surinamese variety which has been cultivated for years for its good performance in dry and rainy seasons. Seedlings were seeded on August 27, 2018. The germination rate for eggplant was 97% and for cabbage 96%. The seedlings were nursed until the first week of October 2018 in the nursery build at the farmer. On October 4, 2018, the eggplant was transplanted on the beds and on October 5, 2018, the cabbage seedlings. To stimulate the farmer to use fewer chemicals, weeding was done manually with hoes and cutlasses twice a week. Cabbage seedlings were transplanted with a plant spacing of 0.45 m by 0.45 m and eggplant seedlings were transplanted with a plant spacing of 0.75 m by 0.75 m.

Figure 4. Transplanting of the vegetable crops.

3.4 Measured data

3.4.1 Soil and water

The soil samples were taken with a soil sampler on August 28, 2018 (at land preparation), on October 3, 2018 (at transplanting), on November 8, 2018 (during crop growth) and at the harvest time of the crops on December 17, 2018. Samples of the soil were taken at depths of 0-35 cm and 35-70 cm. The samples were taken at various locations of the raised or non-raised beds of eggplant and cabbage. The samples were mixed for each depth and a sample of one kilogram was placed in a plastic bag and marked and taken to the soil testing laboratory of the Faculty of Technology (FTeW) for testing. The soil samples were tested on pH H_2O, EC, Org. C, Org. matter, Total N, Total P, Total K, CEC and soil texture. Water samples were also taken on August 28, 2018 (at land preparation), on October 3, 2018 (at transplanting), November 8, 2018 (during crop growth) and at the harvest time of the crops on December 17, 2018. There were two water sampling locations of water, one canal in between the raised and non-raised beds and one next to the raised beds. The water samples were taken in clean water bottles. The bottles and lids were rinsed three times with the sampled water before taking the sample. The bottles were marked and placed in a dark plastic bag. They were kept in a cool place and brought to the lab for testing. The water samples were tested in the lab for pH H_2O and EC.

3.4.2 Observations and measurements

On a daily basis, plants were irrigated and monitored for irregularities. Every two weeks, data was collected to measure the plant performance of cabbage and eggplant. For eggplant, the following data was collected on raised and non-raised beds:

- Plant height was measured with a measuring tape from the base of the plant to the tip of the plant.
- Number of leaves per plant
- Number of flowers per plant
- Number of fruits per plant
- Length of the fruits
- The weight of the fruits
- Root mass and length of the root

For cabbage, the following data was collected on raised and non-raised beds:

- Plant height was measured with a measuring tape from the base of the plant to the tip of the plant.
- Number of leaves per plant.

- Weight of the fruits
- Diameter and circumference of the fruits
- Root mass and length of the root

The fruits of the eggplant and cabbage crop were harvested and tested in the lab for N, P and K. After the harvest, the fruits were marked and placed in a dark and cool bag and brought for testing to the soil laboratory of the FTeW at the AdeKUS. Throughout the research, the crops were observed and any changes or differences were noted at the spot.

3.5 Irrigation, fertilization and pest management

Irrigation took place with a sprinkler system twice a day in the morning for 15 minutes and in the afternoon for 5 minutes for the raised beds and for the non-raised beds in the morning 5 minutes and in the afternoon 2 minutes. Around November 15, 2018 it started raining and irrigation was carried out uniformly on need basis on all beds throughout the research.

Fertilization was done every three weeks. The fertilizers used in this research included:

- Chicken manure with an NPK ratio of 4-3-3 was used on October 4 and 5, 2018 while transplanting the plants on the plant beds. At that time, 20 grams of chicken manure grain was placed in the plant hole in the soil.
- Dugro with an NPK ratio of 15-30-15 which is regarded as a universal fertilizer. It is a water-soluble plant food. The fertilizer was used to give the plants a boost to grow. This was used on October 9 and 28, 2018.
- Vermiwash was sprayed on the plants. This bio-fertilizer was used on November 7, 2018.
- NPK [12-12-17] was used for both vegetables. Twenty grams (20) for eggplant and ten grams (10) for cabbage. NPK was used on November 20 and 30, 2018.

For pest management the following chemicals were used:

- Soap water against ants. Was used on October 17, 2018
- Sugar water mixed with white flour against ants. Was used on October 17 and 23, 2018
- Biopel, a natural pest control for the control of sucking and chewing insect pests. It is a biological and microbial insecticide, caterpillar larvacide. Biopel was used on October 9, 2018 and on November 26, 2018.

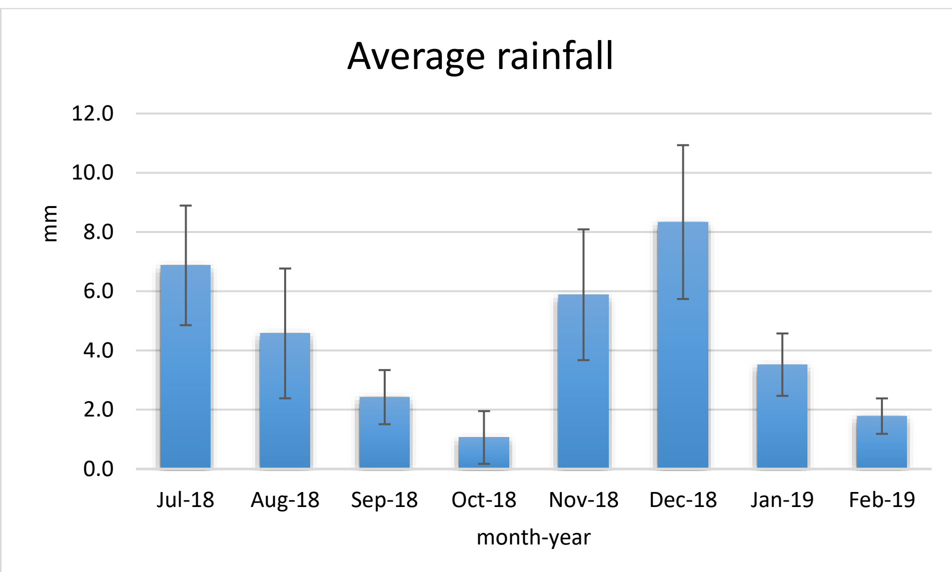
- Imajor is a systemic insecticide with contact and stomach action. It is readily taken up by the plant and is distributed acropetally with a good root systemic action. An insecticide against insects including worms and white flies. Imajor was used on November 23, 2018

4. Results & Discussion

4.1 General

In the humid tropics such as Suriname there is a rainfall excess on a yearly basis which means that the yearly rainfall is higher than the yearly evapotranspiration. During the rainy seasons there is a chance that it may be too wet for crops (Mitro, 2010). In Suriname, the long rainy season usually starts from April 1 - July 31 and then the long dry season starts from August 1 - November 30. After this, the short rainy season starts from December 1 - January 31, while the short dry season starts from February 1 - March 31 (Meteorologische dienst, 1968). In Figure 5 the average monthly rainfall (mm) is presented and in Figures 6 and 7 the Temperature (^{0}C) and in Figure 9 Relative Humidity (%) during the cultivation of cabbage and eggplant.

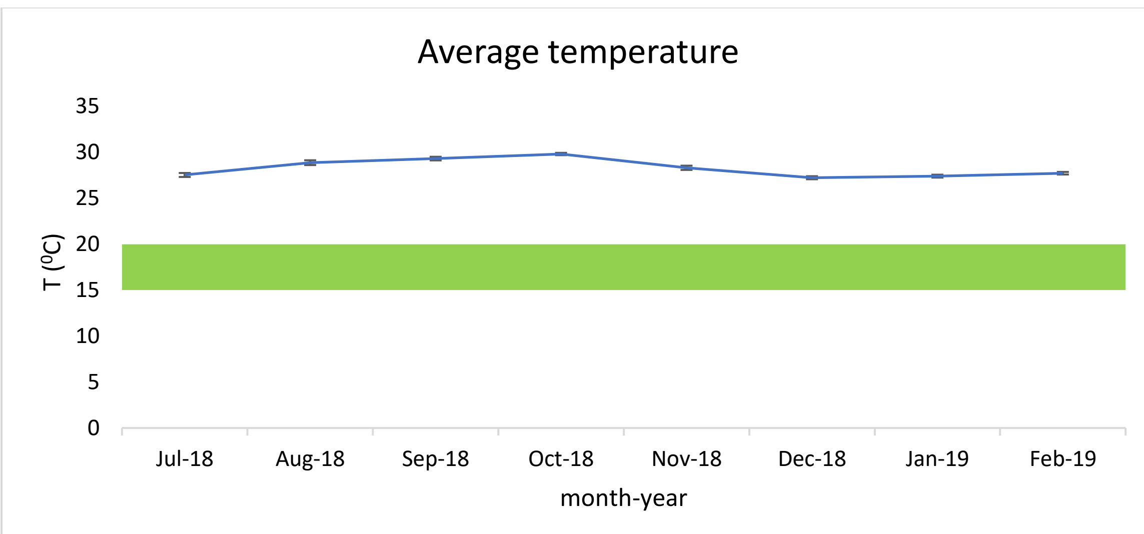
Figure 5. The average rainfall per month at ' Weg naar Zee'.



Note. Rainfall at the Weg naar Zee area. Meteorological service Suriname. Copyright 2019 by Meteorological service Suriname.

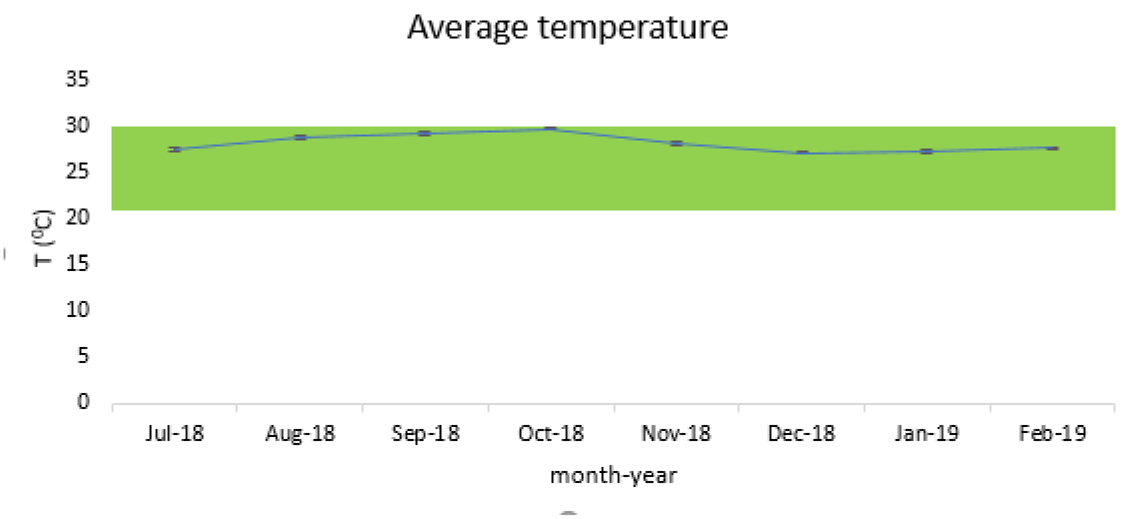
Land preparation activities took place in August and September for the raised and non-raised beds. The average amount of rainfall was the highest in December 2018 (long rainy season) at 6.9 mm and the lowest in October 2018 (long dry season) at 1.1 mm. Transplanting took place in October 2018. The soil was dry and irrigation was required for the plants at this time. Cabbage cultivation lasted until December 2018, while eggplant cultivation lasted until January 2019 for the experiment. The average monthly amount of rainfall in the long dry season (August 1 – November 30) was 3.5 mm and in the short rainy season (December 1 – January 31) was 5.9 mm per month. The amount of rainfall was too low for the cabbage and eggplant growth. In general, 350-500 mm water for the total growing period is needed for cabbage growth (Brouwer & Heibloem, 1986) and 706.43 per total growing period for eggplant growth (Hosni, El-gafy, Ibrahim, & Abowarda, 2014), because of this irrigation was needed. Crop growth does not only depend on rainfall, but also on other climatic factors including temperature and relative humidity. During some periods crop growth may be not suitable for certain crops due to high temperatures. The temperature (Figures 6 and 7) and relative humidity (Figure 8) data of ‘Zorg en Hoop’ were used because there was no temperature data available of the ‘Weg naar Zee’ area.

Figure 6. Average temperature per month and optimum temperature for cabbage growth.



Note. Temperature at the Weg naar Zee area. Meteorological service Suriname. Copyright 2019 by Meteorological service Suriname.

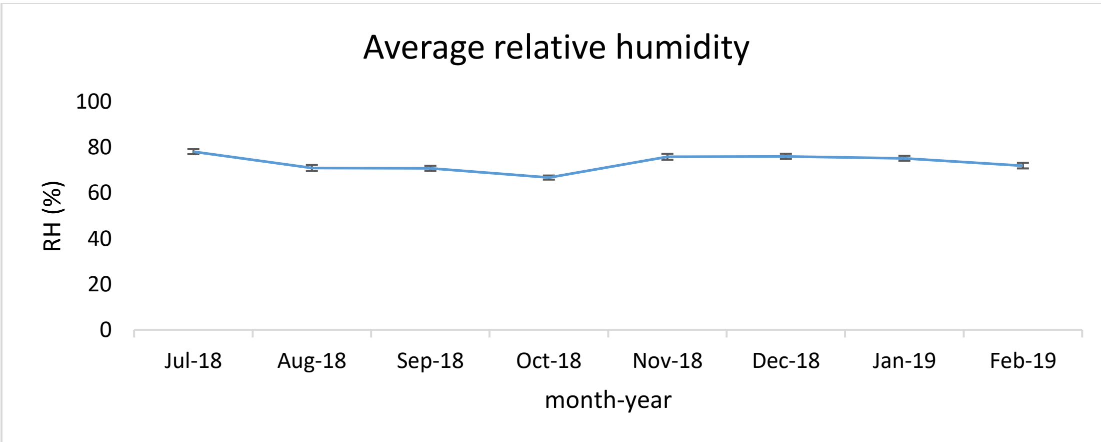
Figure 7. Average temperature per month and optimum temperature for eggplant growth.



Note. Temperature at the Weg naar Zee area. Meteorological service Suriname. Copyright 2019 by Meteorological service Suriname.

The average daily temperature was the highest in October 2018 in the long dry season (during transplanting) at 29.8 ^{0}C. In December 2018, the temperature was the lowest in the short rainy season (during the harvest) at 27.2 ^{0}C. During transplanting in October 2018, the rainfall was very low as shown in Figure 6 and the average monthly temperature was the highest as shown in Figures 6 and 7. The temperature in October ranged from 27.7 ^{0}C to 30.9 ^{0}C as displayed in Figure 8. The temperature was outside the optimum range for cabbage growth which varies between 15 ^{0}C – 20 ^{0}C (Muleke, Saidi, Itulya, Thibaud, & Ngouajio, 2014). For eggplant cultivation, having an optimum temperature range of 21 ^{0}C – 30 ^{0}C (Figure 7), the average monthly temperature during cultivation of eggplant at 'Weg naar Zee' was within range for eggplant cultivation requirement (Ullio, 2003). During this time, irrigation was needed for the plants to grow. The average monthly temperature in the long dry season was 29.0 ^{0}C and in the short rainy season was 27.3 ^{0}C per month. In the long dry season from August 1 - November 30, the average rainfall was low and the average temperature was high compared to the short rainy season December 1 - January 31, where the average monthly rainfall was high and the average monthly temperature was low.

Figure 8. Average relative humidity per month at 'Zorg en Hoop'



Note. Relative humidity at the Weg naar Zee area. Meteorological service Suriname. Copyright 2019 by Meteorological service Suriname.

The average monthly relative humidity was the highest in July 2018 at 78.2 % and the lowest in October 2018 was 66.8 % (Figure 8). The average monthly relative humidity in the long dry season was 71.1 % and in the short rainy season was 75.7 %. The average monthly temperature in the long dry season was high while the average relative monthly humidity was low and in the short rainy season, the average monthly temperature was low and the average monthly relative humidity was high. In October the rainfall was, less, the average monthly temperature was high and the average monthly relative humidity was low. The average monthly humidity was the lowest in October during crop transplanting and in November and December during crop growth, it increased. There was no specific humidity range found for eggplant and cabbage in the literature.

4.2 Soil and water samples at land preparation

pH and EC

From Table 3 it is evident that the pH and the EC of the water samples before planting were about the same in both water canals. The water in the canals was not used for irrigation of the plants, because the EC in the canals A and B were too high for crop growth. According to the literature an EC between 1.5-3 dS/m is reported as being brackish and irrigation must be done with caution

(Hillel, 2000). Because of this, the water in the canals was not used for irrigation. Irrigation water was bought from the SWM. The literature reports that best pH range to grow cabbage is 6.5-7 and for eggplant is between 6-7 (Ullio, 2003). The results for pH from the water analysis in the canals indicated that it was good for the cultivation of the crops (Table 3).

Table 3. Water samples at land preparation

Date	Location	pH H_2O	EC (dS/m)
28 August 2018	Water canal A	6.6	1.693
	Water canal B	6.6	1.601

Texture

The texture of the soils on the raised and non-raised beds at land preparation was classified as a heavy clay, based on the chemical analysis conducted in the Soil Laboratory of the FTeW of the AdeKUS (Table 4). Cabbage grows best on light clay soils and eggplant on permeable, humid sandy soils loamy sand and sandy loam soils (Ministerie van landbouw veeteelt en visserij onderdirectoraat landbouwkundig onderzoek, 2005). Because of this, the conditions for cabbage and eggplant growth were not completely ideal because the soil texture on the beds was heavy clay.

Table 4. Soil texture analysis conducted during land preparation

Date	Description	Sand %	Silt %	Clay %	Texture
28/8/2018	Non-raised 0-35cm	2.3	32.2	65.5	Heavy clay
	Non-raised 35-70cm	0.6	31.2	68.2	Heavy clay
	Raised 0-35 cm	0.2	30.9	68.9	Heavy clay
	Raised 35-70 cm	0.9	35.6	63.5	Heavy clay

De CEC on the beds were high which was expected because of the high clay content. The structure of clay soil is affected by pH. In the optimum range of 5.5 to 7.0 clay soils are easily worked, but if the soil pH is extremely acid or extremely alkaline, it tends to become sticky and hard to cultivate (Perry, 2003). The pH of the soil is between the optimum range. High soil nitrogen is most suitable in clay soils. The microorganisms will convert organic nitrogen into mineral nitrogen for plant uptake. Clay in soils adsorbs ammonium nitrogen which reduces potential nitrogen loss (Angus, Baldock, Farrell, & Norton, 2013). There was no specific range of nitrogen found in the literature for clay soils. Soils with higher clay content have high phosphorus retention capacity because clay particles have very large surface area per unit volume, which can adsorb phosphorus easily (Prasad & Chakraborty, 2019). There was no specific range of phosphorus found in the literature for clay soils. For crop growth a good amount of phosphorus for agronomic crops ranges between 30 and 50 ppm phosphorus in the soil (Douglas, 2002). For crop growth the total P on both beds are above range making them present in sufficient amounts. In clay soils the amount of organic carbon stored increases with increasing clay content (Carson, 2013). There was no specific range of organic carbon found in the literature for clay soil. For crop growth it has been suggested that a critical level of soil organic carbon is 2 %, below which soil structural stability will suffer significant decline (Kemper & Koch, 1966). For crop growth the SOC on both beds are above the critical level making them present in sufficient amounts for crop growth. In clay-rich soils higher organic matter content may be expected (FAO, 2017). There was no specific range of soil organic matter found in the literature for clay soil. For crop growth it has been suggested that a critical level of soil organic matter is 3.4%, below which soil structural stability will suffer a significant decline (Kemper & Koch, 1966). For crop growth the SOC on both beds are above the critical level making them present in sufficient amounts for crop growth. Clay soils with CEC 11-50 range have a moderate capacity to hold nutrients (Cotching , Brown, & Lemon, 2020). The CEC on both beds is within this range making it moderate for crop growth. The EC of the soil is between 0-2 dS/m. The soil is non-saline and the effect it will have on crops is negligible (Shahid & Rehman, 2011). According to FAO (Tanji & Kielen, 2002) eggplant is moderately sensitive at a salt tolerance threshold level (EC) of 1.1 dS/m and cabbage is moderately sensitive at a salt tolerance threshold level (EC) of 1.8 dS/m. At land preparation, the EC on both beds are below the threshold levels making the EC suitable for the crop growth. A low EC indicates low available nutrients. As stated in the literature, the best pH range to grow cabbage is 6.5-7 (Ministerie van landbouw veeteelt en visserij onderdirectoraat landbouwkundig onderzoek, 2005) and eggplant is 6-7 (Ullio, 2003). The pH’s on both the raised and non-raised beds were relatively suitable to grow both cabbage and eggplant.

Table 5. Soil parameters[1] at land preparation

Date	Description	pH H_2O	EC (dS/m)	CEC (meq/ 100g)	Org. matter (%)	Org . C (%)	Tot. N (%)	Tot. P (ppm)
28/8/2018	Raised 0-35cm	5.6	0.92	37.23	16.93	8.4 7	0.59	581
	Raised 35-70cm		5.99	11.98	443	5.6	0.87	34.08
	Non-raised 0-35 cm		8.07	16.14	496	5.8	0.64	33.74
	Non-raised 35-70 cm		2.62	5.25	268	6.1	1.12	32.35

[1]Total K was not measured because of breakdown of the equipment.

4.3 Irrigation and drainage

The irrigation of cabbage and eggplant was estimated at 3.5 liters per m^2 per day (3.5 mm a day). In the dry season, before it started raining, the cabbage and eggplants plants were watered for six weeks, four times per week, on Monday, Wednesday, Friday and Sunday. The area cultivated on was approximately 120 m^2 for cabbage and 120 m^2 for eggplant giving a total cultivated are of 240 m^2. As stated in the literature the total water requirement of cabbage lies between the 350-500 liters per m^2 (Brouwer & Heibloem, 1986) which provides a total water usage of 42000-60000 liters of water for an area of 120 m^2. For eggplant, the total water usage is 706.43 liters per m^2 (Hosni, El-gafy, Ibrahim, & Abowarda, 2014) which estimates approximately 84771.6 liters of water for an area of 120 m^2. The crops were not irrigated the whole growth period because of rain fed and eggplant was not harvested during the whole growth period. The plants were watered for a period of 24 days. The growth period of cabbage is 70 days of which 24 days were irrigated. For cabbage can be estimated that (24:70) x 42000 = 14400 liter of water irrigated and for eggplant it can be estimated that (24:365) x 84771.6 = 5574 liter of water was irrigated. The total amount of water calculated which was used is 14400 liters + 5574 liters = 19917 liters of water. The estimated amount of water that was used for irrigation was based on the assumption that 3.5 liters per m^2 per day was used is (3.5 liters x 24 days) x 240 m^2 = 20160 liters of water. This means it can be estimated that the irrigation used in the field was within range of the calculated value, based on the literature.

In the short rainy season, which started in 2018 from December 1 - January 31 2019, the plants were watered when needed (on average two times a day). The difference in irrigation on the beds was that irrigation on the raised beds was done more frequently than on the non-raised beds. Because of the flooding that occurred on the non-raised beds. The drainage of the raised and non-raised beds took place through short drainage ways between the beds. The water that ended up in these short drainage ways were then further drained into the canals further known as water canal A and water canal B.

Figure 9. Non-raised beds in the rainy season

Figure 10. Raised beds in the rainy season

In the rainy season, the drainage ways of the non-raised beds were flooded as seen in Figure 9. The canals were full with water. The water level in the canals A and B was equivalent to the water level between the beds. But as seen in Figure 10, the canals of the raised beds were not flooded.

4.4 Diseases and plagues

4.4.1 Diseases and plagues of cabbage occurring at the experimental site

During the cultivation of cabbage, the plant was attacked by the following pest and diseases. The caterpillar, (*Agrotis repleta*) in Figure 11 was present in the field during the seedling stage of the cabbage. It was observed that these caterpillars were only present on the non-raised beds since the moisture content of the non-raised bed was higher than comparison with the raised bed.

Figure 11. Caterpillar (Agrotis repleta)

This caterpillar can reach a length up to 44 mm. During the day they hide in the ground around the stem base. At night they appear and eat the plants, leaving large holes in the leaves (Ministerie van landbouw veeteelt en visserij onderdirectoraat landbouwkundig onderzoek, 2005) They have a greasy appearance, are grey to brown in color with faint lighter colored strips and when fully grown, they usually are the color of the soil in which they live. They can be found on the soil surface, beneath leaves and under large soil clods (Ministerie van landbouw veeteelt en visserij onderdirectoraat landbouwkundig onderzoek, 2005). They are always found in the soil. They were very active in the first three weeks of transplanting. Treatment was required because they were eating the leaves of the plant.

The Caterpillar *(Hellula undalis*) appeared at the seedling stage on the plants (Figures 12 and 13). The caterpillar is yellow with a pinkish tinge with seven purplish brown longitudinal stripes. The adult moth is slender, pale yellowish-brown with grey wavy lines on the fore wings (Kumaranag, kedar, Thodsare, & Bawaskar, 2014). These insects appeared right after transplanting. They appeared in the growing point of the cabbage plant after hatching. The adult female lays eggs on the growing point or on the older leaves. The eggs hatch in 2-3 days. They drill and feed in the heart of the cabbage and become fully grown in 7-14 days (Kumaranag, kedar, Thodsare, & Bawaskar, 2014). They appeared on both the raised and non- raised beds of cabbage in equal numbers.

Figure 12. Cabbage affected by caterpillar (Hellula undalis)

Figure 13. Caterpillar Hellula undalis

The mole cricket (*Gryllotalpidae*), appeared in the second week after transplanting. These insects only appeared on the raised beds because the surface of these beds were dryer then the non-raised beds (Figure 14).

Figure 14. Mole Cricket (Gryllotalpidae)

These insects caused damage to the cabbage plants, namely by biting young plants just below the soil. They feed on roots at or slightly below the soil surface and can cause considerable damage before being discovered and destroy cabbage plants. Leaves are cut below the soil surface without any trace or insects on them (Frank & Walker, 2006).

Ants (*hymenoptera*) are a group of colony-forming social insects (Daniel & Benjamin, 2013). The ants were mostly underneath the cabbage leaves with white ant eggs (Figure 15). They damaged the plant by sucking the plant juice of the plant leaves. They were noticed in the second to third week after transplanting. They only occurred on the raised beds of cabbage because these beds were higher and dryer than the non- raised beds.

Figure 15. Ants (hymenoptera) on cabbage plant

White flies' adults (*Aleyrodes proletella*) are approximately 1.5 mm in length (Figure 16). They have white wings with four gray spots (Abdurrahman, Mustafa, & Halil, 2018).

Figure 16. White flies (Aleyrodes proletella)

The white flies were underneath the cabbage plants. They appeared in the second and third week after transplanting. They damage the plant tissue and reduce the productivity of the plant. These white flies occurred on both the raised and non-raised beds. There were more observed on the non-raised beds.

4.4.2 Pests of eggplant occurring at the experimental site

Just like on the cabbage plants, **ants (*hymenoptera*)** were also found on the eggplant leaves (Figure 17). They were underneath the leaves sometimes containing white eggs.

Figure 17. Ants (hymenoptera) on the eggplant leaves

The ants appeared in the second and third week after transplanting of the plant. They damaged the plant by sucking the plant juice from the leaves and leaving it yellow. They only appeared on the non-raised beds.

Fruit rot due to Phytophthora sp. is common during rainy seasons (Figure 18).

Figure 18. Fruit rot due to Phytophthora sp.

The fungus is found in the soil, so that long-hanging fruits can be contaminated by the splashing of soil particles. It brings damage to the fruit due to brown, watery spots on the fruit and fruit drop in which the stem sticks to the plant (Djoeneri, 2005). This occurred only on the non-raised beds, because these beds were prone to flooding in the rainy season.

4.5 Field measurements

4.5.1 Growth of cabbage plants

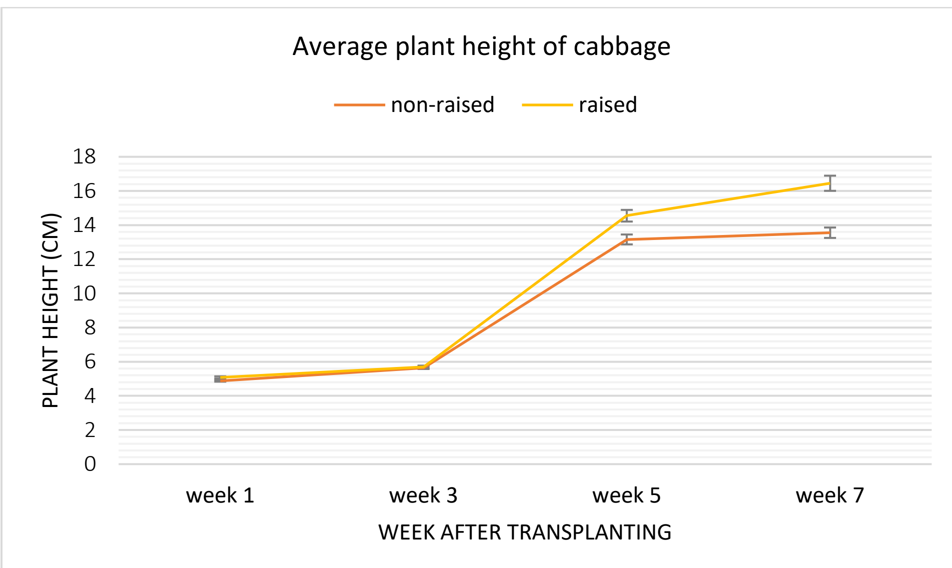
On the non-raised beds, the cabbage cropped poorly in comparison to the cabbage on the raised beds, because of the pest attacks and flooding. The cabbage head development phase is between 60-90 days after sowing (Tetsuo & Yoji, 1978). On both the raised and the non-raised beds, cabbage started cropping in week 5 (Table 7) after transplanting which is approximately 71 days after sowing. On the non-raised beds, the cabbage was cropping very poorly. Because of the flooding and the pest and diseases incidences that occurred more frequently on the non-raised beds.

Table 6. Weekly number of cabbage leaves counted

Week	Non-raised beds	Raised beds
1	4. 00	4.00
3	9.00	9.00
5	Cropping	Cropping

The plant height was measured to gather information on the growth development of cabbage on the raised and non-raised beds (Figure 19). The average plant height of cabbage in week 1 and 3 were about the same for both the raised and non-raised beds. In week 5 and 6 plant height started to differ on the beds. The plant height on the non-raised beds was shorter compared to the raised beds. This was a result of the flooding and the pest and diseases that occurred more frequently on the non-raised beds. According to a research conducted on a silty loam soil the plant height of cabbage was 7.39 cm after twenty days after transplanting, 15.83 cm after 40 days after transplanting and 29, 85 cm after 60 days after transplanting (Firoj, et al., 2015). The plant height from this experiment was lower than that of the research. The reason for this can be because of environmental conditions and other factors including soil type, variety, season, fertilization (Passioura, 2002).

Figure 19. Weekly cabbage plant height



The cabbage on the non-raised beds had a shorter diameter (Figure 21) and circumference (Figure 22) and a lower weight (Figure 20) compared to the raised beds. It can be seen that there are differences with the cabbage parameters on the raised and non-raised beds, in weight, diameter and circumference. The total number of cabbages harvested on the raised beds was higher than on the non-raised beds was (Figure 23).

The harvest of the cabbages on the raised beds was more because the cabbages on the non-raised beds were grown under very bad conditions. The cabbage on the non-raised beds had more pests and the beds were flooded because of the rainy seasons. But still the cabbage production was poor overall.

Figure 20. Average weight of cabbage

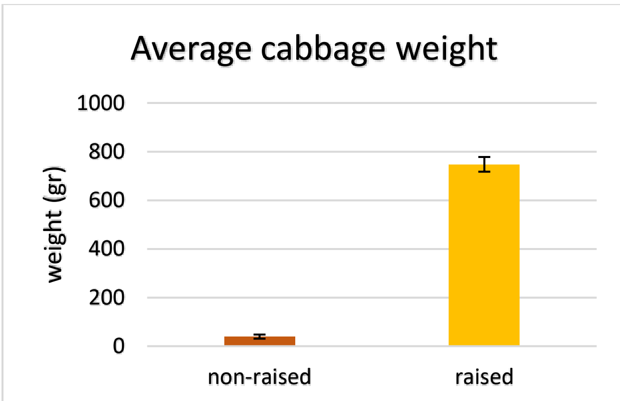


Figure 21. Average diameter of cabbage

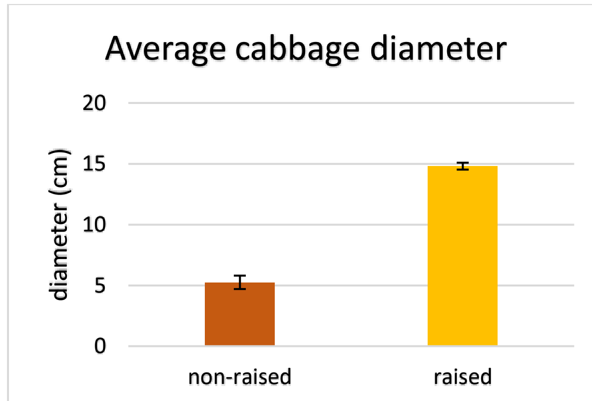


Figure 22. Average circumference of cabbage

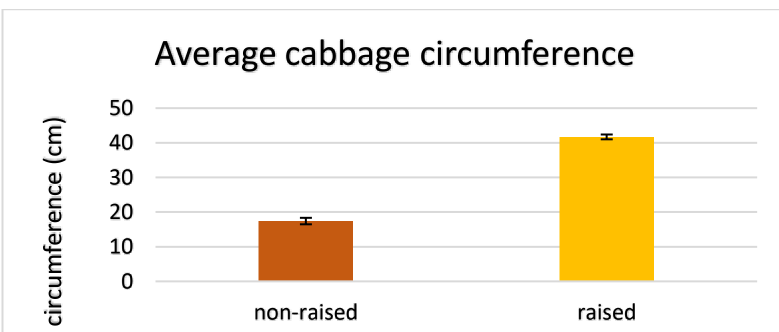
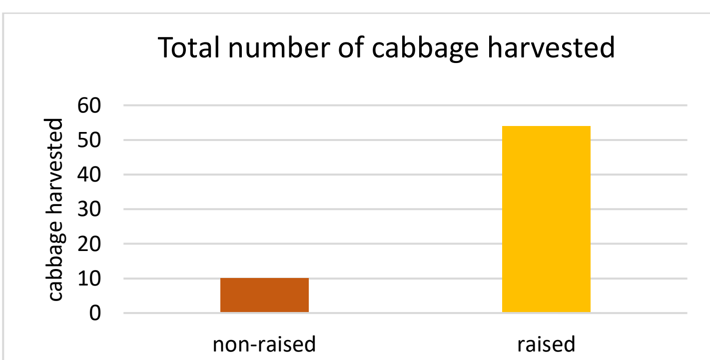


Figure 23. Total number of cabbages harvested



The average mean of cabbage root weight (Figures 24 and 25) and root length (Figure 26) were lower on the non-raised beds. In comparison to the raised beds. The reason for these is because of the flooding and the pests and diseases that frequently occurred on the non-raised beds.

Figure 24. Average root fresh weight of cabbage

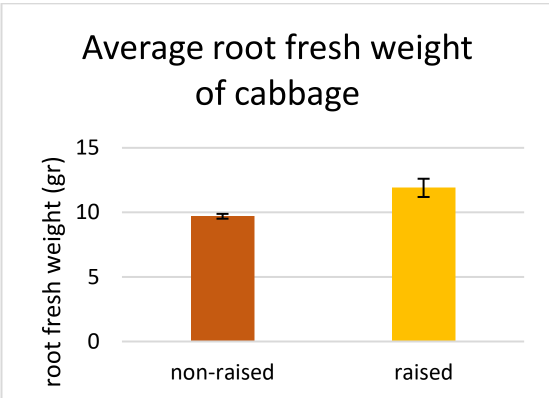


Figure 25. Average root dry weight of cabbage

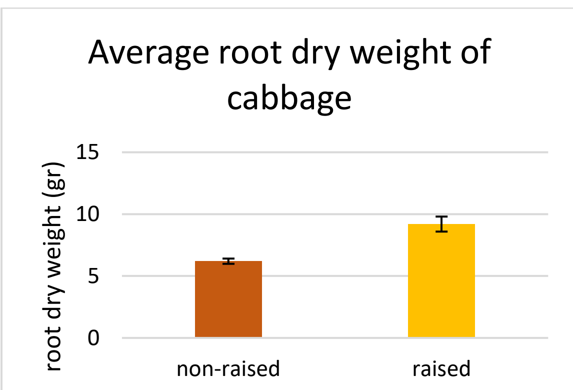
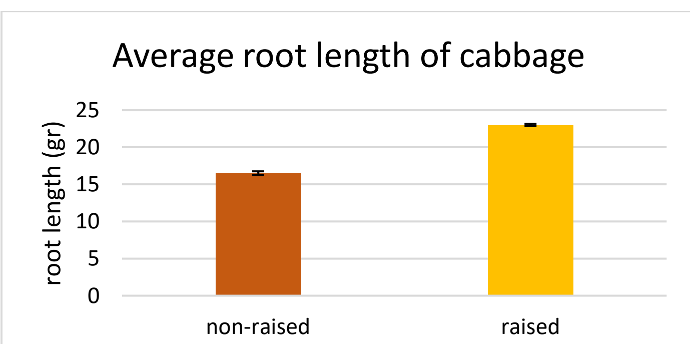


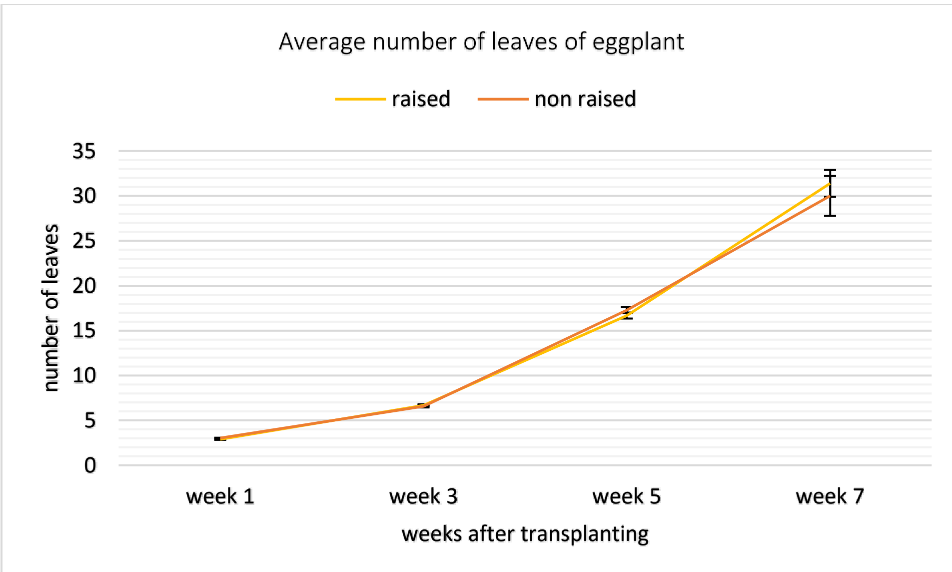
Figure 26. Average root length of cabbage



4.5.2 Growth of eggplant plants

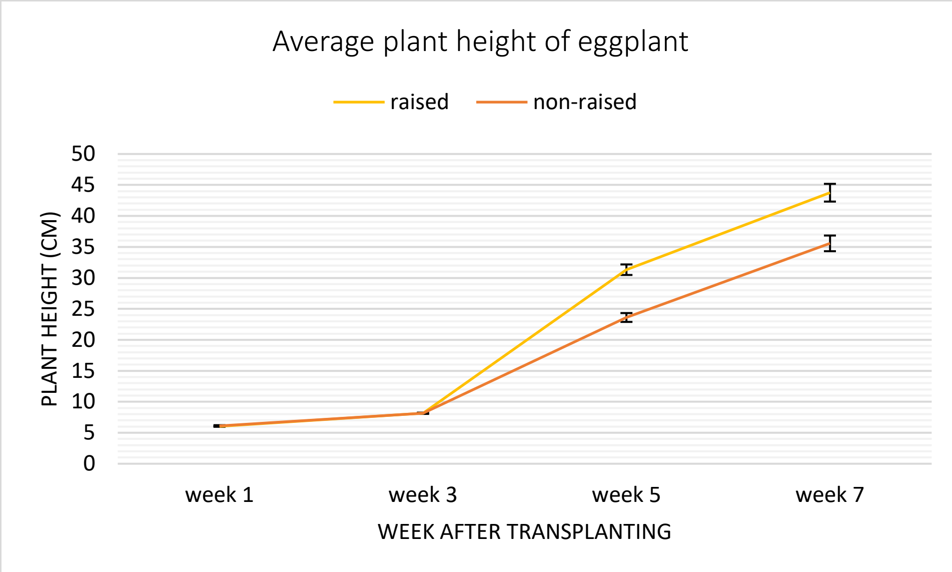
Figure 27 shows that the average number of leaves in week 1 and 3 were the same on both the raised and non-raised beds. However, in week 5 and 7 the number of leaves were slightly higher on the raised beds (Figure 27).

Figure 27. The mean number of leaves of eggplant



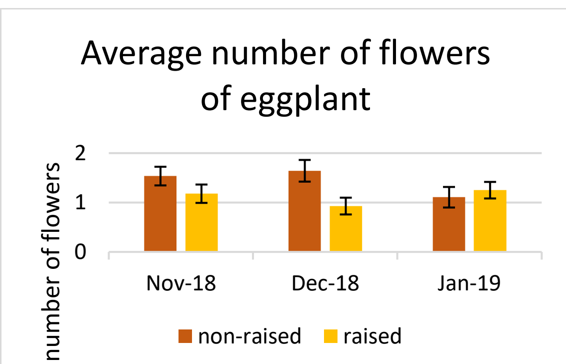
The average plant height of eggplant was the same in week 1 and 3 (Figure 28). In week 5 and 7 the average plant height was taller on the raised compared with the non-raised beds (Figure 28). This, probably as a result of plant stress. Stress in plants occurs when an external factor negatively influences the plant growth, productivity, reproductive capacity or survival (Rhodes & Nadolska-Orczyk, 2001). The external factor in this case was the flooding of the non-raised bed.

Figure 28. The mean plant height of eggplant



The average number of flowers are displayed in Figure 29. The average number of flowers were higher on the non-raised beds in December 2018 and lower in January 2019 (Figure 29). In December -January the flooding occurred this explains the rise and decline of flowers on the non-raised beds. The flowering started in week seven after transplanting.

Figure 29. Average number of flowers per plant.



The length and weight of the fruits were in general lower. It can be seen that the mean weight (Figure 30) and the length (Figure 31) of the fruits were lower on the non-raised beds in comparison to the raised beds. A possible explanation could be related to the 'stress' in plants. This occurs when an external factor negatively influences the plant growth, productivity, reproductive capacity or survival (Rhodes & Nadolska-Orczyk, 2001). Water stress from too much water is the leading cause of poor quality. Standing water for more than 24 hours can seriously damage the crop and reduce the quality of the fruits. So although eggplant is a salt tolerance plant the length of the flooding effected it negetivaly by poor quality of the fruits.

Figure 30. Average weight of eggplant

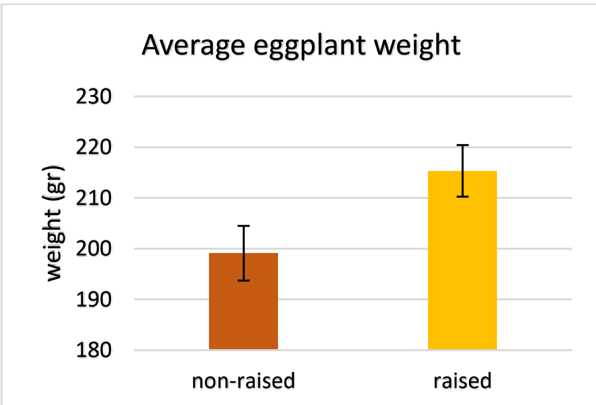
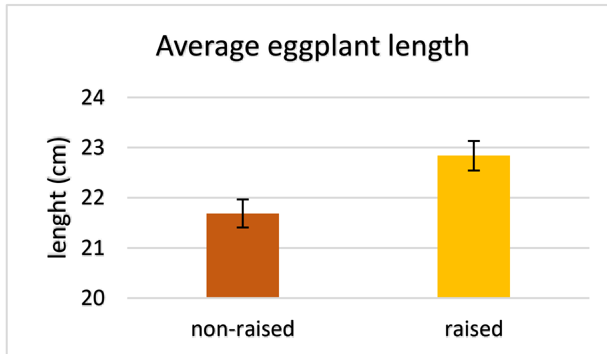


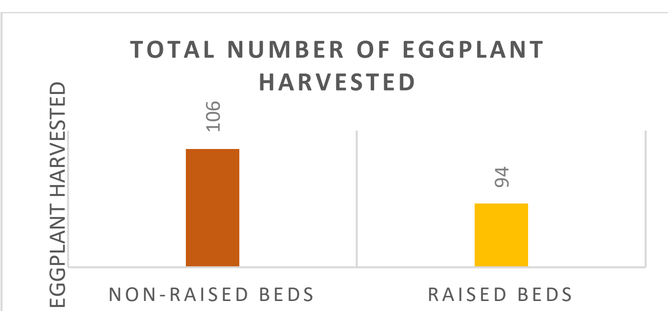
Figure 31. Average length of eggplant



The average number of fruits per plant are displayed in Figure 32. The total number of fruits harvested on the non-raised beds was higher than on the raised beds (Figure 32).

The total number of fruits were higher on the non-raised beds but it appeared that the difference was not as much (difference of 12 fruits more on the non-raised beds). Study shows that eggplant is most tolerant to seawater flooding while cabbage is the least tolerant (Youping, Joseph, & Genhua, 2015). Although the total number of the fruits were somewhat higher on the non-raised beds the quality of the fruits were poor.

Figure 32. Total number of fruits harvested of eggplant.



From Figures 33, 34 and 35 it can be noted that both, the root weight and root length were lower on the non-raised beds. The roots on the non-raised beds experienced flooding and resulted in a lower root weight and root length in comparison to the non-raised beds.

Figure 33. Root fresh weight of eggplant

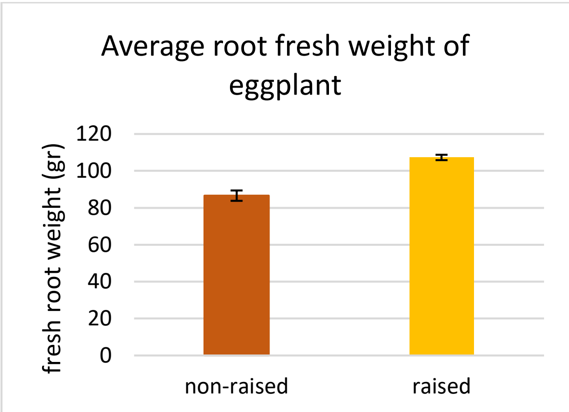


Figure 34. Root dry weight of eggplant

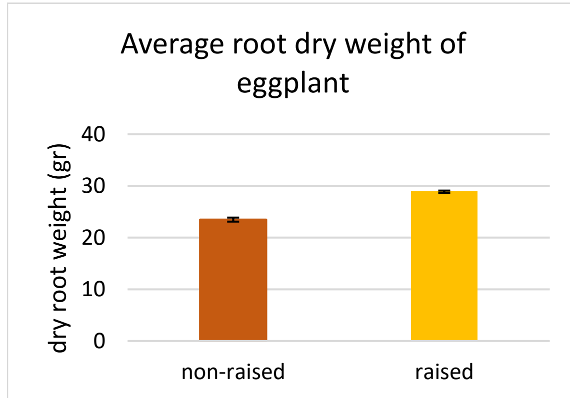
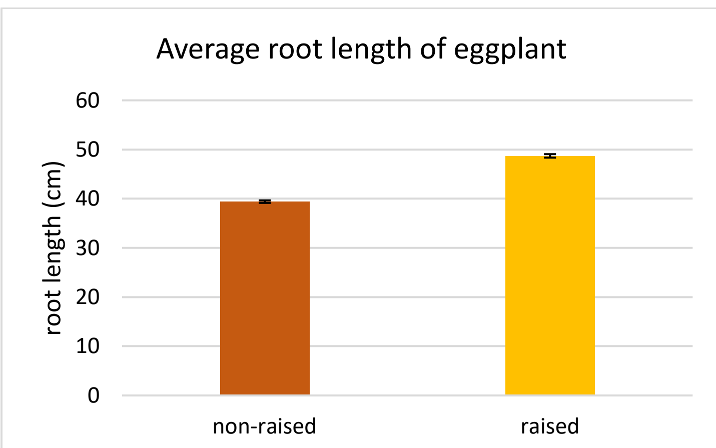


Figure 35. Root length of eggplant



The roots on the raised beds were thicker and firmer and the roots on the non-raised beds were thinner. The roots on the non-raised beds experienced flooding that is why the roots mass is lower and root length is shorter on the non-raised beds.

Figure 36. Eggplant roots on non-raised beds

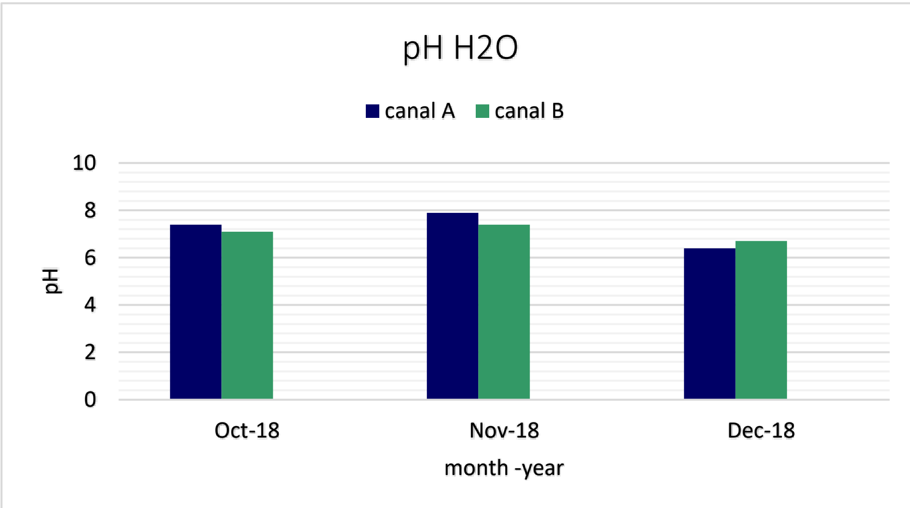
Figure 37. Eggplant roots on raised beds

4.6 Laboratory analysis

4.6.1 Water samples during plant growth and harvest

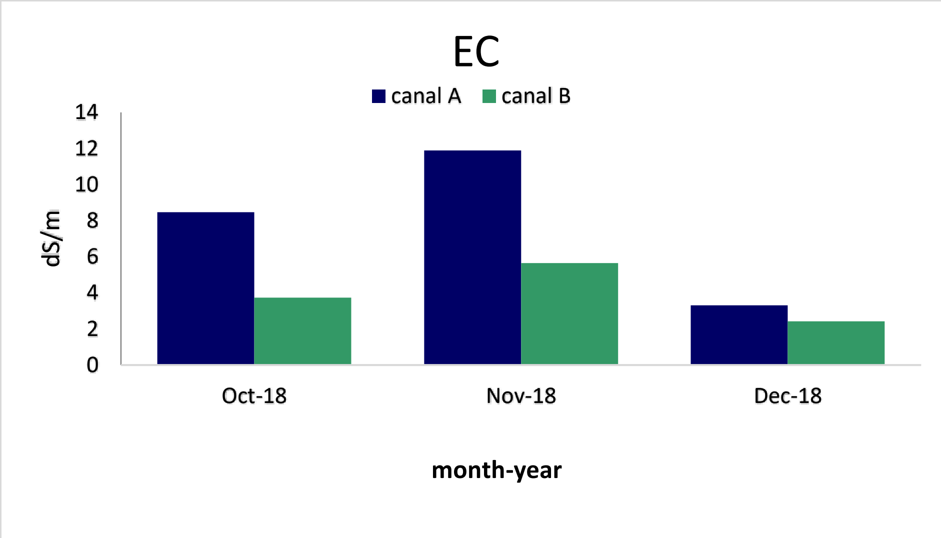
From Figure 38 it can be seen that in October 2018 and in November 2018, the pH in canal A was slightly higher during plant growth. The reason for this can be that on October 4, 5 and on November 9 and 28, 20 grams of chicken manure and Dugro, a water-soluble plant food fertilizer was used for the crops. Fertilization can increase oxygen levels, pH levels and reduces transparency of lake water (Obire, Ogan, & Okigbo, 2008). Some of this fertilizer could have drained into canal A during irrigation. In heavy clay soils nutrients can be washed away from the soil surface easily because the water stays on top of the soil and does not move inside easily. Canal A was the canal between both beds, so both water from the raised and non-raised beds were flowing from the soil surface into canal A. In December 2018, the pH in canal A was slightly lower during the harvest the reason for this could be because during this time there was no fertilization done on the beds, so the water from the soil surface flowing into canal A had less fertilizer. The last fertilization was done on November 30 with NPK 12-12-17. As stated in the literature, the best pH ranges to grow cabbage is 6.5-7 and for eggplant is 6-7 (Ullio, 2003). Overall, the pH of the water in the canals was good for cultivation of both cabbage and eggplant.

Figure 38. pH (H_2O) of water samples



From figure 39 can be seen that the electrical conductivity was the highest in canal A during the entire research investigation. Canal A was the canal between both beds. This has to do with the location and the intrusion of seawater. In December, the EC range was between 1.5-3 which means that the water was brackish and irrigation must be done with caution if considered as an option (Hillel, 2000). In November, the EC range was between 8-15 which suggested that the water in canal A was saline (Hillel, 2000). The water in the canals was not suitable for irrigation. Because of this SWM water was used for irrigation.

Figure 39. Electrical conductivity (dS/m) of water samples



4.6.2 Soil samples during plant growth and harvest

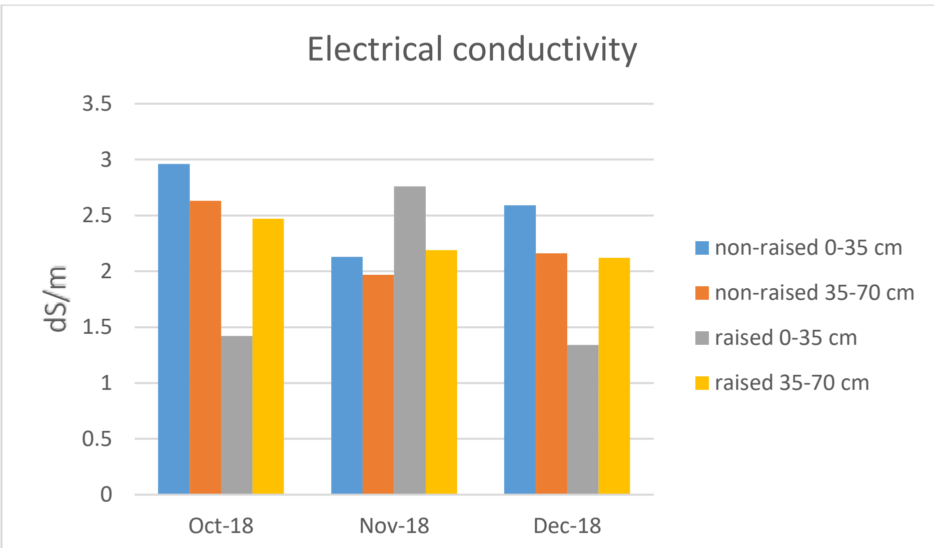
EC

Soil electrical conductivity is a measure of the amount of salt in soil or the salinity of the soil. On the raised beds in November 2018 during plant growth, the EC was the highest (Table 10). This was not expected but the difference was not as much. The EC on the raised beds at a depth of 35-70 cm were higher compared to the depth of 0-35 cm. The reason for this could be that during ploughing the underlayer was brought above and the top layer was brought under. The soil on the non-raised beds contained more water than the raised beds. On the non-raised beds in October 2018 the EC of the soil was slightly higher. Also, in December 2018, the EC was slightly higher on the non-raised beds. This was expected because when it started raining and the non-raised beds were flooded, the soil was saturated with water. Salt intrusion occurred more readily at the non-raised beds. The EC on both beds was not completely favorable to grow the crops because the EC was for the most part between 2- 4 in the soil. This indicates slightly saline conditions and the yields of sensitive crops may be restricted (Shahid & Rehman, 2011). Salinity effected the production during growth of cabbage and eggplant. Cabbage is moderately sensitive at a salt tolerance threshold level (EC) of 1.8 dS/m and eggplant at an EC of 1.1 dS/m (Tanji & Kielen, 2002). All the beds had an EC above 1.1 and 1.8 dS/m and only the non-raised beds in October and December had a salinity level of slightly beneath 1.8 dS/m.

Table 7. Electrical conductivity of the Soil

EC soil (dS/m)	Oct-18	Nov-18	Dec-18
non-raised 0-35 cm	2.96	2.13	2.59
non-raised 35-70 cm	2.63	1.97	2.16
raised 0-35 cm	1.42	2.76	1.34
raised 35-70 cm	2.47	2.19	2.12

Figure 40. Electrical conductivity of the soil



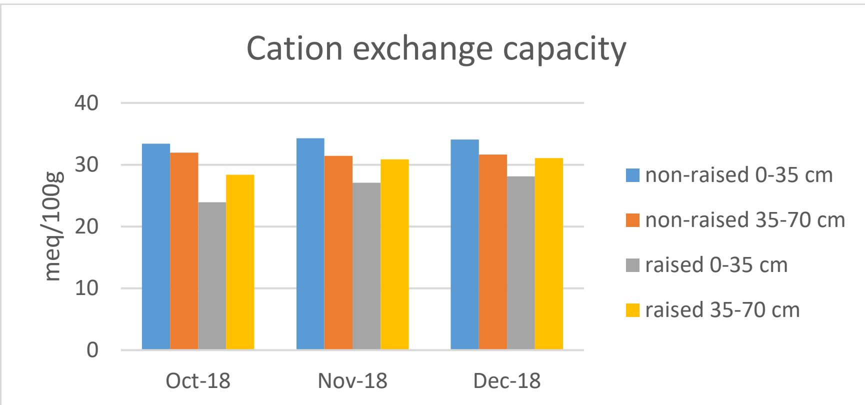
CEC

The CEC for clay soils ranges between 11-50 meq/100g. Soils with this range have a high clay content (Cotching , Brown, & Lemon, 2020). The CEC on the raised and non-raised beds were within this range as expected. The type of bed has no influence on the CEC, because it is the same soil used. The CEC is important to plant growth because it is a useful indicator of soil fertility. It shows the soil's ability to supply three important plant nutrients: calcium, magnesium and potassium. Soil with a high CEC have the ability to hold more cations making them sufficient in calcium, magnesium and other cations. Soil with a higher clay fraction tend to have a high CEC content (Cotching , Brown, & Lemon, 2020).

Table 8. Cation exchange capacity of the soil

CEC soil (meq/100g)	Oct-18	Nov-18	Dec-18
non-raised 0-35 cm	33.38	34.27	34.09
non-raised 35-70 cm	31.95	31.43	31.64
raised 0-35 cm	23.91	27.11	28.12
raised 35-70 cm	28.38	30.86	31.09

Figure 41. Cation exchange capacity of the soil



Soil Organic Matter and Soil Organic Carbon

Soil organic matter is the basis of soil fertility. It is important to plant growth because it releases nutrients for plant growth, promotes the structure, biological and physical health of soil and is a buffer against harmful substances. Rainfall and temperature influence the soil organic carbon levels. The SOC is higher where rainfall is higher and temperatures are cooler (Milne, et al., 2015). On the raised beds, the SOC was the highest in November 2018. On the non-raised beds, the SOC was the lowest in October 2018 (Table 12). In October 2018, the temperature was the highest resulting into a lower SOC of the soil. Organic carbon was overall the highest on the raised beds (Table 12). It has been suggested that a critical level of soil organic carbon is 2% and that below 2% the soil structural stability will suffer a significant decline (Kemper & Koch, 1966). Organic matter breaks down over time and human influences. Soil organic carbon accounts for less than 5% on average of the mass of upper layers and diminishes with depth (Blanco-Canqui, et al., 2013). The levels of SOC were adequate for plant growth. Overall, the soil organic carbon and soil organic matter increased over time due to fertilizers used in October 4, 5, 9, 28 and November 7, 20, 30. Most soils contain 2 – 10 percent organic matter (Bot & Benites, 2005) implying that the levels of soil organic material were adequate on the experimental site. Fertilizer enhances the production of biomass (Alexandra & Jose, 2005). Biomass refers to organic matter that comes from plants and animals. It was expected that the soil organic matter increased higher at the raised beds because the raised beds did not experience flooding.

Table 9. Soil organic carbon of the soil

Soil Organic Carbon (%)	Oct-18	Nov-18	Dec-18
non-raised 0-35 cm	1.71	4.64	4.06
non-raised 35-70 cm	1.36	1.23	1.6
raised 0-35 cm	2.77	4.19	3.47
raised 35-70 cm	3.18	3.76	3.85

Figure 42. Soil organic carbon

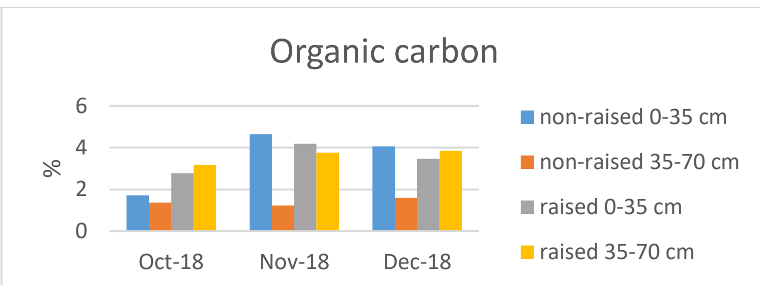
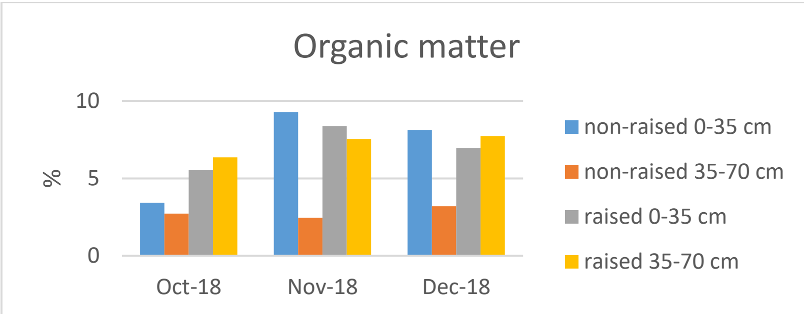


Table 10. Soil organic matter of the soil

Soil organic matter (%)	Oct-18	Nov-18	Dec-18
non-raised 0-35 cm	3.42	9.28	8.12
non-raised 35-70 cm	2.73	2.46	3.2
raised 0-35 cm	5.53	8.38	6.95
raised 35-70 cm	6.36	7.53	7.71

Figure 43. Soil organic matter



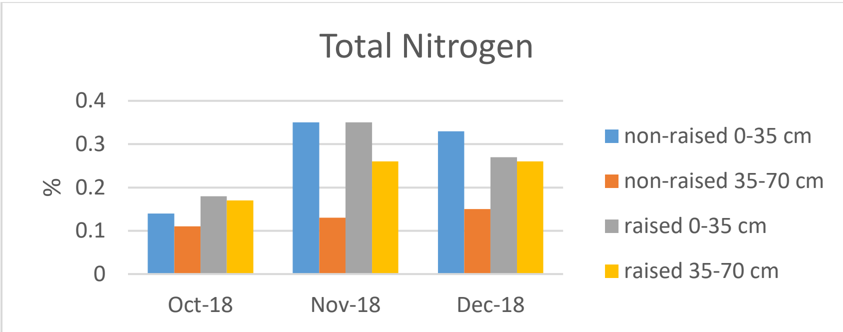
Total N

Total N is an important element for growth and development of plants. It significantly increases and enhances the yield and its quality by playing a huge role in the biochemical and physiological functions of the plant (Jahan, et al., 2016). In November 2018 and December 2018, the total N was the highest on the beds because of the fertilizers that was used of an NPK ratio of 4-3-3 and 15-30-15. The total N increased on the beds and then decreased in December. The reason for the increase can be because in October and November Fertilization was done and for the decrease in December there was no fertilization added (Al-Ethawi & Salem, 2019). The last fertilization was done on November 30.

Table 11. Total nitrogen of the soil

Total Nitrogen (%)	Oct-18	Nov-18	Dec-18
non-raised 0-35 cm	0.14	0.35	0.33
non-raised 35-70 cm	0.11	0.13	0.15
raised 0-35 cm	0.18	0.35	0.27
raised 35-70 cm	0.17	0.26	0.26

Figure 44. Total Nitrogen of the soil



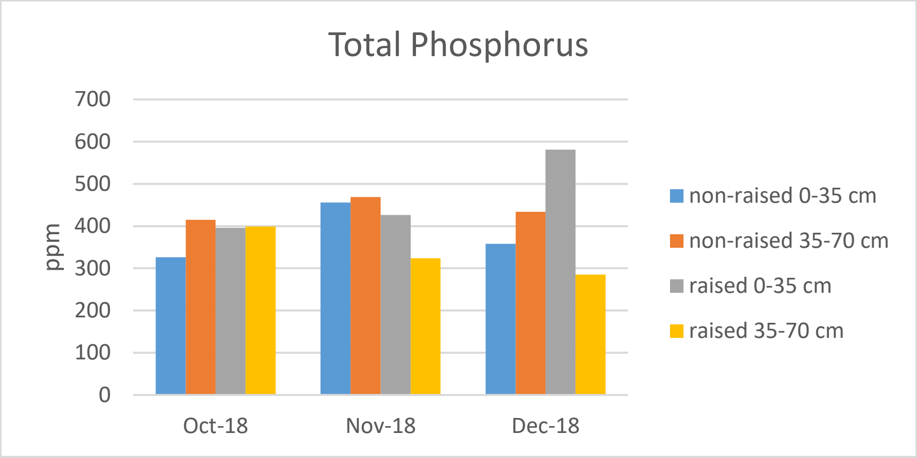
Total P

Total P is an important element for growth and optimum crop production (Grant, et al., 2005). Total P of soil usually ranges from 100 to 2000 ppm (Cynthia, Shabtai, Marcia, Christian, & Christian, 2004). The Total P clearly increased in November. The reason for this is because of fertilization that took place in October 4. 5, 9, 28 and November 7, 20, 30. In December there was a slight decrease because there was no fertilization added and of the flooding but not with much difference overall (Salem, Al-Ethawi, Eldrazi, & Nouraldien, 2014).

Table 12. Total phosphorus of the soil

Total Phosphorus (ppm)	Oct-18	Nov-18	Dec-18
non-raised 0-35 cm	326	456	358
non-raised 35-70 cm	415	469	434
raised 0-35 cm	396	426	581
raised 35-70 cm	399	324	285

Figure 45. Total Phosphorus of the soil.



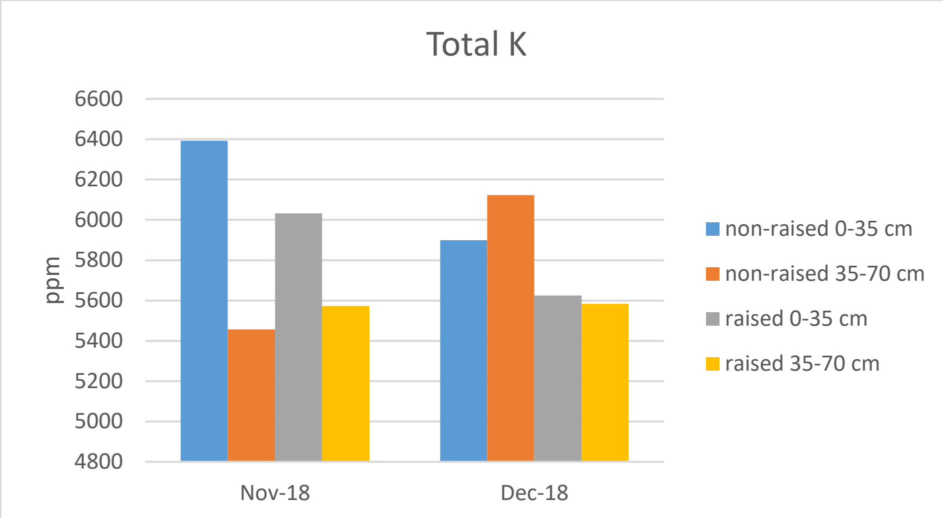
Total K

Total K in the soil is an important element for plant productivity and crop quality (Weil & Nyle, 2017). The total amount of potassium was the highest on the beds at 0-35 cm in November during plant growth (Figure 46). This is because of the fertilization that had been taken place with an NPK ratio of 15-30-15 (Rawat, Sanwal, & Saxena, 2016). The potassium content of various clay minerals is different (Schon, 2011). The total K decreased in December on the beds. The reason for this can be because there was no fertilization done in December. The last fertilization was done in November 30.

Table 13. Total potassium of the soil

Total Potassium (ppm)	Nov-18	Dec-18
non-raised 0-35 cm	6392	5899
non-raised 35-70 cm	5457	6122
raised 0-35 cm	6032	5625
raised 35-70 cm	5572	5584

Figure 46. Total K of the soil



*Total K in **October** was not measured because of breakdown of the equipment.

Soil Texture

In Table 17, the texture of the soil is displayed. On October 3, 2018, the soil texture on the raised beds was analyzed as a silty clay and the non-raised beds a heavy clay. During plant growth on the November 8, 2018 the texture of the beds was all heavy clay. And close to the harvest on the December 17, 2018, the soil texture on the non-raised beds were classified as a silty clay and on the raised beds as heavy clay. The texture of the soil is heavy clay and, in some places, silty clay, because of the heterogeneity of the soil.

Table 14: Soil texture analysis conducted during growth of crops

Date	**Description**	**% Sand**	**% Silt**	**% Clay**	**Texture**
3 October 2018	Non-raised 0-35cm	0.2	31.4	68.4	Heavy clay
	Non-raised 35-70cm	0.2	35.2	64.6	Heavy clay
	Raised 0-35 cm	6.5	50.3	43.2	Silty clay
	Raised 35-70 cm	0.4	48.7	50.9	Silty clay
8 November 2018	Non-raised 0-35cm	0.4	32.9	66.7	Heavy clay
	Non-raised 35-70cm	0.0	33.5	66.5	Heavy clay
	Raised 0-35 cm	0.6	37.5	61.9	Heavy clay
	Raised 35-70 cm	0.3	32.6	67.0	Heavy clay

17 December2018	Non-raised 0-35cm	0.2	31.4	68.4	Heavy clay
	Non-raised 35-70cm	0.2	35.2	64.6	Heavy clay
	Raised 0-35 cm	6.5	50.3	43.2	Silty clay
	Raised 35-70 cm	0.4	48.7	50.9	Silty clay

4.7 Overall Results and Discussion

The average amount of rainfall in October 2018 was the lowest during transplanting of the crops with an amount of 1.1 mm rainfall. The monthly average temperature in the long dry season during transplanting was high and the monthly average relative humidity was low. Because of this, irrigation was needed for the crops in the long dry season. The temperature was very high in October. It ranged between 27.7 ^{0}C – 30.9 ^{0}C. This temperature range was outside the optimum range for cabbage growth which ranges between 15 ^{0}C – 20 ^{0}C (Muleke, Saidi, Itulya, Thibaud, & Ngouajio, 2014). But the monthly average temperature was very good for eggplant which grows best at an optimum temperature range between 21 ^{0}C – 30 ^{0}C (Ullio, 2003). The water in the canals were not used for irrigation because the EC in the canals ranged between 1.5-3 dS/m which means that the salinity level was too high for crop growth (Hillel, 2000). The texture of the soil was heterogeneous. Because cabbage grows best on light clay soils and eggplant on permeable, humid sandy soils and loamy sand, sandy loam soil, the clay texture of the beds was not completely ideal for the crop growth (Ministerie van landbouw veeteelt en visserij onderdirectoraat landbouwkundig onderzoek, 2005). An EC of soil ranging between 0-2 dS/m establishes the soil as a non-saline and is suitable for crop growth (Shahid & Rehman, 2011). During transplanting the EC was suitable for plant growth but during plant growth all the beds had an EC above 2 dS/m which is not suitable for plant growth and only the non-raised beds in October and December had a salinity level between 0-2 dS/m. The pH of the soil was between 5.6 - 6.1, establishing that the pH on both the raised and non-raised beds was relatively favorable to grow both cabbage and eggplant (Ullio, 2003). In the rainy season, the non-raised beds experienced flooding but the raised beds did not because the raised beds were 25 cm higher than the non-raised beds. Because of the flooding of the canals, the plant performance of cabbage on the non-raised beds was very poor because of its low salt tolerance (Tanji & Kielen, 2002). The EC in the canals A and B were too high for the crop growth. Because the flooding on the non-raised beds was continued over a period of time, it also started to affect the eggplant plant performance (Djoeneri, 2005). The flooding also made it difficult for crop management such as weeding and fertilizing of the crops. From the soil analysis it was evident that organic carbon and organic matter were overall the highest on the raised beds which also led to better plant performance. The NPK on the beds were in sufficient amounts on the beds. Although the number of eggplant fruits was higher on the non-raised beds, the visual effects of the fruits in weight and length were lower compared to the raised beds. Further, the eggplant plants were dying off because of the lack of oxygen at the roots in January 2019. This was because of the stress as a result of flooding the plants experienced on the non-raised beds (Gustavo, 2012). The average means from the parameters weight, diameter and circumference show a difference with the cabbage and eggplants on the raised and non-raised beds. The weight of the eggplant on the raised beds were heavier and had fewer incidences with diseases and insects compared to the non-raised beds.

5. Conclusion and recommendations

Conclusions

The aim of this research was to investigate the impact of raised beds and non-raised beds on the growth performance of eggplant and cabbage on an agricultural field in the coastal area with salt water intrusion in the research area 'Weg naar Zee' at the brantimakkaweg.

Descriptive statistics was used for the research investigation on the raised and non-raised beds. Soil, water and plant samples were taken for the research.

The results of the soil samples showed that the electrical conductivity in the soil was the highest on the non-raised beds in the rainy season when the flooding occurred. Salt intrusion occurred more readily on the non-raised beds because of the flooding of the canals which had a high electrical conductivity.

The results of the water samples showed that the electrical conductivity in the canals was too high to be used as irrigation for the crop. Eggplant and cabbage can have a good plant performance on clay soils but plowing and irrigation is needed in the dry season. Eggplant has a higher salt tolerance level than cabbage. To know which crops are best to grow at the brantimakkaweg depends on the salt sensitivity of the crop.

The results of the plant samples showed that the plant performance on the raised beds was much higher than the non-raised beds. In the rainy season the raised beds did not experience any flooding; only the non-raised beds experienced flooding. Both eggplant and cabbage fruits were bigger and heavier on the raised beds. The plants on the non-raised beds experienced more diseases and insects compared to the raised beds. Fertilizer on the raised beds was more efficient because, the raised beds were not flooded. Crop management was easier on the raised beds since the beds are easier accessible. The raised beds were better suited for cultivation but the non-raised beds were not.

Recommendations

It is better to grow crops like cabbage and eggplant on raised beds at the 'Weg Naar Zee' area, because of the flooding and salt intrusion that occurs.

The water in the canals must not be used for irrigation because of its high EC levels. Irrigation water from the SWM or rain fed water can be used.

In the rainy seasons when threatened with flooding raised beds are recommended.

Because of the high salt levels in the soil and water, plant crops with a higher salt tolerance level are recommended for cultivation in this area such as eggplant, Cantaloupe, Vietnamese eggplant also known as Antruwa, legumes (jarpesi).

Agricultural areas are predominantly in the young coastal plain which often lay under water in the short and long rainy season. Therefore, cultivating according to the raised bed system is advised at the ‘Weg naar Zee’ area to avoid plant loss.

Future studies can be done of other methods that can be used to eliminate or minimize the effects of soil salinity and flooding have on plants.

Also, future studies in which species of crops are best suited to grow in soils with high salinity level and flooding can be done.

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