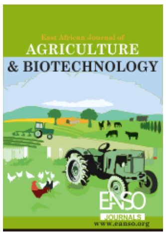

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Original Article

Influence of Dykes' Characteristics on Food Crop Production in Lower River Nyando Basin, Kenya

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ABSTRACT

Dykes minimise flood risks among riparian communities. In Nyando basin, Kenya, dykes were constructed to minimise flood impacts on human activities in the riparian plains. The dyke characteristics could change the rate of silting. In spite of these dynamics, some farmers now use fertilisers as a new way of coping with nutrient deficiency. Several researches have been done in Kenya on the effects of floods on human activities; however, there is no clear link between dyke characteristics like period of existence, length and height and their influence on food crop production. The dykes in Nyando have reduced floods in the region; however, it is not clearly understood how the dyke characteristics influence the food crop. Therefore, the purpose of this study was to examine the influence of dyke characteristics on food crop production. Planning Theory was used. Descriptive cross-sectional research design applied. The target population stood at 34,460 households. At least 384 Household heads were recruited via simple random sampling and a questionnaire administered, while purposive sampling was useful in identifying relevant experts in the field of study. Primary data was obtained by interviewing key informants and focused group discussions. Other tools include observation and photography. Secondary data was obtained from publications and print media, and SPSS was utilised in data analysis. Qualitative data was analysed by coding and organisation of data into themes and sub-themes where generalisation was made. The results from the multiple coefficients of determination (R^2) indicated that 45.4% (R^2 = .454, p = .039) of the variation in the general crop yield was explainable by the combined change in Dyke Characteristics. The dykes' characteristics significantly influenced crop production.

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INTRODUCTION

In the Nyando basin, food crops majorly grown are rice, maise, beans, millet, and sorghum, and mixed cropping is the common cropping pattern utilised by the farmers (WHP, 2002). A study by Ochola (2010) indicates that flood events can result in long-term benefits to agricultural production by recharging water resource storages, especially in drier, inland areas, and by rejuvenating soil fertility by silt deposition. Floodwaters carry lots of nutrients that are deposited in the plains. Farmers love such soils, as they are perfect for cultivating some kinds of crops. An investigation by Rubin (2016) indicates that floods can distribute large amounts of water and suspended river sediment over vast areas. The study by Rubin (2016) reports that before the Mississippi and associated rivers were controlled in dykes in southern Louisiana, the rivers would frequently spill their banks. These processes made the lands of the Mississippi Delta rich and raised.

Over time, as indicated by Rubin (2016), the Mississippi area has slowly subsided with time, and without the continued replenishment of sediment from river floods, much of it has dropped to elevations below natural sea level. Therefore, there is a call for more studies on the relationship of dykes and the altitude of the wetland. This study will thus seek to investigate the subsidence of wetlands and their fertility protected by dykes.

Duong (2014) indicates that the Vietnamese Mekong Delta (VMD) plays an important role in food security and socio-economic development of the country with its protection dykes. Being a low-lying coastal region, the VMD is particularly susceptible to both riverine and tidal floods, which provide, on one hand, the basis for the rich agricultural production. Triple rice cropping became possible in farmlands covered by "full-dykes", i.e., those high and strong enough to prevent flooding. In these protected floodplains, rice can be grown even during the peak flood period (September to November). This study only looked at "full-dykes' ', that is, high and strong dykes; therefore, there is a need to provide an in-depth understanding of the influence of all forms of dykes, including low and weak ones, on food crop production.

Yamanouchi et al. (2022) & Adam (2008) revealed that arable farming had intensified since the middle of the 18th century, and by 1850, 60–80% of the coastal marshes were used for cereal production and the acreage of winter cereals had increased as well. Natural grasslands were replaced. The resulting homogenisation of the agricultural landscape had far-reaching consequences, as it greatly reduced the relative abundance of many species, and so, large-scale arable farming gave way to new pests and diseases: cereals were vulnerable to plagues caused by rodents and anthropophilic birds. Apparently, farmers preferred rain-spoiled years, indicating that the land had been drying up. This study reveals that the drying up of wetlands with the presence of the dykes leads to resistant pests and diseases in the farmlands. However, it does not clearly provide information on the pests and diseases. Therefore, it is necessary to provide adequate information on the pests and diseases brought by dykes that influence food crop farming.

According to Osouli et al. (2014) and Karim pour et al. (2015), raised and stronger dykes mean a reduction in incidences of overtopping and overtopping is a source of fertile silt deposition into the floodplain farmlands. On the contrary, Islam et al. (2015) report that the dykes would reduce the natural fertility of the floodplains. Consequently, farmers would potentially have to

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use more fertiliser applications to sustain their yields, thus creating cumulative negative impacts. A study by Buu (2013) reports that dykes that encircle large rice fields in the VMD could have negative environmental impacts in the long run, and any economic benefits farmers get will be short-lived. He states that while the dykes allow for the growing of more crops a year by keeping seasonal flooding at bay, severe degradation of soil is caused, and that would hit farmers hard. However, as he further indicates, farmers in the area are happy with the dykes, for they have boosted incomes sharply. Farmers have been able to cultivate the third crop every year and earn higher incomes. Experts, however, as indicated by Ni (2004), say the dykes cause greater harm than farmers realise. Ni (2004) notes that in Vietnam, dykes have blocked the inflow and outflow of flood waters into the Plain and the Quadrangle, and that would create serious problems. Floods bring alluvia to the soil, giving nutrition back to the land after crops and the alluvial deposits during the flooding also help strengthen the weak stratum of the "young delta," which also, after several months, when the flood gets out of the fields, carries the waste of chemical fertilisers and pesticides out to the sea. This study provides sufficient information that reveals flushing out operation freshens the fields for the new crop, which means fewer pests and diseases. Therefore, there is a need for more information on the influence of dykes on food crop production with reference to undrained chemicals and fertilisers.

A study by Tuan (2004) indicates that the dykes have changed the nature of the delta. Studies done by Ni and Tuan (2004) have also shown that soil quality in rice fields has degraded strongly after five or six years of cultivating three crops each year. They express concern about the losses farmers face now and in the future. This is a short-sighted approach as profit and other benefits from the encircling dykes cannot make up for the impacts on the environment, as well as long-term socio-economic impacts. A study by Ni (2004) reports that Farmers in the delta acknowledged that they do recognise the degradation of soil. However, the studies provide inadequate information on the level of degradation. Therefore, there is a need to clearly reveal whether the presence of dykes degrades soils such that they negatively influence food crop production.

Mutai (2009) observed that dykes have led to reduced soil moisture and the changing in cropping calendars and have an effect of reducing production in crop fields. However, this study did not look at other dyke-characteristics: height and strength. This study seeks to evaluate these dyke characteristics and their influence on food crop production. A study by Mahn et al. (2014) indicates that the dyke networks are designed to protect crops from intense flooding events and to provide year-round irrigation, and the compartments which are formed facilitate highly productive agriculture in deltas around the world, such as the Mekong as studied by Hung et al. (2014). With declining fluvial sediment loads, such networks disconnect floodplains from their rivers and potentially limit the supply of fluvial sediment reaching the surface of the delta. Therefore, this study seeks to clearly highlight the influence of the dyke networks on food crop farming and fluvial load deposits on the floodplains.

A study by Venterink et al. (2006) reports that sediment deposition in compartments is important for maintaining dyke surfaces above rising sea levels, and nutrients that are bound to deposited sediments make deltaic soils and ecosystems some of the most productive. A study by Nixon (2003) indicates that the continued provision of such natural nutrients can, therefore, reduce the need for costly chemical fertilisers. A study by Ibáñez et al. (2013) states that farmers have been making the economic benefits of natural sediment deposition for centuries through practices such as digging sediment out of the canals and spreading it over the floodplain in the Nile Delta, engineering siltation projects, and in the Ebro Delta and making strategic decisions on dyke height which allow overflow, as indicated by Manh et al. (2014) it was traditionally the case in the Mekong Delta. Ibáñez et al. (2013). This has grown in significance in recent years as strategic sediment delivery for land-building has been

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identified as a key adaptation strategy to sea-level rise (Ibáñez et al., 2013). Therefore, there is a need to provide information on dykes and maximum sediment deposition in relation to food crop farming.

In Bangladesh, India, vegetable cultivation and other crops on pond dykes are encouraged. A study by USAID (2016) shows that dyke farming increases women's economic empowerment. Vegetable production would ultimately ensure food security and that the study area respondents produced on average 218.47 kg of vegetables annually from one decimal dyke area, which is completely overproduction. The fallow dyke areas are brought under vegetable cultivation by using improved methods. A study by Jafrin et al. (2009) states that dyke cultivation practices to grow vegetables in small patches of land require no chemical fertilisers or pesticides.

Bloemertz (2014) noted that the impact of flooding on crop farming has continued to be of great concern since agriculture is the backbone of the economy; it creates employment and earns foreign exchange. Opere (2013) says that this has raised debate on the farming practices not only in Kano floodplains but also in Budalangi. It is evident from these areas that crop farming had been compromised by floods, and the Government of Kenya, in association with other non-governmental organisations, took measures in the construction of dykes to manage floods in these areas. For instance, as studied by NRC (2006), in Budalangi, the National Water Conservation and Pipeline Corporation engineers who had worked at the Budalangi Dyke rehabilitation Project appealed to the Department of Agriculture to advise the farmers on the consequences that would be caused by the destruction of the dykes. According to Okayo et al. (2015), the dykes have managed various areas affected by the floods and the flood zones have attracted agricultural activities; crop farming due to the naturally enriched alluvial soils from the silt load. According to NRC (2006), residents of Budalang'i in Busia District are satisfied with the flood control measures implemented by the Government, and Budalang'i is now lush green – because the maise, beans, cassava, groundnuts, and vegetables are flourishing despite the heavy rains that continue to pound the area Huho & Kosonei, (2014). According to the study by Okayo et al. (2015), residents like the new trend after many years of crop losses and disease. This study focuses on the increase of farms and farmlands but does not clearly indicate the dyke characteristics that would have caused these changes. Therefore, this study seeks to assess the dyke characteristics that influence food crop farming.

MATERIALS AND METHODS

Study Area

The lower River Nyando basin (Figure 1) is within Kisumu County. The River traverses both the Nandi and Kericho counties before causing annual flooding havoc in the lower Nyando basin. It has been associated with massive crop failures in the recent past due to sheet erosion. It has a catchment area of 3450 square kilometres and is about 153 kilometres long. It occupies two-thirds of the lower half of the Nyando River catchment. The Lower section of the River Nyando has several tributaries and distributaries, viz. R. Nyamasaria, R. Miriu, R. Orongo, Awach Kano, Nyaidho among others. The River Nyando originates in the Tinderet forest, where it collects nutrients from well-fertilised farms from the Rift Valley (Integrated Flood Management for Nyando River basin- Main Report, 2014). Farmers within the basin have been tempted to interfere with dykes, perhaps to allow the flow of the rich silt into the crop lands leading to annual flood menace. Dykes have been constructed and reconstructed to address the flooding challenge since 1975.

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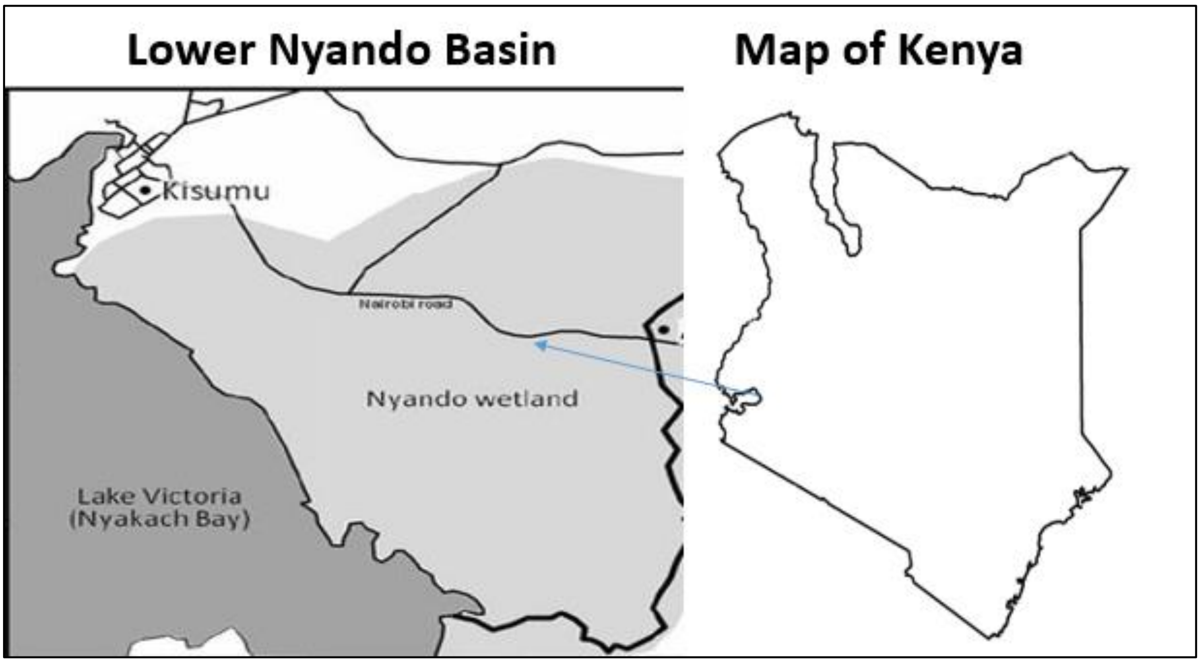
Figure 1: A Map showing the location and outline of the study area



Map of the study area. **Source**: adapted and modified from G.o.K (2019)

METHODOLOGY

The descriptive cross-sectional research design was found suitable for the study because data dykes' characteristics collected at an instance could explain the variation in food crop production. The target population was 34,460 households; a sample of 384 household heads was derived using Fisher's formula. Based on the assumption of homogeneous population distribution, systematic random sampling was applicable. The main data collection tool was a questionnaire; however, key informants, focused group discussions, photography, measurements, and observation were also included in the survey. Using mixed data collection tools helps in minimising bias. About 10% of questionnaires were pretested, and a Cronbach's reliability analysis was performed; a coefficient of (r = .71) was realised. Given the strong reliability, the instrument was applied without further correction. Data was coded and organised depending on themes; the quantitative data and linear coefficient of determination were then analysed using SPSS and data presented in tables, figures, or plates.

RESULTS AND DISCUSSION

Distribution of Food among the households Bordering Dykes

The majority (50%) of the households in the lower Nyando basin relied on farming (*Table 1*). This was closely supplemented with food bought from the market at (25%). Less than 10% of the households depended on donations and other sources. In the period 2018 to 2022, it is reported that the households were adopting more crop farming in the greater western Kenya and Nyanza region (Oduor, Mutavi, & Long'ora, 2022). The increased crop farming uptake implies that many of the farmers whose farms bordered dykes benefited from the ongoing dyke construction and reconstruction. These findings agree with Huho (2005) that farmers increased their activities on dry farms and with the dykes as security at Budalangi. 29% reported no change. This implies that even with the dykes there was no change in food crop farming. A study conducted by Rogger et al. (2017) examined climate change markers. He concluded that reduced rainfall amounts with climate change led to food crop failure. The study area has those who do not know if food crop yields have increased and no change, respectively. This can be explained by overtopping and water not

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flowing back to the channel. Through observation, overtopping river flows can reach into the farms, causing severe floods and decreased food crop yields. GOK (2008) reports that farmlands are destroyed in overtopping in Budalangi, raising the fear of food shortage. Olufemi et al. (2020) observe that overtopping is a major environmental disaster affecting mankind, ranging from crop destruction. This finding agrees with that of Olufemi et al. (2020) in that overtopping reduces food crop yields on a large scale.

Table 1: Distribution of food among the households bordering dykes

	Frequency	Per cent	Cumulative Percent
Donations	24	6.3	6.3
Farming	192	50.0	56.3
Market Sources	96	25.0	81.3
Others	24	6.3	87.5
Water Sources	48	12.5	100.0
Total	384	100.0	

Table 2: Descriptive statistics on Dykes' characteristics and crop yields

	Mean	Std. Deviation	N
Food crop yields (in Kgs/acre) in lower Nyando	317.5	97.70	384
Dykes' height (Metres)	1.3	.32	384
Dykes age (Years)	9.4	6.70	384
Dykes Length (Metres)	27.7	11.10	384

The mean crop yield was 317.5 kg/acre in lower Nyando (*Table 2*), while the mean dyke age was slightly more than 9 years of age. Both the dykes' height and length measured an average of 1.3 and 27.7 metres, respectively. Crop yields have been known to vary with the dykes' characteristics, for example-controlled flood gates have been observed to influence rice production in Indian paddy fields (Armah, Yawson, Yengoh, Odoi, & Afrifa, 2010). However, mismanaged flood gates for the case of lower Nyando affect the yields negatively due to induced overflows into adjacent farms (Reed, Anderson, Kruczkiewicz, Nakamura, Gallo, Seager, & McDermid, 2022).

Table 3: Period of Dykes' existence and change in food crop yields

	Frequency	Per cent	Cumulative Percent
<1 year	59	15.4	15.4
>5 years	177	46.1	61.5
1-5 years	148	38.5	100.0
Total	384	100.0	

The recently constructed dykes (*table 3*) had the lowest crop yields, while older dykes were associated with higher food crop yields. This was possibly due to the fact that most older dykes were worn out or perforated, allowing fertile silts into the crop fields (Week & Wizor, 2020).). Fertile crop fields have been known to positively influence crop health and vigour (Ajaero, 2017).).

Table 4: Dykes height and Food crop Distribution

	Frequency	Per cent	Cumulative per cent
<0.5 metres	208	54.2	54.2
>0.5 metres	176	45.8	100.0
Total	384	100.0	

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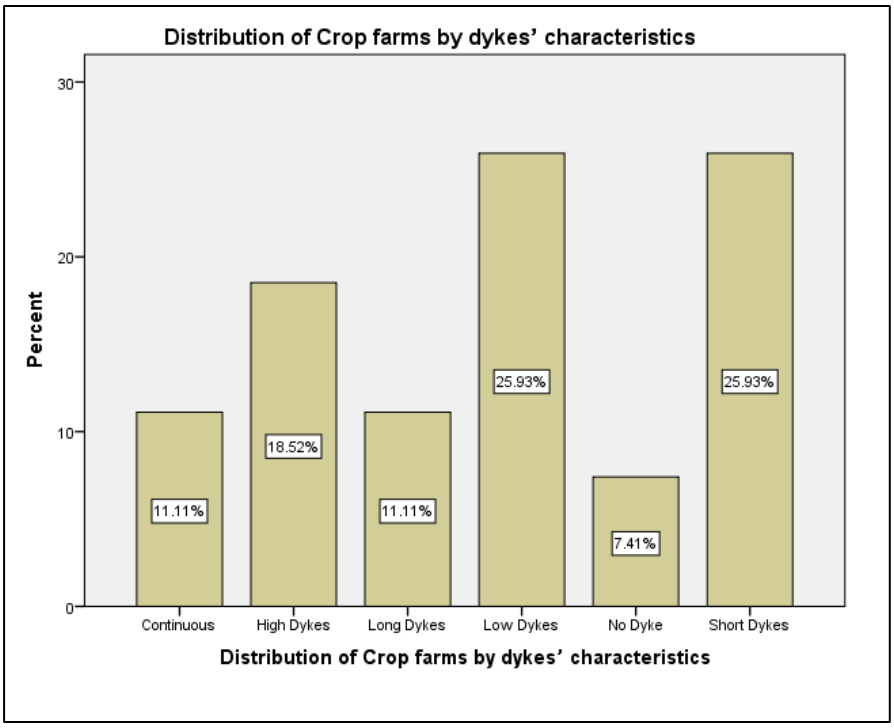
The results (*table 4*) indicated that the distribution of the high and low dykes was nearly equal. According to the Ochieng, Charles, & Ang'awa (2017) report, the county government of Kisumu constructed dykes of 0.7 m along the lower river Nyando to curb floods. On the basis of observation, the height of dykes in the study area is nearly equal because of construction by one body, that is, the County Government of Kisumu, apart from areas where construction was carried out by private developers: with low dykes (0.7 m) at 53.85% and high dykes (1.3 m and above) at 46.15%.

Figure 2: Distribution of Crop farms by dykes' characteristics



The results (*Figure 2*) show that most food crops were found in areas covered by short and low dykes (25.93%) respectively. However, areas with no dykes (7.41%) registered the lowest yields. This is because of the reconstruction period of the dykes-2017 (GOK, 2018) and continuous repairs. According to GOK (2018), dykes' construction in the River Nyando was to minimise the perennial migration and food crop loss. A Focused Group Discussion was reported;

> *Low and short dykes along the lower river Nyando are good for crop production because they easily allow nutrient-rich water into the farms and are easy to drain out.*

Table 5: Dyke's type and crop yield

	Continuous dykes	No dykes	Perforated dykes	Washed out dykes	Compromised dykes
Increased yields	56%	8%	28%	38%	49%
Decreased yields	7%	26%	52%	52%	44%
No change	29%	64%	17%	8%	6%
Not known	8%	2%	3%	2%	1%
Total	100%	100%	100%	100%	100%

Respondents (*Table 5*) were asked to state, ´´If their food crop yields increased, decreased, had no change, or did not know if there was a change in the food crop yields. The results from the table indicate that; In the areas not covered by dykes, the respondents intimated that 64% had no change

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in crop yields, 26% had decreased yields, 8 % increased yields, and 2% did not know if there was a change. This implies that a majority did not experience in their food crop yields. According to Musah, Mumuni, Abayomi & Jibrel (2013), the period of exposure to a given function influences the level of adaptation to that function. This agrees with the findings that areas with no dykes expose farmlands to no dynamics of the function dykes hence no change. This is followed by the influence of decreased yields. This implies that areas with no dykes have experienced a decrease in food crop yields. Through observation, the study was able to obtain that flood waters still get to the farmlands destroying crops and the dykes upstream acting as barriers to the water flowing back to the channel. This finding is consistent with the study of Ajiboye & Orebiyi (2022), that dykes along the Mississippi River stop water backflow. A small group of 8% reported increased yield. This implies that even with their farms exposed to the river waters, their yields have increased. According to Kaida (1991), Sedimentation on Aswan High Dam decreased silt deposition on farmlands. The absence of dykes encourages rich silt deposition encouraging food crop growth and yields. In areas covered by perforated dykes, 52% of the respondents had decreased crop yields, 28% increased yields, 17% had no change, and 3% not knowing if there was a change in their crop yields. Along the washed-out dykes, the crop yields were at 54% for decreased, 38% for increased yields, 8% for no change, and 2 % did not know if there was a change in the yields. Along the compromised dykes, 49% had increased yields, 44% decreased yields, 6% no change, and 1% recorded not knowing if the food crop yields increased.

Dyke Height and the General Crop Yield

The information on the relationship between dyke height and crop yield was sourced and presented as shown in *Table 6*.

Table 6*: Crop yields distribution in relation to height of dykes*

	Increase	Decrease	No change	Total
High dykes	52%	40%	8%	100%
Low dykes	58%	40%	2%	100%

The study sought to find out the influence of dyke height and food crop production. Responses on dyke height indicated (*Table 6*) that where there were high dykes: increased yields were at 52%, decreased at 40% and no change at 8%. Equally, on low dykes: increased yields at 58%, decreased at 40%, and 2% reported no change. This means that areas with high dykes had a lower percentage increase as compared to low dykes. This can be explained by the fact that low dykes experience overtopping, which introduces silt deposition to the farms increasing yields. This agrees with the study by Pandey (2015), sedimentation on Aswan High Dam decreased silt deposition on farmlands. The absence of dykes encourages rich silt deposition encouraging food crop growth and yields WRMA (2014).

Dyke Age and the General Crop Yields

The information on the relationship between dyke age and food crop distribution was sourced and presented as illustrated in *Table 7*.

Table 7: Distribution of food crop yields and age of dykes

	Increase	Decrease	No change	Not know	Total
2016 and before	54%	30%	10%	6%	100%
2017 and beyond	62%	26%	10%	2%	100%

The study (*Table 7*) also investigated the influence of age of dykes and food crop farming. Food crop farming and age of dyke responses were as follows: before 2016 increase in yields at 54%, decreased yields at 30%, no change at 10% and 6% did not know whether the yields increased. 2017 and beyond, increased yields at 62%, decreased yields at 26%, 10% reported no

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change and 2% did not know if there was a change in food crop yields. This means that farmers who have had dykes for longer enjoy more yields than those who have had them for a shorter period. The areas that have had dykes for a shorter period have experienced a reduced percentage increase as compared to those with dykes for a longer time. Supported by Banerjee (2010), the period of exposure to a given function influences the level of adaptation to that function. This agrees with the findings that areas with longer existing dykes expose farmlands to dynamics like flood barriers hence increasing yields Van der Ven, (2004). This is followed by a decrease in crop yields due to silt nutrient depletion Redd (2017).

Table 8: Harvest Obtained in the Last One Year.

Rank of Harvest	Frequency	Percentage
Excellent	5	1
Very Good	20	4
Good	10	3
Fair	84	24
Poor	251	68
Total	360	100

In food crop farming, 68% of the households reported poor yields in the last year (*Table 8*). 24% had fair yields, while 3%, 4% and 1% experienced good, very good and excellent harvest, respectively. A total of 90% of the respondents ranked their harvest fair and below. *Table 4* shows food crop yields by households in the last year.

Most maise farmers reported poor harvests (See *Plate 1*), while a number of farmers of crops such as sorghum and cassava reported very good and even excellent yields. This means that farms with maise recorded reduced yields, but those with sorghum and cassava recorded higher yields (*Table 4*). This can be explained by cassava and sorghum doing relatively well in infertile farmlands. An indication that there is an influence of dykes on food crops. The majority of respondents agree that there is an influence of dyke on food crop production. Similarly, according to Buu (2013), Sedimentation on Aswan High Dam decreased silt deposition on farmlands. Dykes discourage rich silt deposition reducing soil fertility and reducing food crop yields. This showed that there is an influence of dykes on food crops. Again, Okayo et al. (2015) report that in Budalangi, agriculture improved after the construction of dykes along River Nzoia. This study agrees that there is an increase in food crop production. Siltation has been a major source of cheap and readily available nutrients for farming households Nixon, (2003). Plate 1 displays a failed maise crop due to drought. Notice the totally scorched crops due to lack of soil moisture. A key informant observed;

> *We are faced with a double problem: when it is dry, we lose almost the entire crop yield to drought. When it rains heavily in the neighbouring counties, our crops are faced with imminent threats from floods.*

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Plate 1: Crop Failure in farms with reduced soil fertility and drought

Dykes' Characteristics and the General Crop Yields

Table 9: Influence of Dykes' characteristics on the general crop Yields

Model	R	R Square	Adjusted R Square	Sig
1	.685[a]	.461	.454	.039

a. Predictors: (Constant), Dykes length (Metres), Dykes age (Years), Dykes' height (M

Table 10: Multiple linear regression coefficients

	Sig	t	df
Age of the Dyke (Years)	.033	-1.759	3
Height of the Dyke (Meters)	.21	1.522	381
Length of the Dyke (Meters)	.049	2.911	384

The research (*table 9*) found that 45.4% (R^2 = .454, p = .039) of the variation in the general crop yield was explainable by the combined change in Dyke Characteristics. The reanalysis of the linear model (table 10) indicated that the Age of the Dyke (t = -1.759, p = .033) was linear, with a statistical significance of prediction; however, it was negatively related to the general crop yield. Conversely, the Height of the Dyke (t = 1.522, p =.21) and the length of the Dyke (t = 2.911, p = .049) had a significant positive linear association with the general crop yield in lower Nyando. The results identified by Gadain et al. (2006) noted that the period of exposure to a given function influences the level of adaptation to that function. Longer and higher dykes should be constructed to protect larger crop farming areas and to protect crops from floods related disasters. However, Dykes should be constructed with controllable floodgates to allow silt and nutrients into the adjacent farms (Bunn and Arthington, 2002). It is recommended that further research be conducted in the same region to determine the coping mechanisms of the residents with the influence of dykes on their livelihood activities (Takago A. et al., (2016). It would be of interest to study and policymakers in developing appropriate flood mitigation measures and also creating awareness. This means that food crop production significantly depended directly and indirectly on the dykes' characteristics (Friend, 1990). According to GOK (2018) reports, the dykes were reconstructed in 2017 in the Lower River Nyando when it was realised that apart from household displacements, crop fields were becoming more vulnerable to unprotected river banks. A key informant reported;

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The dykes along the lower river Nyando basin were first constructed in the 70s. Reconstructions to a small scale have since been done by locals and major ones done by the national Government, like in 2003, 2007 and 2012. The county government of Kisumu constructed dykes along the river in the last quarter of the year 2016 as a response to the major floods in the region at the time. Very few NGOs (JICA affiliate) have partnered with WRMA, too, in the reconstruction of these dams.

CONCLUSIONS

The variation in dykes' characteristics significantly influenced crop production in the Nyando basin. Both the length and height of the dyke had a positive influence on crop yield. However, the age of the dyke showed a significant negative influence on the overall crop yields. The current study findings show that most households in the lower River Nyando basin have had the dykes influence crop production. There are significant differences in food crop farming. This means that there has been a significant increase in food crop farming with farmers exploiting the fertile silt deposits (locally known as "*Mo'*") trapped back by the Dykes.

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