Original Research Article

CROP PRODUCTION IN IRRIGATION SCHEMES IN TURKANA COUNTY, KENYA, BEFORE AND DURING COVID-19 (2018-2021)

ABSTRACT

Turkana County, in Kenya, is an arid county. It is hot throughout the year except at the higher elevations, and, due to high ambient temperatures, it experiences high evapotranspiration rates on flora and rapid drying of open water bodies. It is the poorest county in Kenya, with a poverty index of 79.3 % vs. 34.4% for the country. Due to its aridity, crop production is severely constrained and the County is a net importer of foodstuffs. However, crop production in the operating irrigation schemes depends on water from retreat flooding in March-May and any that is let into and retained in canals when the seasonal rivers are flowing. This project aimed to assess the influence of COVID-19 and other undetermined factors on crop production in 10 irrigation schemes along the Tirkwell River, over the period 2018-2021. The study administered a semi-structured questionnaire to 104 randomly selected farmers, who owned farm plots in the irrigation schemes. One-on-one interviews were held, due to the high level of illiteracy of respondents. Twelve elders and administrators were the key informants. The study established that sorghum was the dominant crop grown in 9 out of the schemes, except in Kooliyoro-Kaaiteese, where maize was the dominant crop. Other crops in declining order by production volume included cowpeas, green grams, black grams and in Keekoroe-ngole, green vegetables are grown. The weight of the dominant crop and other crops varied significantly ($p \leq 0.05$) in the same irrigation scheme across the years of crop production, and also across the schemes over the period under study. COVID-19 breakout did not affect crop production in the irrigation schemes studied. Farmer poverty level, lack of expert extension services, use of uncertified and reused seed, unreliable water supply, and regular droughts affected crop production. The most productive schemes in descending order by crop production volumes were Nanyee, Napool and Keekoroe-ngole, whereas the least productive was Naremit. To improve crop production, the study recommends provision of expert extension services, a steady water supply, annual donation of certified seeds, improvement in crop-care services, streamlining crop marketing services and upgrade of schemes' governance and management.

Keywords: Kenya; Turkana County; Crop Production; Influencing Factors; COVID-19; 2018-2021

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The objective of the study missing
The study population for this study not sufficient for example ministry of agriculture, NGOs like world Vision, KRCS, missing
Key terms also not satisfactory for instance 2018 – 2021, Kenya, Turkana County etc have terms like Irrigation, Arid, Schemes, foodstuffs, crop production, retreat flooding, farmers,
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INTRODUCTION

Kenya is a country in Eastern Africa that borders Uganda, Tanzania, South Sudan, Somalia and Ethiopia at its international borders to the west and Northwest, Southwest, North, Northeast, and North, respectively. About 15-20% of the country is arable, with the rest being arid and semi-arid. The arid and semi-arid parts of the country are referred to as ASALs. The country's climate is generally tropical. The ASAL northern, northwestern and northeastern regions of the country receive low amounts of rainfall, ranging from 50-250 mm per annum (Lokuruka, 2008). Nomadic pastoralism based on traditional livestock keeping, is the major mode of production and livelihood in the ASALs. These regions have over 70% of the national cattle, goat, sheep and camel herd and cover ~ 80% of the country's land mass (IUCN, 2020). However, the whole country's camel herd is found in the ASALs. Despite the low agricultural potential of the ASALs, some crop production of traditional and hardy cereal crops, mainly sorghum, millet, pulses, cassava and an assortment of tropical fruits are grown along the banks of the seasonal rivers by irrigation.

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FOOD PRODUCTION IN KENYA AND THE ASALs

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The main cash crops for Kenya are tea, coffee and horticultural produce, which are also the main exports.

The staple foods for the majority of the country's population are maize, rice, potatoes, meats, pulses, fish, tubers and an assortment of tropical fruits and green vegetables; While the staple foods may be similar across the country, the crops that do well in the arid and semi-arid zones of the country differ from those grown in the highlands, as the latter are endowed with more rainfall than the ASALs. The crops that are grown in the ASALs include short maturing cereal crops such as sorghum, millet, cassava and pulses; the latter include beans, green and black grams. An assortment of tropical fruits including pawpaw, lemons, oranges and mangoes thrive under irrigation in the ASALs. Kales, collards and spinach are grown alongside the cereal crops and pulses. The major rivers in the ASAL Counties provide the water required for irrigated agriculture. In Turkana County, these are the Tirkwell, Keriyo, Lomogol, Kacoda/Loo-arengak and Tarac.

The ASALs, where Turkana County falls, support over 70% of the national cattle, goats, sheep, donkey and 100% of the camel herd (Ministry of Devolution and ASALs, 2019). They are the major suppliers of meats both for domestic consumption and export. They meet more than 50% of Kenya's meat needs (Kenya National Bureau of Statistics-KNBS, 2009).

Turkana County

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Turkana County, the second largest county in the country and with a current population of 1.2 million people, has a population density of 14 persons/Km^2 vs. a population density for the country of 94 persons/$Km.^2$ (KNBS, 2009). The family size in the County is 6.4 persons (KNBS, 2009). It is the poorest County in Kenya, with a poverty index of 79.4% (Turkana County Government, 2018) down from 94.3% in 2009 (KNBS, 2009). The reduction in the poverty index is due to the devolution of resources and governance to the Counties from Central Government beginning in 2013, which for Turkana County, resulted in the transfer of over 100 billion Kenya Shillings (over US Dollars 10 billion) to the County from 2013 to 2022. Nevertheless, the County is still far from self-sustaining, especially in food production, as the investment in crop production is still low.

Lodwar in the central part of the County is the major commercial and administrative town. It is also the main market for farm produce from the irrigation schemes studied in this project. Ambient temperatures over the Turkana plains are in the range of 24-28^oC (night time), 36-40^oC (daytime) throughout the year (Lokuruka, 2021). At lower altitudes, day-shade temperatures average 34-38 and night temperatures of 24-28^oC, while the relative humidity (Rh) hovers around 40% and very rarely goes higher than 60%. Turkana County is therefore hot and dry throughout the year, except at the higher elevations (mountains) at the International border areas with Uganda, Ethiopia and South Sudan.

The evapotranspiration rates on flora are very high and any open water body dries very fast. It is a low lying, large plain that mostly lies below 1100 m above sea level, except along the international borders, where the higher elevations can reach 2,000 m above sea level (Lokuruka, 2020). The County is generally recognized as the poorest County in Kenya, with an absolute poverty index of 87.5 % vs. 45.2% for Kenya (SID, 2009); County food poverty index hovers around 84% (Lokuruka, 2008). As such, any new initiatives for increased food production in the

County are critically important and necessary. The major constraints to food production in the County include the low rainfall (average of 50 mm/annum) and the high ambient temperatures of 36-40^{o}C at day time across the county (Lokuruka, 2008). Water scarcity for crop production and human consumption is real, as underground water is generally unexploited. However, crop production by irrigation uses water from retreat flooding retained in canals in the rainy season (when rivers are flowing), mainly in the period of April-May. The major rivers traversing the County are all seasonal. The banks of these major rivers provide the land for the current and potential irrigated agriculture.

This project was carried out in Turkana County in Kenya, along the Tirkwell River, in the period 2018-2021 (pre-COVID-19 and up to 2021, the time the pandemic started to subside). The first COVID-19 case was reported in Kenya on 12th March, 2020, with a traveler who had come on a flight from the USA via London (VoA, 2020). The project was done to assess the influence of COVID-19 and other undetermined factors on crop production in 10 irrigation schemes in Turkana County. "Other factors" are described here as such because, the project sought to establish them. They were regarded as unknown at the time the study was being undertaken and the project therefore sought to establish these "undetermined factors."

METHODS AND PROCEDURES

The project used a semi-structured questionnaire which was administered to 104 farmers (2312 farmers in total were registered in the 10 irrigation schemes, where this study was done), who were selected randomly. One-on-one interviews were done with all the 104 respondents, as over 80% of them were illiterate; 12 elders and administrators were the Key Informants. It is also generally recognized that the one-one interview method is more accurate than delivering questionnaires for self-filling by respondents; the potential for better and honest responses is also higher with one-on-one interviews and thus the reason for their use in this project; probing was done as necessary in order to obtain better and complete answers to the questions put to the respondent-farmers.

The Irrigation Schemes: 10 irrigation schemes all along the Tirkwell River were studied in this project. The furthest and the nearest was over 60 and 30 km away from Lodwar, respectively. Lodwar town is the main commercial and administrative town of the County, and has a

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population of over 70,000 inhabitants, which is ~ 7% of the County's population (KNBS, 2019). Lodwar is also the main food market in the County and therefore the most important town for the marketing of farm produce from the irrigation schemes and also the point of purchase of farm inputs.

COVID-19 SITUATION IN KENYA AND TURKANA COUNTY (2020-2022)

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In March 2020, the COVID-19 pandemic shock hit the economy hard, disrupting international trade and transport, tourism, and urban services activity. Fortunately, the agricultural sector, a cornerstone of the economy, remained resilient, helping to limit the contraction in GDP to only 0.3%. (World Bank, 2021). In 2021, the economy staged a strong recovery, with a growth of 7.5%, although some sectors, such as tourism, remained under pressure. GDP growth is projected at 5.5% in 2022 (World Bank, 2021). Although the economic outlook is broadly positive, it is subject to elevated uncertainty, including through Kenya's exposure (as a net fuel, wheat, and fertilizer importer) to the global price impacts of the war in Ukraine and uncertainties in fuel production and pricing.

Total COVID-19 infections in Kenya by 26th May 2022 were 344,500, while the reported deaths were 5,651 by the same date (Statista, 2022). In Turkana County, total infections were 534 while 62 deaths were reported up to 10th June, 2022 (no new infections were reported between December 2021 and 10th June 2022). However, a new wave started in Kenya on 23rd May, 2022, but no new infections were reported in Turkana County by 10th June, 2022. Over the period December 2021-June 10th 2021, new infections in Kenya were 1085, thus bringing the country total to 325,554 infections, with no deaths reported in the period. Over the period of the pandemic and until about the end of May 2022, the vaccination uptake in the country was reported by the Ministry of Health as ~ 32% of adults. It is, however, bound to have gone up as more people were convinced it was safe. By the 1st April, 2023, Kenya had reported 343,537 cases and 5,689 COVID-19 deaths to the WHO (WHO, 2023), while by the same date, 23,750,431 vaccine doses had been administered in the country.

Public response to COVID-19 breakout and its effect on the country's economic growth

The main effects of the pandemic were felt between March 12th (the date of the 1st reported infection in Kenya) and October 2020; on the 19th of April 2020, the Kenya Government through

the Ministry of Health asked the country residents to stay home, start taking precautions such as masking, social distancing and frequent hand-washing to reduce the spread and transmission of the virus. However, in Kenya, the crop planting season comes in March-April; over the crop planting period in 2020, most farmers disobeyed the orders issued by the Government to stay home and instead worked on their farms for most of April 2020.

By the 20th of April 2020, the Government had ordered all schools, Colleges, Universities to close. Private businesses continued in minimalist ways, while the Kenya Government suspended all public services by the end of April 2020. However, by the time of the breakout of the pandemic in Kenya in March 2020, crop planting had already been started by many farmers, such that the effect on food production was not drastic in the 2020 crop growing season. In this report, 2018/2019 is the for the determination of the effect of the pandemic on the country's economy. The GDP for the financial year 2018/2019 was 5.9 down from 6.3% in 2017/2018 financial year) (World Bank, 2020); in the 2021 planting season, farmers and farm input suppliers had adjusted to the pandemic, although there was a decline in economic growth, which was an indication of the effect of the pandemic. The GDP percentage growth of GDP for 2019/2020 financial year was 5.4%) (World Bank, 2021). This reported slowdown in the percentage growth of the GDP was due to the experienced knock-on effects on the economy that were experienced worldwide. It should be remembered that air travel, exports and imports were curtailed in almost every country, in order to restrict movement of goods and people across the world, as knowledge of how to contain the spread of the virus continued to evolve.

Although no records are yet available, travel restrictions and curtailment of exports and imports may have caused an unquantified fall in food production, as the supply of fertilizer and pesticides, are imported into Kenya. This situation was experienced mainly in the calendar year, 2020. In-country travel and marketing services for goods and services were also interrupted and this may have contributed to the negative effect on food production mainly through the low application of crop care services, inadequate farm machinery and tractor maintenance and use, fuel supply interruptions, and other food production and marketing related factors as both physical and financial effort by the Kenyan Government was devoted to planning and financing for the pandemic mainly by way of vaccine purchase, import, in-country transport and the building of infrastructure for the storage of the medical supplies in hospitals across the country.

Although the effect of the COVID-19 pandemic has not been quantified in Kenya, the economy suffered a slide. This is shown by the figures for the GDP growth rate which pre-COVID were 6.3, and 5.4% for the financial year 2018/2019 and 2019/2020, respectively (Wankuru et al., 2019; World Bank, 2020). The growth in GDP in 2020/2021 fell to 4.5% (World Bank, 2021). The projected growth for the financial year 2021/2022 was 5.9% (World Bank, 2021). which indicates an expectation of some recovery in the country's economic performance. The estimated GDP growth for 2022/2023 financial year is projected to be 7.5% (World Bank, 2022).

Observed COVID-19 effects in Turkana County

In Turkana County, there was minimal interruption to business and livelihoods, mainly because people disobeyed orders not to travel within the county, as most of them were in denial and dismissed the existence of the illness; only out-of-county travel was strictly restricted by the Kenya Police Service and the County Public Health Personnel enforcement wing. One could be detained in a police cell for a few days and court fines were sometimes imposed to discourage disobedience. Food imports were interrupted between May and October 2020 as uncertainty over the mode of infection and transmission of the virus was unknown. Many people did not therefore take precautions and care and were averse to following instructions given by the Ministry of Health.

Turkana County is a net importer of cereals, pulses, sugar, green vegetables, fruits, etc. The food consumed in the County comes mainly from the neighbouring Trans Nzoia County in Kenya and Mbale, Soroti and Karamoja Districts of Uganda. It has been shown that high temperature and high UV radiation kills the SARS CoV-2 virus instantaneously and this may partly explain the low infection rates that were exhibited in Turkana County, where ambient daytime temperature range between 34 and 38^{o}C and 24 to 28^{o}C at night-time, with a Rh of between 50 and 60%. These ambient environmental conditions would not be conducive to virus survival (Schuit et al., 2020). The authors showed that the virus is killed by UV radiation when present on a natural surface at 40^{o}C, 50% RH in less than 24 hours. The experimental ambient conditions are similar to those in Turkana County in Kenya. It may feasible that the high UV radiation with the cloudless sky over Turkana, could have limited the survival rate of the virus in the County, thus minimizing viral infections and saving lives.

Farm plot characteristics

The names of the 10 irrigation schemes that this project worked in are given in Table 1. Among them is Turkwel, which occupies approximately 450 acres, and was the first one to begin operating in 1966. The most recent and which was established in 2010, is Kooliyoro-Kaaiteese, which occupies a land area of 320 acres. The schemes are sub-divided into small plots of about 2 acres or less for a family. The land is tilled by the family members as soon as the rains are expected to come, beginning in March of each year. The land preparation, sowing the seeds and weeding are all done using hand-hoes and cutlasses. Insect pests, and crop diseases are generally not controlled in order to cut down the cost of inputs. However, once in a while, the Turkana County Government feels philanthropic and donates seed, fertilizer, pesticides and prepares all the land for the farmers, at no cost to them. This is, however, done inconsistently. The use of manual methods of farming as described above are inefficient and therefore restrict the size of the plots that can be managed by the family. As fertilizers, certified seeds and pesticides are expensive for families, they are generally not regularly used. This study was done for about 3 months in the 10 irrigation schemes, between June and August, 2021.

Data analysis

The crop production data analysis was done using SAS 9.2 (SAS Institute Inc, Cary, NC, USA).

RESULTS AND DISCUSSION

There were significant differences in the volumes of the main crop (sorghum) between the schemes and even in the same scheme across the 4-year period of food production ($p \leq 0.05$). There were also significant differences in each scheme with the volumes of the crops grown, and over the years for each crop grown in each scheme.

The 10 irrigation schemes operated independent of each other, such that, the type of crops grown were decided by each Scheme Management Committee without reference to the Management of the other schemes. Families largely decided what they grew on their plots, often without reference to the Scheme Management Committee. However, the main crop preferred in 9 out of the 10 schemes was sorghum, most likely due to the low water requirements of the crop, and the short time to reach maturity. It is also a traditional crop, whose agronomic knowledge may be

familiar with the local farmers, thus making it popular. Sorghum, despite being a traditional crop that is fast maturing, and requires very little water to grow, is also resistant to extensive pest damage. It matures within 3 months of planting as long as it receives adequate rain to enable it sprout and then about 2-3 showers to grow to full size, flower and produce grain. Turkana County receives an average of about 5-20 inches of rain annually depending on altitude. However, the 10 irrigation schemes have constructed canals that let in water into the farm plots from the river Tirkwell, when it is flowing, after it rains in the catchment area in Mount Elgon, over 300 kilometres away at the border of Kenya and Uganda.

For the sake of simplicity, the author has categorized the crops produced into 3 groups, across the schemes, based on the volumes produced. Category 1 rank crop was the one produced in the largest volume across the schemes, while category 3 rank crops included those that were produced in the least quantity across the 10 irrigation schemes. Green vegetables were not placed in any of the categories discussed here, as only Turkwel Irrigation Scheme produced a small quantity of green vegetables (collards and spinach) mainly for domestic consumption by the farming families and the non-farming townspeople; any excess production was sold on the roadside to travelers going through the Keekoroe-ngole urban centre. Category 2 set of crops were therefore produced in volumes between those of category 1 and Category 3 crops.

Category 1 crop was sorghum. It was the main crop grown in the family plots in all the 10 irrigation schemes over the period of the study, 2018-2021. The best 3 producer-schemes for sorghum were Nanyee, Napool and Kalemunyang, with average production of 267,000 kg/year, 117,000 kg/year and 100,000 kg/year, respectively, over the 4 years of the study (Table 1).

Category 2 crops were: maize, cowpeas and green grams, but in one scheme, it was sorghum (Kooliyoro-Kaaiteese) (Table 2). In this irrigation scheme, sorghum was the second most produced crop, while maize was the major crop unlike in the other 9 schemes, where sorghum was the dominant crop grown by the farmers each year over the period of the study.

Category 3 crops: These were cowpeas and green grams, except in the Turkwel Irrigation Scheme where in addition, green vegetables production in the year 2020 was considerable (Table 3). Turkwel Irrigation Scheme is the oldest and the largest among the irrigation schemes in terms of the acreage that can potentially be placed under crops (420 acres). The scheme is also the most developed and therefore the one that supplies some of the food grown to the residents of Lodwar, Lorugumo and other urban centres in Loima sub-county. The town of Keekoroe-ngole has a

population of more than 6,000 residents and it is therefore expected to produce enough food for the population of the town. Due to that fact, most of the crops grown in the scheme and even in the neighbouring schemes of Kalemunyang, Nakamane, and Kooliyoro-Kaaiteese, goes to feed the urban dwellers in the town of Keekoroe-ngole. Only the surplus food production from Keekoroe-ngole and occasionally the other schemes, goes to Lodwar. Nevertheless, Uganda and Kitale in Ttans Nzoia still supply most of the fresh produce for the residents of Lodwar, with Uganda increasingly becoming the major supplier, due to proximity to Lodwar.

The crop production in the irrigation schemes by category of crop is given in Tables 1, 2 and 3.

Table 1: Production (Kilograms) of category 1 crops in the period, 2018-2021

Name of scheme	**Annual production (Kilograms) of category 1 crops**			
	2018	**2019**	**2020**	**2021**
Napool	150,000a (Sor)	---	126,000b (Sor)	75,000c (Sor)
Kaekuto	2,500[a] (Sor)	2,500[a] (Sor)	7,500[c] (Sor)	5,750[d] (Sor)
Turkwel	30,000[a] (Sor)	25,000[b] (Sor)	14,000[c] (Sor)	45,000[d] (Sor)
Kalemunyang	---	104,500[a] (Sor)	150,000[b] (Sor)	45,000[c] (Sor)
Naremit	17,500[a] (Sor)	12,500[b] (Sor)	24,000[c] (Sor)	---
Tiya	---	---	30,000[a] (Sor)	35,000[b] (Sor)
Kabulokor	---	24,000 (Sor)	---	---
Kooliyoro-Kaaiteese	30,000[a] (Sor)	20,000[b] (Sor)	---	60,000[c] (Sor)
Nanyee	300,000[a] (Sor)	150,000[b] (Sor)	---	350,000[c] (Sor)
Nakamane	---	---	25,000 (Sor)	---

Legend: a) Sor----Sorghum;
a) Figures with the same superscript were not significantly different ($p>0.05$)
b) The spaces with the dashes mean no crop was planted that year in the scheme;
c) The figures of food production are rounded down because the bagging was in 50-Kilogram bags

Table 2: Production (Kilograms) of category 2 crops in the period, 2018-2021

Name of scheme	Annual production (Kilograms) of category 2 crops			
	2018	**2019**	**2020**	**2021**
Napool	40,500[a] (Mai)	---	40,000[b] (Mai)	22,500[c] (Mai)
Kaekuto	1,000[a] (Cop)	500[b] (g/grams)	1,500[c] (Cop)	1,500[c] (g/grams)
Turkwell	22,500[a] (Mai)	25,000[a] (Mai)	14,000[b] (Sor)	18,000[c] (Mai)
Kalemunyang	5,000[a] (Mai)	5,000[a] (Mai)	12,500[b] (Mai)	22,500[c] (Mai)
Naremit	2,000[a] (Mai)	3,000[b] (Mai)	2,500[a] (Mai)	---
Tiya	---	---	24,500[a] (Mai)	45,000[b] (Mai)
Kabulokor	---	7,500 (Cop)	---	---
Kooliyoro-Kaaiteese	30,000[a] (Mai)	12,000[b] (Mai)	---	150,000[c] (Sor)
Nanyee	40,000[a] (Mai)	49,500[b] (Mai)	---	40,500[a] (Mai)
Nakamane	40,000[a] (Mai)	49,500[b] (Mai)	---	49,500[b] (Mai)

Legend: a) Cop----Cowpeas; g/grams---green grams; Mai---maize;

a) The figures with the same superscript were not significantly different ($p>0.05$)

b) The dashes mean no major crop was planted that year in the respective scheme;

c) The figures of crop production are rounded down because the bagging was in 50-Kilogram bags

Table 3: Production (Kilograms) of category 3 crops in the period, 2018-2021

Name of scheme	Annual production (kilograms) of category 3 crops			
	2018	**2019**	**2020**	**2021**
Napool	3,000 (Cop)	---	---	---
Kaekuto	1,100[a] (Cop)	500[b] (g/grams)	1,000[a] (g/grams)	1,500[c] (g/grams)
Turkwell	1,200[a] (Cop)	20,000[b] (g/veg)	---	1,050[a] (Cop)
Kalemunyang	---	---	2,000[a] (g/veg)	6,300[b] (Cop)
Naremit	500[a] (Cop)	1,000[b] (g/grams)	1,000[b] (g/grams)	---
Tiya	---	---	4,500[a] (Cop)	5,000[a] (g/grams)
Kabulokor	---	2,000 (g/grams)	---	---
Kooliyoro-Kaaiteese	9,000[a] (Cop)	5,000[b] (g/grams)	---	10,000[c] (Spot)
Nanyee	17,500[a] (g/grams)	3,500[b] (g/grams)	---	2,500[c] (g/grams)
Nakamane	---	----	---	---

Legend: a) g/veg---green vegetables; Spot---sweet potatoes; g/grams---green grams;
a) Figures with the same superscript were not significantly different (p>0.05)
b) The spaces with the dashes mean no major crop was planted that year in the scheme;
c) The figures of crop production are rounded down because the bagging was in 50-Kilogram bags

The major crops grown in the irrigation schemes were cereals (sorghum and maize), legumes (cowpeas, green grams, black grams), in that declining order by volume of produce). Fruit trees (mangoes, and pawpaws, are produced in small quantities due to inadequate care of the small orchards); green vegetables and root tubers are less common and were grown only in the Turkwel Irrigation Scheme. Substantial food is lost through insect pests, plant diseases, and, birds. However, the volumes of loss of the various crops was not determined in this study. It was also observed that livestock invade the farms during drought periods, resulting in further crop losses and conflict between farmers and the nomadic herders. The crop losses through different avenues in the period of the study, 2018-2021, were not determined and quantified.
COVID-19 did not affect crop production in the irrigation schemes studied in this work. Natural and socio-economic factors were the main factors that influenced food production in the irrigation schemes over the period of the study.

CONCLUSIONS

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- High poverty level in the farming community kept crop production low. Also, very little marketing of any surplus food occurred due to undeveloped food value chains, long

distances to Lodwar, and the expensive transport to the main food market in Lodwar; semi-illiterate and non-progressive leadership also contributed to compound the problems. Poverty resulted in low input levels of fertilizer, certified seed, pesticides, etc. Poor maintenance of water intake canals made water intake irregular and unreliable and therefore contributed to low crop production in the irrigation schemes, generally.

- Droughts which are increasing in frequency and severity, were a major factor contributing to declining crop production. The occurrence of drought and its effects on water availability and therefore food production is exacerbated by climate change and weather variability, especially the amount of rainfall and the period of precipitation, which has also become unpredictable.
- Low water availability reduced crop production. The irrigation schemes depend on rain for the water supply when the river Tirkwell is flowing, which occurs when it rains in the source areas in Mount Elgon on the border of Kenya and Uganda.
- Livestock keeping by some of the farmers reduced time for crop farming on the family plots as they split their productive time between crop production and animal husbandry. The animals go on free range grazing and therefore require a lot of attention as they roam away from the homesteads in search of water and pasture.
- However, on the other hand, the high ambient temperatures hasten the sprouting and growth of crops, despite the faster evapotranspiration rates on crop surfaces.

Generally, low and erratic rainfall, the mobility of the farmers who become herders for part of the time, the small farm sizes, and low mechanization, are contributors to the low crop production in the schemes.Increasing sedentarization of the farmers, is likely to improve crop production in the irrigation schemes.

RECOMMENDATIONS

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- The production of maize, a staple cereal crop, should be reduced in favour of sorghum; Unlike sorghum, maize requires greater fertilizer use and more water in its growth cycle and has a lower protein content of lower nutritional quality by amino acid score (Jung, 2020).

- Modern climate-adaptive farming methods and technologies should be introduced for adoption in the irrigation schemes
- Boreholes to provide a steady and adequate water supply for human consumption and crop irrigation should be provided in each scheme by the Turkana County Government. This will reduce dependence on the unreliable floodwater from the river Tirkwell for crop production.
- Water-sparing technologies should be adopted in the schemes.
- Siltation due to the strong winds that blow soil into the canals interferes with water flow and therefore clearing the water inlets and canals of silt, should be done better, and more frequently, than is done currently.
- The Turkana County Government should, through its County Department for Irrigation and Land reclamation, and the Ministry responsible for Cooperatives and Trade, assist the farming community by providing appropriate extension services, restructuring the running of the schemes and enabling progressive governance and management.

Sustainability remains the major problem faced by the farmers in the irrigation schemes studied in this project. Operationalizing the recommendations provided in this article, is likely to help the farming community work towards ensuring that the operations of the irrigation schemes become sustainable.

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