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Technological Developments and Livelihood of Smallholder Vegetable Farmers in Kampala, District, Uganda

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Abstract:
In an effort to minimize the adverse impacts of climate change and variability, technological development is a critical method of adaptation to climate change and variability. The aspect of usage of technological developments by smallholder farmers is either ignored or taken for granted by actors in urban climate change and variability research and development. Measuring technological development in agriculture and further assessing their impacts on livelihood hold the key to strengthening resilience and sustainability of livelihood outcomes. The objective of this article was to assess technological developments practiced by urban farmers in Kampala district and ascertain their effects on smallholder livelihoods. A comprehensive literature review showed that there are various forms of technologies for climate change adaptation including; traditional, modern, soft and hard. The study was conducted in January 2021, using a cross sectional survey of smallholder vegetable farmers in five divisions of Kampala district (Kampala Central, Rubaga, Makindye, Nakawa and Makindye). The study was dominantly field research that employed semi structured questionnaires, interview schedules and observation as techniques of data collection employed in two phased process (explanatory sequential). The study revealed that, technological developments employed by farmers were; use of organic fertilizers, harvesting of rain water, practicing of irrigation. It also showed that some farmers did not use water pans and new crop varieties. Sources of information on climate variability were television, newspapers, radio neighbors and NGOs. And that there is a significant positive and strong relationship between technological improvements and livelihood of smallholder vegetable farmers. Consideration of multiple factors that underlie adaptation decisions, expansion of public and private partnerships is proposed to obviate technological adaptation challenges, using largely farmers' involvement.

Keywords: Climate variability, technological adaptation, Livelihood, smallholder farmers

1. Introduction

Ugandan farmers are categorized into two categories with very distinct features. Smallholder farmers are the majority estimated at 80%, they operate between 1-3 acreage, seldom use production inputs, pray for rains to come and operate on a subsistence basis. Similarly, they perceive agriculture as a means of survival rather than a business thus explaining the low production and productivity in the sector (Republic of Uganda, 2011a). On the other hand, large scale farmers deal mainly in cash crops and livestock, operate large pieces of land, have access to farm inputs, and credit (Republic of Uganda, 2011).

Urban farmers are categorized into four groups; a small group of urban farmers who produce mainly for the urban market (this group tends to be reasonably wealthy and has access to commercial credit); second group mostly in the more peri-urban parts of the city; third group engages in farming to achieve a measure of food security (their income is predominantly from non-agricultural sources, purchase the majority of their food from the market but farming is an important activity nevertheless); the larger group that farm because they have no other means, often single women with children recently widowed or abandoned by their husband(Maxwell,1994; (Opitz, Berges, Piorr, & Krikser, 2016).

In the early 1990's, urban agriculture (UA) was widespread both within the built-up areas of Kampala City and in peri-urban areas, 35 percent of households engaged in crop agriculture, in 1992 56 percent of land within municipal boundaries was used for agriculture, while an estimated 70 percent of poultry products consumed in Kampala were produced in the city (Maxwell 1995 as cited in David et al. 2010). Many residents practice agricultural activities ranging from horticultural crops like fruits, vegetables and flowers; root tubers like cassava, yams, sweet potatoes; legumes and cereals; livestock farming (cattle, poultry, pigs and goats) and some paddy rice fields in the swampy areas (Semwanga, 2000 as cited in (Byamugisha, Odongo, Nasinyama, & Lwasa , 2008). Popular vegetables grown within Kampala city

include; Amaranthus (dodo, bugga, and jobyo), kales, Spinach, cabbages, egg plants and bitter berries (entula) (Prain & Lee-Smith, 2010).

Farmers engage in urban agriculture to ensure household food security, save on food expenditure, income generation, employment, home consumption, access to healthy and fresh foods, interaction among urban neighbors and supply city markets with fresh foods (Olivier, 2017; Lawson, 2016). Despite its significance, climate variability is becoming a major threat to livelihood of many poor smallholder vegetable farmers. For instance, Kampala's rainstorms typically happen suddenly both during and outside wet seasons (Garcia & Markandya, 2015) and the frequency of flooding in Kampala has increased over recent years (Lwasa, 2010). Sliuzas et al. (2013) cited in (Garcia & Markandya, 2015) add that, severe flooding occurred quite often in many areas along the primary channel in the Lubigi catchment with depths of up to 2m and durations of more than 24 hours.

The most significant impacts have come from increased precipitation that leads to flooding (UN-HABITAT, 2010, 2013, 2014; Lwasa, 2010). Floods in Kampala have caused deaths; destroyed and damaged buildings, mobility and transport, and energy distribution infrastructure; increased the costs and challenged the feasibility of water supply; led to health problems and negatively affected livelihoods and food security (Garcia & Markandya, 2015).

Smallholder farmers have got no option but to find and implement sound strategies of adjusting to the adverse effects of climate change and variability so as to survive. The article focuses on smallholder technological adaptations as a way of adjusting to the ever changing climate. A critical adaptation method that can quickly result in meaningful livelihood resilience and sustainability is technological development. Climate technology refers to, 'a piece of equipment, technique, practical knowledge or skills for performing a particular activity (Intergovernmental Panel on Climate Change, 2000). Technology development and transfer is a broad set of processes covering the flows of knowledge, experience and equipment for mitigating and adapting to climate change amongst different stakeholders including governments, private sector, financial institutions, non-governmental organizations and research/education institutional.

In agricultural societies, technologies for adaptations to climate change include; use of new irrigation systems, drought-resistant seeds, insurance schemes, crop rotation patterns (UNFCC, 2006). According to Smit and Skinner (2002) technological development adaptation strategies include; crop development strategies and resource management innovations. A recent study for instance reported that, there exists a range of climate change indigenous and scientifically derived knowledge and technologies with potential for uptake but scattered among institutions locally and within the east African region (Tenywa, Margaret , Twinomuhangi, & Mfitumukiza, 2017). The objective of this study was to identify technologies for climate change adaptation and their effects on livelihood of smallholder vegetable farmers in Kampala district, Uganda.

2. Literature Review

2.1. Technological Adaptations and Livelihood

Earlier studies by scholars have heralded both traditional and modern technological developments necessary in climate change and variability adaptation and their effect on farmers' livelihood. Kohli, Singh, Sharma and Gupta (2016) observed that climate smart technologies such as the introduction of resilient varieties such as millets potentially reduce the vulnerability to climate change. In addition, practices as zero or minimum tillage, traditional crop establishment practices such as *bhokha*(direct drilling) or *paira*(relay cropping) and use of traditional water harvesting structures (the *ahaar*)prevalentin the plains of south Bihar have an advantage over the conventional technologies practices (Kohli, Singh, Sharma & Gupta 2016).

Ismail et al. (2013) adds that resilient varieties are least dependent on external inputs ,have a lower incidence of pests and diseases and are capable of completing their life cycle from seed to seed solely on the soil moisture residual from the previous crop. A study by Valdivia et al. (2010) in Bolivian Altiplano to assessed the relationship among livelihoods, strategies, capitals, and knowledge. The study assessed local knowledge development of future climate scenarios using participatory research. Findings indicated local knowledge about climate forecasts is the main source of information in all communities whereas in northern Altiplano communities the radio is a common source of information.

A study conducted by Musa and Umar (2017) described the indigenous best practices employed against climate change for food security by irrigation farmers in Ajiwa and Dutsinma agro-ecological zones of Katsina State in northern Nigeria used mixed method approach. The study revealed that, majority of irrigation farmers identified other farmers such as friends, relatives and neighbors as important sources of information on climate change, followed by use of the radio, cooperative group members, open market, internet, mobile phones and government extension agents. The study also showed that the relevance of soothsayers as a source of information on climate issues had diminished with the advent of Islam in the study area.

The World Meteorological Organization (WMO) recommends that each country has a National Meteorology Service (NMS), to provide weather, hydrologic, and climate forecasts and warnings that are locally relevant (Otim & Waisswa, 2012).InUganda, out of 300 established rainfall weather stations, 35 are operational and out of 16 established agro met weather stations 8 are operational and those that report weather information regularly are fewer (Otim & Waisswa, 2012). Smallholder farmers continue to experience incidences of unpredicted erratic rainfall, floods crop pests and diseases that threaten their livelihood outcomes.

A study by Gebru and Mworozi (2015) conducted in project intervention districts of Soroti, Nakasongola and Sembabule, as well as the control district of Rakai in Uganda assessed climate adaptation information and communications needs of the communities. The study employed mid-line and end-line surveys, involving 640 households in each survey,

focus group discussions and in-depth interviews. The findings of the study indicated that, the top hazards affecting Uganda's cattle corridor communities included drought, prolonged dry spells, unpredictable rainfall, and floods which lead to loss of crops and livestock. The study also found that the timely delivery of localized climate information reduced crop loss and damage by 67% ($226 - $325 per household per year); increased funding to improve farmers' access to adaptation information significantly reduced crop loss and damage and made communities more resilient to the impacts of climate variability and change.

2.2. Conceptual Framework

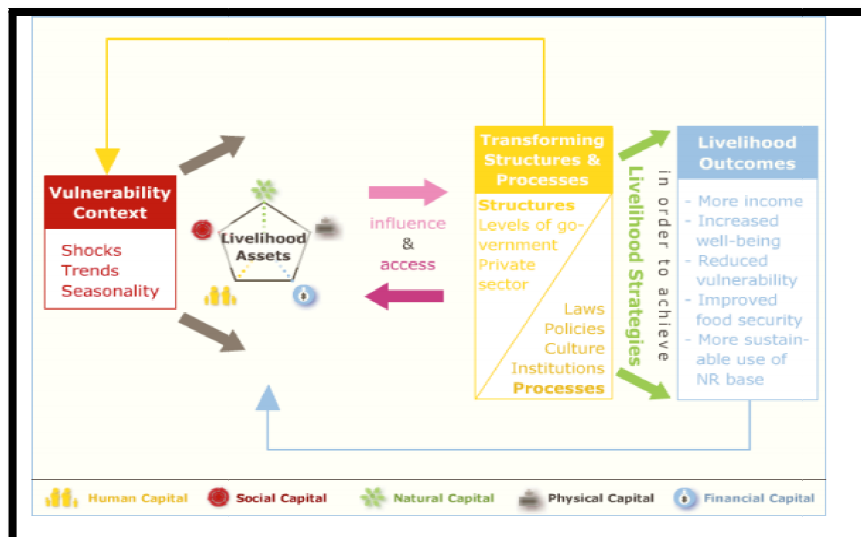The study was guided the Sustainable Livelihoods Approach (SLA) specifically the DFID sustainable livelihood approach.

Figure 1: The DFID Sustainable Livelihoods Framework (SLF)
Source: DFID (2000)

The livelihood of smallholder vegetable farmers in Kampala district can be explained under the SLA in the following manner. Poor smallholder urban vegetable farmers are targeted in the study and are seen to build their livelihood strategies on a number of capitals (natural, human, financial, social and physical); on capabilities to satisfy their farming needs; perform certain adaptation activities, and aim at achieving a number of self- defined livelihood goals. The study believes that when the root causes of poor livelihood are not understood, then policy interventions are likely to be ill informed and unlikely to succeed in moving the poor out of poverty. The approach also applies to the study in a sense that that it spells out shocks like; human, livestock or crop health shocks; natural hazards, like floods or earthquakes; economic shocks; conflicts in form of national or international wars outside smallholder's control. The sustainable livelihood approach is also applicable to the study as it describes institutions, organizations, policies and legislation that shape livelihoods.

The sustainable livelihood approach has been associated with advantages like having a flexible design, adaptable to diverse local settings, helpful in the identification of development priorities and new activities and in finding potential beneficiaries or partners in practice (Kollmair&Gamper, 2002). The framework provides an analytical structure to facilitate a broad and systematic understanding of the various factors that constrain or enhance livelihood opportunities, shows how factors relate to each other (Elasha, Elhassan, Ahmed &Zakieldin, 2000), enables understanding of the underlying causes of poverty and shows how the poorest of the poor are active decision makers, not passive victims in shaping their livelihood (Lasse, 2000; De Haan, 2012; Sarah, 2015).

The approach has been widely used in empirical studies of livelihood strategies and adaptation (Odewuni*et al.,* 2013; Yaro, Bisonga, & Okon, 2016), livelihoods and poverty (Ansoms& McKay, 2010), and livelihood diversification (Naznin, Elias & Khairul, 2015). The approach is commonly used to assess people's livelihood assets and how the external environment of social relations, institutions, organizations, policies, seasonality, trends and shocks modify access to and ability to convert livelihood assets into livelihood outcomes (Ansoms& McKay, 2010; Vedeld, Jumane, Wapalila, &Songorwa, 2012; Sarah, 2015).

3. Materials and Methods

The study was carried out in Kampala District Uganda a rapidly growing, sprawling district that houses the capital city of Uganda. Kampala district is administratively divided into five divisions; Makindye, Nakawa, Rubaga, Kawempe and Kampala Central, it is located in the central region on the northern shores of Lake Victoria, spreads over 839km^2 and is bounded by Mukono to the East, Wakiso to the West, Buikwe in the South and Luwero in North (Sabiiti, et al., 2014).

Kampala is situated at an altitude of 1120m above sea level and sits on 24 low flat-topped hills that are surrounded by wetland valley (K.C.C.A, 2016). According to Uganda Bureau of Statistics (2016), Kampala district has a

total population size of 1,507,080 persons, population density of 7,928km², average household size of 4 persons and 61%, residents live in informal housing (locally known as muzigo tenements).
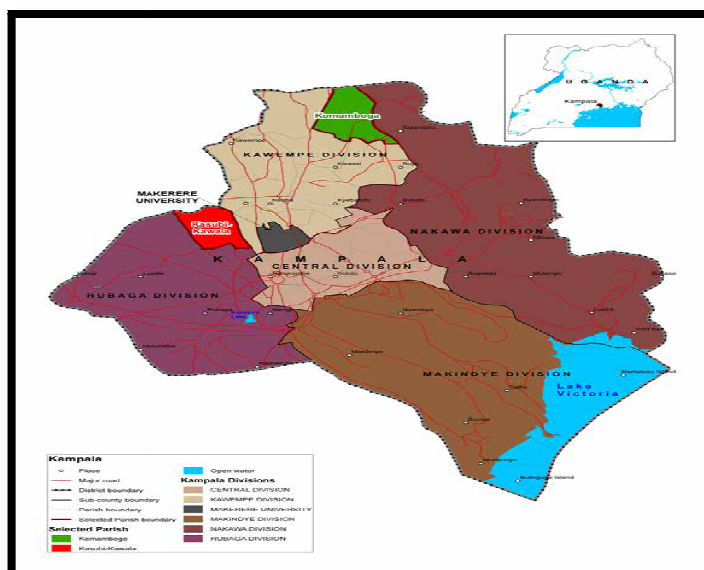

Figure 2: Map Showing the Location of Five Divisions of Kampala District,
Where Household Survey Was Carried Out

Kampala district receives bimodal rainfall averaging 1,290mm, March –May is the main rainy season peaking in April whereas October –December forms the secondary rainy season (KCCA, 2016). Uganda National Meteorological Authority (2018) states that, Kampala rains are expected to reach the peak levels around mid- October and end around early December, average annual temperature is 21.3 °C, driest month is July and on average the temperatures are always high.
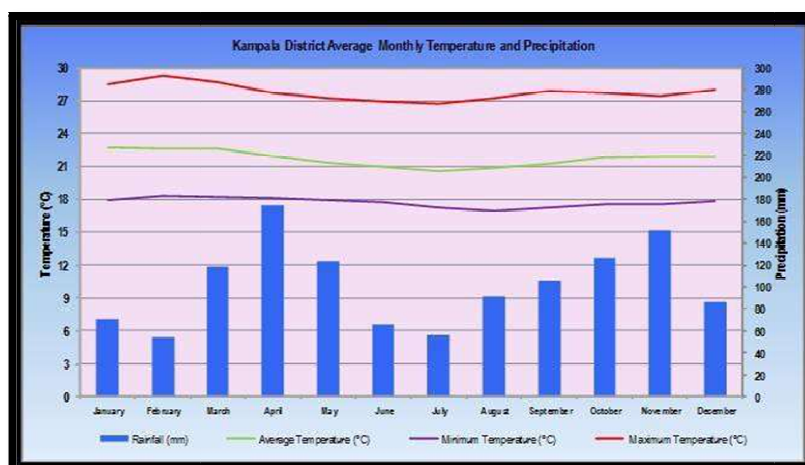

Figure 3: Showing Rainfall and Temperature for Kampala District

Kampala's topography combined with a tendency for rainfall in brief but heavy downpours, blocks drainage systems create ideal conditions for flooding (Matagi, 2002 as cited in Sabiiti, 2014).
Small scale agriculture is widely distributed in urban and peri-urban areas. In terms of distribution by agricultural land, Nakawa division occupied 35%, Makindye 24.5% and Kawempe 20.6%. Apart from Agriculture other land uses in Kampala district include built up area, industrial activity (Maxwell, 1994).

At the beginning of 2021, primary quantitative and qualitative data were collected in Makindye, Kawempe, Rubaga, Kampala Central and Nakawa divisions. Data were collected sequentially starting with collection of quantitative data and then qualitative data. According to Johnson et al. (2007) as cited in Creswell and Clark (2011 p.4) neither quantitative nor qualitative methods are sufficient by themselves to capture data on variables of the study. Similarly, a mixed approach was used to ensure that there are no gaps in information. Secondly, the researcher used qualitative methods to probe, explain quantitative. Quantitative method was the dominant method in the study. Onwuegbuzie, Leech and Collins (2011), argue that quantitative dominant crossover mixed analysis is used when the researcher seeks to answer research questions through a post positivist (quantitative) stance while also believing that qualitative data and analysis help address the research question(s) to a greater extent.

Semi-structured questionnaires were used to collect data on demographic characteristics, farm characteristics, use of adaptation strategies, technological developments and on effect of technological adaptations on smallholder livelihood.

3.1. Data Analysis

Data from questionnaires was analyzed using both descriptive and inferential statistical methods. Descriptive statistics consisted of mean and standard deviation while inferential statistics consisted of Pearson Product Correlation coefficient and multiple regression analysis. Data was subjected to correlation and regression analysis with the aid of Statistical Package for Social Sciences (SPSS V23).For instance, questions like gender of respondents were coded as 1 if the respondent was a male and 2 if the respondent was a female; education was re-coded to primary education and above as 1 and no education as 0; monthly income of respondents with 6 options was re-coded to refused as 0 and 10000-100000 as 1, 110000-200000 as 2, 210000-300000 as 3, 310000-400000 as 4. Qualitative responses were transcribed, and transcribed data was cleaned up and codes were developed.

3.2. Model Specification

Multiple regression was used to predict the value of a variable based on the value of two or more other variables. The variable predicted was the dependent variable. The variable used to predict the dependent variable was the independent variable. To determine the influence of the independent variables on the dependent variable as captured by the null hypotheses H_{01}, H_{02}, H_{03} and H_{04} multiple regression was undertaken using multiple regression model as follows:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X4 + \varepsilon$ ....

The variables in the model are;

Y	= Livelihood
X_1	= Technological development adaptation strategies
X_2	= Government programs
X_3	= Farm production adaptation strategies
X_4	= Farm financial management adaptation strategies
ε	Error term (the residual error, which is an unmeasured variable)

The parameters in the model are;

β_0	= Coefficient of the model (the value of change in y when X = 0,
β_1	=The first regression coefficient (the value of change in y when X=1)
β_2	=The second regression coefficient (the value of change in y when X=2)
β_3	= The third regression coefficient (the value of change in y when X=3)
β_4	= The fourth regression coefficient (the value of change in y when X=4)

4. Results

4.1. Demographic Characteristics of Smallholder Farmers

The study results on demographic characteristics of respondents revealed that 146 (72.6%) were female, while 55(24.7%) of the sample were male. This implies that females are more involved in urban farming than their male counterparts. This is true as gender division of labor still dictates that women mostly manage the compound and plant vegetables in their compounds hence the phenomenon of feminization of crop production where certain crops like vegetables are regarded as female crops is still apparent.

The information on respondents' marital status shows that 114 (56.7%) are married, 39(19.4%) widowed/widower, 36 (17.9%) single, 5(2.5%) separated while the least 4(2%) are divorced. The finding could be associated with collaborative relationships with their husbands which enhance agriculture practices. The age pattern of respondents shows that majority are adults. This implies that a biggest percentage of the respondents are less than 41 years hence still energetic. On education, majority of the respondents 89(44.3%) had secondary education level, 64(31.8%) had primary school education, 24(11.9%) had undergone tertiary institution, 19(9.5%) attained university education while the least 1(0.5%) had not attained any education level. The findings show that majority of the small holder vegetable farmers in Kampala district had acquired formal education while a very small percentage had not acquired formal education.

Information on household headship revealed that out of the 201 respondents only 94(46.8%) are household heads while 107(53.2%) are not household heads. Given that majority of the smallholder farmers are women it follows that they were also not household heads and therefore not at the center of adaptation decision making. The findings could be also be associated with decision making process in households which is characterized by gender stereotypes based on female male traits or attributes. On household income the study finding revealed that 125(62.2%) earned between 10,000 and 100,000 Uganda shillings, with 29(14.4%) earned between 110,000 and 200,000 Uganda shillings, while 17(8.5%) earned between 210,000 and 300,000, and the least, 6(3%) earning above 510,000 Uganda shillings (Table

Characteristic	Category	Frequency	Percent	Cumulative Percent
Gender	Male	55	27.4	27.4
	Female	146	72.6	100.0
	Total	201	100.0	
Marital status	Missing data	3	1.5	1.5
	Married	114	56.7	58.2
	Single	36	17.9	76.1
	Widow/widower	39	19.4	95.5
	Separated	5	2.5	98.0
	Divorced	4	2.0	100.0
	Total	201	100.0	
Age group	18-25	17	8.5	8.5
	25-30	28	13.9	22.4
	30-35	35	17.4	39.8
	35-40	26	12.9	52.7
	40 years and above	95	47.3	100.0
	Total	201	100.0	
Education Level	Missing data	4	2.0	2.0
	Never went to school	1	.5	2.5
	Primary school	64	31.8	34.3
	Secondary school	89	44.3	78.6
	Tertiary Institution	24	11.9	90.5
	University	19	9.5	100.0
	Total	201	100.0	
Household head	Yes	94	46.8	46.8
	No	107	53.2	100.0
	Total	201	100.0	
Income	Refused	5	2.5	2.5
	10000-100000	125	62.2	64.7
	110000-200000	29	14.4	79.1
	210000-300000	17	8.5	87.6
	310000-400000	10	5.0	92.5
	410000-500000	9	4.5	97.0
	510000 and above	6	3.0	100.0
	Total	201	100.0	

Table 1: Demographic Characteristics of Smallholder Vegetable Farmers
Source: Researcher, 2021

4.2. Respondents Farming Characteristics

In articulating the set objectives, farming characteristics provided significant information that helped in answering the main objective of the study. Information on respondents farming characteristics reveals that 147(73.1%) engaged in vegetable farming, while 54(26.9%) engaged in both vegetable and livestock farming. On the type of vegetables grown in 2020, majority of respondents 147 (73.1%) indicated that they planted leafy vegetables, 53 (26.4%) planted fruit vegetables and the least 0.5% planted root vegetables. This showed that most of the smallholder vegetables farmers preferred leafy vegetables. On the duration vegetables take to mature, majority of the respondents 186(92.5%) agreed that vegetables take 1-3 months, 4.5% indicated that vegetables take between 4 -7 months and the least 2.5% showed that vegetables take one month to mature. The duration the vegetable take to mature was important in predicting the effect of climate variability.

On the location vegetable farms, majority of respondents 169 (84.1%) indicated that they grew vegetables in their homestead (On-plot), 31 (15.4%) on land away from their residences (off-plot). The finding could be associated with need to closely monitor vegetables. Lastly, number of farming years is an important characteristic that enable farmers to appreciate and give good account of the impacts of climate variations in their environment. The study reveals that a large percentage of farmers 130 (64.7%) had farming experience that ranged between 1-5 years, 40 (19.9%) and 11(5.5%) had 6 -10 and 11- 15 years of farming experience respectively, 10 (5%) had 16 -20 years as well as more than 20 years farming experience, while 10 (5.0%) had farming experience of above 20 years.

Characteristic	Category	Frequency	Percent	Cumulative Percent
Type of urban farming practiced	Vegetable	147	73.1	73.1
	Both vegetable and livestock	54	26.9	100.0
	Total	201	100.0	
Vegetables grown in 2019	Fruit Vegetables	53	26.4	26.4
	Leaf Vegetables	147	73.1	99.5
	Root vegetables	1	.5	100.0
	Total	201	100.0	
How long do vegetables take to mature?	Non-response	1	.5	.5
	Less than one Month	5	2.5	3.0
	1-3Months	186	92.5	95.5
	4-7Months	9	4.5	100.0
	Total	201	100.0	
Where do you grow vegetables?	Non-response	1	.5	.5
	Homestead (On-plot)	169	84.1	84.6
	Land away from the residence(off-plot)	31	15.4	100.0
	Total	201	100.0	
How long have you grown Vegetables?	1-5years	130	64.7	64.7
	6-10years	40	19.9	84.6
	11-15years	11	5.5	90.0
	16-20	10	5.0	95.0
	20years and above	10	5.0	100.0
	Total	201	100.0	

Table 2: Smallholder Farming Characteristics
Source: Researcher, 2021

4.3. Perception and use of Climate Variability Adaption Strategies in 2020

There was a general perception among the smallholder farmers that climatic conditions have changed over the last 20 years. Commonly observed climatic trends included; more variable rainfall (M=4.24, SE=0.06), higher temperatures (M=4.21, SE=0.05) and greater wind flow (M=3.78, SE=0.08) in 2020. This indicated that climate variability indicators such as rainfall, temperature and wind changes were evident among the farmers and this was important in developing adaptation strategies. Information on use of climate variability adaptation strategies in 2020 reveals that, majority of the farmers 168(83.6%) had used adaptation strategies, while a very small percentage 33 (16.4%) had not used adaptation strategies. This finding portrays the significant importance attached to adaptation strategies as means to minimize climate variability impacts on their farmland. The study identified four major strategies usually adopted by urban farmers in the study locations to include technological, farm production, government subsidy programs and financial adaptations.

4.4. Technological Development Adaptation Strategies

Farmers were asked whether or not they used technological adaptation strategies. The study established the respondent's level of agreement on technological development adaptation strategies using a 5-point Likert scale. A total of thirteen statements were used to establish technological development adaptation strategies. Accordingly, majority of farmers agreed to have used at least one technological development strategy while others disagreed to have used some technological adaptation strategies.

	Min	Max	Mean	Std. Error	Std. Deviation
I received climate and weather information	1.00	5.00	4.00	0.07	1.06
I harvested rain water	1.00	5.00	3.85	0.08	1.07
I practiced irrigation	1.00	5.00	3.78	0.08	1.13
I used water pans	1.00	5.00	3.76	0.09	1.25
I planted new vegetable varieties	1.00	5.00	3.69	0.09	1.27
Overall mean			3.82	0.05	0.59

Table 3: Technological Development Adaptation Strategies
Source: Researcher, 2021

These findings reveal that majority of the respondents relied on weather and climate information systems, rain water harvesting, irrigation, new crop varieties and used water pans as technological developments in adaptation to climate variability.

4.5. Climate and Weather Information

The finding revealed that majority of farmers (M=4.00) relied on climate and weather information to cope with changes in climate patterns. This means that farmers value climate variability information in pursuit of their vegetable farming. The finding is not surprising since seasonal rainfall forecasts are particularly suited for rain-fed farming systems which constitute the main source of livelihood for poor households. This finding is supported by interview data which revealed that the government of Uganda through its meteorological department provided climate information to farmers on a regular basis so as to prepare themselves.

The significance of weather and climate information has been widely emphasized by scholars. For instance Gebru and Mworozi (2015) indicated that timely delivery of localized climate information reduced crop loss and damage by 67% per household per year and made communities more resilient to the impacts of climate variability and change. In addition, Valdivia et al. (2010) stressed that weather forecast assisted farmers in taking management decisions, develop and apply operational tools to manage weather related uncertainties in rapidly changing environments. While, Acqual – de Graft and Onumah (2011) found that lack of information on climate change impact and adaptation option is a major barrier to adoption. It can be argued that detailed information on climate and weather information as well as its implications is a precursor to sustainable urban farming and thus livelihood.

4.6. Sources of Climate and Weather Information

The study sought to find out sources of climate information and it was established that majority of respondents accessed weather information via television (M=3.77, SE=0.08), NGOs (M=3.77, SE=0.08), neighbors (M=3.75, SE=0.09), radio (M=3.70, SE=0.09) and Newspapers (M=3.52, SE=0.09) as shown in Table 4below.

	Min	Max	Mean	Std. Error	Std. Deviation
Television provided weather and climate information	1.00	5.00	3.77	0.08	1.10
Newspapers provided weather and climate information	1.00	5.00	3.52	0.09	1.33
Radio provided weather and climate information	1.00	5.00	3.70	0.09	1.26
Neighbours provided weather and climate information	1.00	5.00	3.75	0.09	1.24
NGOs provided weather and climate information	1.00	5.00	3.77	0.08	1.10
Overall mean			3.70	0.05	0.49

Table 4: Showing sources of information

The findings indicate that climate and weather information was disseminated to farmers via various modes of information dissemination. The findings also indicates that a large percentage of respondents received weather information via television and the least number of respondents accessed weather information via Newspapers. This means that TV viewing is widely spread in Kampala district. This finding is supported by National Information Technology survey report of 2017/18 which established that Kampala had the most households (42%) who reported to own television individually, half (52.1%) of urban respondents in Uganda watched TV compared to only a third (33.9%) of rural respondents (BBC Media Action, 2019). In an interview with a representative of the directorate of gender, community services and production he noted that 'the major television channels that provide climate and weather information to respondents were NTV, Bukedde, NBS and Spark TV'. The finding contradicts that of Musa and Umar (2017) which indicated that information on climate change was largely disseminated informally through friends, relatives and neighbors.

4.7. Water Harvesting

The findings reveal that rainwater harvesting was the second popularly used adaptation strategy. This could be associated to the tradition of harvesting rainwater as a means of water access by many households in Uganda. This result conquers with that of Kohli, Singh, Sharma and Gupta (2016) which indicated that smallholder farmers use traditional water harvesting practices as water conservation technique to increase availability of water in areas that have inadequate resources. A representative of NAADS in Kampala district noted that '*NAADS gives regular trainings to vegetable farmers on how to harvest rain water using modern technologies.*' The finding is supported by Smit and Skinner (2002) who indicated that farmers employ farm level technologies to harvest rain water in order to address the risks associated with changing climatic conditions. The ability of smallholder farmers to properly handle, adopt and practice rainwater harvesting adaptation strategy is vital in responding to the water needs of the farmers.

4.8. Irrigation Technique

During times of adverse drought in 2020, farmers employed irrigation adaptation strategy with a mean of 3.78. This means that farmers agreed to have used the strategy. The finding is consistent with that of Antwi-Agyei (2012), Musa and Umar (2017) and Osewe , Liu and Njagi (2020) who found out that farming households rely greatly on irrigation to cope with climate change, especially during the dry season. Osewe , Liu, and Njagi, (2020) revealed that, the decision to adopt irrigation practice was determined by whether the farmers had drought experience, membership to a water user group, owned assets, received extension services and had membership to farmer organizations, as well as by the gender of the smallholder household head. Findings from key informant interviews confirmed that farmers used small scale traditional irrigation techniques to cope with erratic rainfall. Further, interview method revealed that many farmers relied on seasonal or permanent shallow wells, bucket systems and motorized pumps to irrigate vegetables. According to Wanyama, et al. (2017) although urban and peri-urban informal irrigated agriculture covers a small percentage of the total irrigated area, it accounts for between 60% and 100% of the consumed leafy vegetables in the urban areas depending on crop and season. It can therefore be argued that irrigation adaptation strategy has a significant socio-economic impact of boosting food and nutritional security and incomes of farmers in urban areas. Irrigation is considered formal when systems whether public or private are developed with proper planning and universally established technical standards or informal when farmers spontaneously develop systems without planning and with little or no technical assistance (Gutierrez-Malaxechebarria, 2014). Informal irrigation is characterized by use of basic and sometimes inappropriate technology (FAO 2015).

Figure 4: Showing Ground Water Source at Kyanja

4.9. New Crop Varieties

As to whether or not farmers used new crop varieties in 2020 as a technological development, a proportion of farmers (Mean =3.69) indicated that they planted new crop varieties. This means that farmers agreed to have used new crop varieties in 2020. Findings from key informant interviews confirmed that farmers planted hybrid vegetables like cabbages, broccoli, spinach, AmaranthusDubius, (dodo), African Spider flower, eggplants, pepper and okra. The findings could be associated to availability of information on new vegetable hybrids offered at Kyanja Agricultural Resource Center managed by Kampala Capital City Authority. The center offers numerous empowerment programs for example climate smart agriculture, urban farming skills, and technical support. The finding concurs with that of Ismail et al. (2013), who noted that adoption of climate smart technologies such as the introduction of resilient varieties which are least dependent on external inputs, have a lower incidence of pests, diseases and are capable of completing their life cycle are popular among farmers in India. The adoption of technological improvements is an ingredient for increasing agricultural productivity and reducing poverty.

4.10. Factor Analysis for Technological Development Adaptation Strategies

Factor analysis results for technological development adaptation strategies indicated that the KMO was 0.625 and Bartlett's Test of sphericity was significant (p<.05) and a Chi-square value of 217.779 confirmed that data collected for technological development adaptation strategies was adequate (Table 4).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.625
Bartlett's Test of Sphericity	Approx. Chi-Square	217.779
	df	10
	Sig.	.000

Table 5: KMO and Bartlett's Test for Technological Development Adaptation Strategies
Source: Researcher, 2021

From Principal Component Analysis using varimax rotation method, none of the items were deleted and all retained (Table 4.18). From the Rotated Component Matrix**,** two factor components were extracted, with four items load virtually exclusively on Factor component one (1). Factor component two (2) had one items load substantially on it.

Therefore, technological development adaptation strategies were measured using the following five items derived from Rotated Component Matrix.

	Component	
	1	2
I used organic fertilizers during planting vegetables	.811	
I used water pads to irrigate crops	.810	
I practiced irrigation in my vegetable farm	.695	
I harvested rain water to use in my garden	.694	
I do not planted new vegetable varieties		.957

Table 6: Rotated Component Matrix for Technological
Development Adaptation Strategies

Extraction Method: Principal Component Analysis.
 Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.
After extraction, Varimax rotation was used to maximize the variance of each of the factors, so the total amount of variance accounted for was redistributed over the four extracted factors. The two principal component factors accounted for 67.17% of the variance in rotation sums of squared components associated with the factors (Table 4.19). The first factor explained 45.577% and factor 2 explained 21.596% of the variance in the data.

Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	2.279	45.577	45.577
2	1.080	21.596	67.174

Table 7: Total Variance Explained for Technological Development Adaptation Strategies
Source: Researcher, 2021
Extraction Method: Principal Component Analysis

The study results (r= 0.810, p =0.000) reveal that there was a significant strong positive correlation between technological strategies and livelihood of smallholder vegetable farmers. Since the *p*< 0.05 the null hypothesis (Ho$_1$) was rejected.This implies that for every increase in adaptation of technological development strategy, there was a corresponding improvement in livelihood of smallholder vegetable farmers in Kampala districtThis suggests that technological development adaptations were largely adopted and benefited vegetable farmers and hence influenced their livelihood in a positive manner. The finding is consistent with a previous study by Ogada, Rao, Radeny, Recha and Solomon (2020) which demonstrates that a positive correlation existed between asset index, household income and adoption of climate smart agriculture technologies. Further, the same was pointed out OECD (2001) states that farmers adopt technologies that can contribute to an economically efficient farm sector, financial viability for farmers, increase production, profits and productivity while improving environmental performance. Therefore, adoption of adaptation technologies and innovations can improve household livelihood outcomes, either directly or indirectly by increasing crop productivity gains and reduced cost of production, leading to improved food and nutrition security, and household income and wealth indicators.

Thus, adoption of improved and appropriate agricultural technologies is an important step towards achieving food and nutritional security and general household welfare. This has led to investment in adaptation technologies to minimize the vagaries climate variability like floods and drought. As such this has led to implementation of technologies, practices and innovations that are profitable. Interview data revealed that farmers were largely aware of and adopted traditional and modern adaptation technologies in agriculture; however they were faced with a number of adaptation constraints. A NAADS representative noted *'vegetable farmers are constrained by lack of capital, limited education and training, and have problem in applying technologies.* Technologies can help reduce climate variability for farmers to attain their desired outcomes.

5. Discussions

Across the divisions studied, smallholder farmers largely engaged in vegetable farming as 147 (73.1%) indicated that they planted leafy vegetables, 53 (26.4%) planted fruit vegetables and the least 0.5% planted root vegetables in their homestead (on-plot), land away from their residences (off-plot) on a small scale and are vulnerable to adverse climatic events. More than 80% (475 million) of the world's farms operate on less than two hectares of land, smallholder farms account for only 12% of the world's farmland however, provides an estimated 80% of the food produced in Asia and in sub-Saharan Africa (SSA) (Lowder et al., 2014). Consequently, the livelihood sustainability of farmers is closely interwoven with choice of adaptation options taken.

Kampala district vegetable farmers are particularly vulnerable to frequent floods and dry spells. Floods have caused deaths; destroyed and damaged buildings, mobility and transport, and energy distribution infrastructure; increased the costs and challenged the feasibility of water supply; led to health problems and negatively affected livelihoods, disease outbreaks and food security. In addition, droughts have reduced water supply and energy generation,

damaged and disrupted navigation infrastructure and transport, and affected livelihood in terms of increased cost of energy, decreased food production and health problems (Garcia & Markandya, 2015). Such scenario is expected to increase vulnerability and create new poverty pockets among farmers.

Fortunately, farmers in the study area were aware that climate had changed as they believed that rainfall had increased, was unpredictable while temperatures had increased over time. The findings could imply that smallholder vegetable farmers were in a position to make adaptation decisions basing on their awareness of changes in climatic patterns.

Farmers in the five divisions of Kampala district reported to use various technological developments to deal with impacts of climate variability on their livelihood. One of the most common technological development for farmers is the application of organic fertilizers. A sub set of farmers also relied heavily on rain water harvesting and irrigation. While a considerable number showed that they did not use new crop varieties and water pans. Farmers reported facing constraints like, limited capital to purchase farm equipment, limited land for farming, decline in soil fertility, lack of clean seeds or planting materials, insufficient labour, soil and water pollution all of which have been classified as constraints to adaptation (David, et al., 2010). Such constraints make farmers extremely vulnerable to climatic and non- climatic threats that further reduce household income, food availability household assets and financial independence.

The study revealed that for every increase in adaptation of technological development strategy, there was a corresponding improvement in household income, financial independence, food availability and household assets. While these technological improvements clearly help to minimize impacts on smallholder farmer livelihoods, the fact that most farmers did not receive government support suggests that these adaptation strategies are insufficient. In addition, there are limits to how much different coping strategies can be successfully used. For example, use of organic fertilizers is often restricted by capital and knowledge. Harvesting rain water for use in dry periods may be unsustainable in the long run, if farmers lack the right skills and knowledge. In addition, if farmers have incomplete weather and climate information, farmers are unable to make adequate farm decisions. There is therefore an urgent need to address the limitations and offer adaptation strategies to farmers as a package comprising of technological developments, government subsidies, knowledge of on- farm production practices and farm financial strategies which can better lead to sustainable livelihood. Moreover, every adaptation method involves some kind of technology.

6. Conclusions and Recommendations

This article explores technological adaptations and livelihood of smallholder vegetable farmers in Kampala district in Uganda. Most of the farmers used organic fertilizers, harvested rain water, practiced irrigation , while others agree not to have used water pans and new crop varieties as technological improvements. The study also concluded that, technological developments had a significant effect on livelihood of smallholder vegetable farmers. Therefore, for every increase in adaptation of technological development, there was a corresponding improvement in livelihood of smallholder vegetable farmers.

Since technological improvements are of much significance, barriers to accessing technological developments like weather forecasts, water harvesting, use of organic fertilizers require to be reduced fundamentally. The findings have broader implications for Kampala district and elsewhere. Specifically, Kampala district, should establish a data base of all smallholder farmers through a census with respective area of land they hold. Additionally, extension services targeting addressing technological challenges and improving farmers' skills should be introduced. Public and private partnerships should be built and consolidated in urban agriculture sectors to negotiate and address technological challenges faced by smallholder vegetable farmers. Further, it is essential to expand collaboration between KCCA, NGOs and other private entities to provide training, skill development, and capital to strengthen success of livelihood outcomes.This article has several limitations for instance there were limited recent studies on use of organic fertilizers by urban farmers. Similarly, there was limited empirical studies on uptake of new crop varieties. Prior studies relevant to the study had been conducted in rural areas as compared to urban areas. There was limited access to respondents most respondents could not be located at agreed time and location as they were engaging in other income generation activities. The researcher exercised patience and in some other cases rescheduled the meetings. Attempts to visit various offices to acquire study materials were limited by the Covid -19 pandemic. The researcher requested officials to send relevant materials on climate change and variability via her email address.

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