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Large-scale Agricultural Investments and their Implications on Water Access and Quality for Local Communities in northern Uganda

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Abstract

Water is a critical factor of production in agriculture and a highly sought-after resource by large-scale agricultural investors. However, it is rarely included in many land acquisition contracts that downplay the user rights of the adjacent communities. This study investigated the implications of LSAI on local communities' access to water and effects of human activities around LSAI on water quality. Data were collected from 388 respondents using a structured questionnaire and eight key informants were interviewed with the help of a question check list. Water samples were taken from five points located 200 meters apart along a 1,000 m transect on River Nyamukino. The samples were analysed in Public Health and Environmental Engineering Laboratory at Makerere University using the American Public Health Association protocols. Data were subjected to chi-square test and one-way ANOVA. Results revealed that activities on LSAI farms slightly affected water quality. Watering of livestock, lack of pit latrines and application of agro-chemicals on the LSAI farms further polluted water. Although water quality slightly declined, results of the laboratory tests revealed that the water quality parameters in the wet and dry seasons were within the limits of potable water in Uganda. The relationship between distance and walking time to water source was statistically significant ($F=3.34$; $p=0.0332$). There was a claim that a skin disease incidence was due to use of water polluted with agrochemicals. In this regard, it is recommended that activities of LSAI need to be regulated in conformity with the provisions of the Uganda National Environment Act 2019. Furthermore, studies are needed to establish the cause-effect relationship between agro-chemical pollution of water sources and the skin disease to guide future LSAI on-farm application of agro-chemicals.

Keywords: *Water quality; LSAI farms; Water; Smallholder farming households; Pollution*

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Introduction

Investments in agriculture to increase production and productivity aimed at meeting the ever growing food demand of the increasing population escalated over the last four decades and coincided with extensive use of agrochemicals. Scholars concur that agricultural development has fundamentally altered the earth's system and resulted in land degradation, decline in soil fertility and reduction of water quality (Hébert *et al.*, 2019). The demand for irrigation water has also increased and raised concerns about reduction of surface water quality by surface run-off contaminated with inorganic fertilisers and pesticides from farmlands (FAO, 2013; Quick and Woodhouse, 2014; UNEP, 2016). In the agriculture sector, local communities can be alienated from water sources through land grabbing by large-scale land acquisitions (Dell 'Angelo *et al*., 2018). Water is essential in agricultural production and it has, since the last decade, accounted for 70% to 90% of the global fresh water consumption (Ravnborg, 2014). This has also resulted in water loss through evaporation, decline in water quality and restricted access to fresh water (Ravnborg, 2014; FAO, 2020; United Nations, 2022). However, there are sufficient water resources in many Sub-Saharan African countries to meet the demands from new and existing agricultural schemes as well as for other uses (Quick and Woodhouse, 2014). Thus, understanding the effects of large-scale agricultural investments (LSAIs) on local community's access to water and water quality is paramount.

Agricultural landscapes in developing countries have come under immense pressure from increased interest by agribusiness enterprises and investments (Zoomers, 2010; GRAIN, 2015, 2016). Countries in Africa, Asia and Latin America as well as local and foreign companies continue to invest in agricultural land (Cotula *et al*., 2009). In some instances, the investors circumvent national laws and policies, exploit unequal power relations, capitalise on corruption and disrespect the tenure rights of local communities (Alden, 2012). Global discourse on land acquisition points to the fact that large areas of land have been acquired in Africa for agricultural investments. The Land Matrix, an online database which documents large-scale land deals, shows that by 2013, about 35% of the 48,829,193 hectares acquired globally were in Africa and out of theses 76,962 ha were in Uganda (Land Matrix, 2013) an indication that the land deals were the most common in Africa. In such deals, land enclosed by domestic and foreign companies and individuals is used for agriculture, mining and conservation (Benjaminsen and Bryceson, 2012; Corson and MacDonald, 2012; Julia and White, 2012). Studies of land acquisition increased in the last two decades and focused majorly on land acquisition dynamics with limited attention paid to understanding how LSAI affects local communities' access to water and how LSAI farm activities influence water quality (Makki and Geisler, 2011; Filer, 2012; Grajales, 2013).

Water is rarely included in large-scale land deals yet it is one of the main factors considered when determining the location of LSAI farms. Availability of water, bearing in mind the possibility of irrigation, determines the types of crops grown (Quick and Woodhouse, 2014, The World Bank, 2014). When water is included in land acquisition contracts, it is not featured prominently and valued. The water rights of local communities and the impacts of large-scale land use, occasioned by LSAI are not adequately considered when land is being leased (Sidibé and Williams, 2016). Yet literature indicates that LSAIs increase water scarcity, environmental degradation and pollution (Mujenja and Wonani, 2012; Sipangule, 2017; Zaehringer *et al*., 2018). It is reported that LSAIs compete with traditional uses of water during periods of rainfall scarcity. In addition, water is poorly managed in a number of large-scale irrigation schemes resulting in wasteful and inefficient water use as well as environmental degradation (Djiré, 2010; Sindayigaya, 2011; Deininger, 2011; Deininger and Byerlee, 2011; German *et al*., 2013; Zaehringer *et al*., 2018; Oberlack *et al*., 2021;).

In Nwoya district, 4.48% of the total land area (about 21,213 ha) has been converted to large-scale farms. Prior to the coming of LSAI to the district, local communities easily accessed water and the water quality was good. It is evident from literature that application of inorganic fertilizers, pesticides and fungicides on farms that are adjacent to water bodies reduces water quality through pollution (Hébert *et al*., 2019). Given that LSAIs are expected to attract migrant labour, the need to guarantee access to water and maintain water quality is critical.

Disregarding water as a critical factor in land investment contracts exposes local communities to the consequences of irresponsible water usage and can lead to conflicts over water access, compromising of water quality and creating water scarcity. This study investigated the implications of LSAI on local communities in terms of water access taking into account variables such as distance of the small holder farming households from the LSAI farms, availability and the quality of water in Nwoya district. There is evidence that LSAI farms practice irrigation, apply inorganic fertilizers and use other agrochemicals that affect the quality and quantity of water on the farmed landscapes (Scanlon *et al*., 2007; UNEP, 2016, Khan *et al*, 2017; Kadyampakeni *et al*., 2018). Although LSAI has been documented, much of the debate has focused on land acquisition and its effects on local communities' livelihoods (German, 2015; Herrmann and Grote, 2015; Cotula and Berger, 2017; Herrmann, 2017) and limited attention has been paid to effects on water quality and access by local communities.

Generally, LSAI affects local communities' livelihoods, biodiversity and agro-ecosystem services (Willemen *et al*., 2013; Landis, 2017). LSAI also puts pressure on fragile ecosystems and increases competition among water users (African Union *et al*., 2014). Water is critical for irrigation, spraying crops and other farm operations (Dell'Angelo *et al*., 2018). However, LSAI usage of water poses a threat to local communities' access to water and can be a source of conflict (Dell'Angelo *et al*., 2018). This phenomenon is referred to as green grabbing (Weeber, 2016). Most of the LSAI farms grow crops with a high-water intake used for irrigation and spraying of agrochemicals. Most of the agricultural farms use glyphosate for managing weed and NPK to increase production (Hébert *et al*., 2019). These activities pollute water that humans also use and can result in conflicts amongst water users (Dell'Angelo *et al*., 2018; Bitew *et al*., 2022). There are a number of LSAIs in Nwoya district due to prevalence of peace and security after the rebel insurgency ceased in the early 2000s. The activities of LSAI needs to be guided by researched information which is currently lacking. This study is part of the effort to provide such information to guide government agencies responsible for regulating LSAI activities. The research questions that we attempted to answer were: How do activities on LSAI farms affect water access by the local communities? How have the farm activities affected water quality? To what extent has distance from LSAI farms influenced pollution of water sources? How do local communities perceive water access and quality?

Materials and Methods

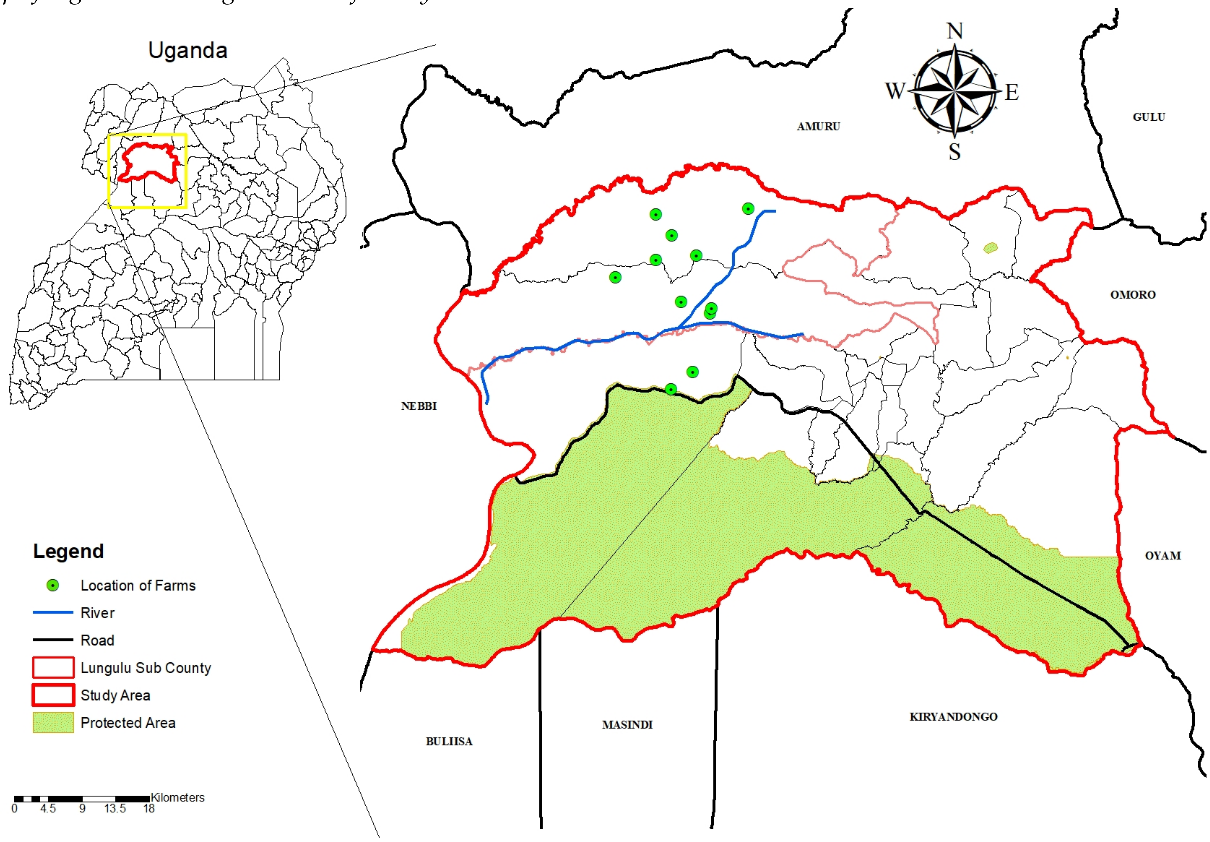
Study area

The study was conducted in Nwoya district (02°38′N and 32°00′E) shown in Figure 1. It covers an area of 4,736.2 km² and is bordered by Omoro district to the east, Oyam district in southeast, Kiryandongo and Buliisa districts in the south, Nebbi district in the west and Amuru district in the north. The district experiences an average annual temperature of 18°C-30 °C and two rainy seasons from March to July and September to November (Bamanyaki & Muchunguzi, 2020). The mean annual rainfall is about 1,500 mm (Twinomujuni & Rwabwogo, 2011; Mwungu *et al*., 2019,). It is drained by River Nile (Victoria Nile), River Aswa, River Nyamukino and several small streams and swamps. Nwoya district has a relatively flat terrain covered with fertile loamy soils (Wichern *et al*., 2023) that support production of cassava, maize, rice, tobacco, cotton and simsim (sesame).

The population is about 133,506 people and it grew from 41,000 at a rate of 9.9% per annum from 2002 with a density of 10 persons per km² (UBOS, 2017). In 2014, the population was projected to grow to 214,200 by 2019 (Uganda Bureau of Statistics, 2014) but it was distablised by the rebel insurgency between 1986 and 2006 which confined the majority of the population in internally displaced people's camps (IDPs). Customary land tenure is dominant, the average land holding is 18.1 acres per household and few people have land titles (Broegaard and Ravnborg, 2022).

Figure 1

Map of Uganda Showing Location of Nwoya District.



Selection of study area and sampling procedure

Nwoya district was purposively selected because there are a number of large-scale commercial agricultural investments (LSAIs) that use agrochemicals and pollute water. A multistage random sampling procedure (Sarantakos, 1988; Sedgwick, 2015,) was applied and a sample of 400 respondents selected. In the first stage, a random sample of 20 villages was selected. In Uganda, a village is an administrative unit with clearly delineated boundaries, leadership and interconnected pathways (Marron, 2019). Probability proportionate sampling was applied to the total population in order to randomly select villages from each parish (Abdulla *et al.*, 2014) (Figure1). In the second stage, respondents were selected from each village using probability proportional to size (PPS) method (Abdulla *et al.*, 2014). The village population as a proportion of the total population was then derived. In the third stage, respondents who were 18 years and above were selected randomly from a list of person's resident in the village. The list was compiled with the help of local community leaders at the village level. Each entry in the sampling frame was numbered using a random number generated in Excel (Marsaglia, 2003; Abd-Alhameed *et al.*, 2006). With this approach, a total of 400 respondents were selected consisting of farmers and local community members.

Water sampling procedure

Water samples were collected from downstream points, within the farmlands, on River Nyamukino in Lebnec village, Lungulu sub-county, Nwoya district in two seasons. The first set of samples was collected on 6th March 2022 in the dry season and the second set was collected on 5th June 2022 at the peak of the rains. The water samples were taken from five points at 200 metre intervals along a longitudinal distance of 1,000 m at a depth of 30 cm taking into account possible temporal and spatial changes in water quality. At each sampling episode, water was collected in 500 ml bottles and labeled with date, time and sampling point to ease analysis and maintain the same sampling locations for different seasons (Rainwater and Thatcher, 1965). The samples were packed in an ice box and maintained at about 4°C to inhibit photochemical processes that would alter the chemical composition of the water during transportation from the field to the Public Health and Environmental Engineering Laboratory at Makerere University.

Questionnaire interviews

Three hundred and eighty-three respondents were interviewed between 27th March and 18th April 2019. Selected individuals were assigned pseudo names using a 6-digit code for anonymity and confidentiality. The information gathered during preliminary field studies on LSAI and local farmers guided development of the questionnaire. Questions covered individual and household assets, demographic characteristics, land ownership, farming practices and water usage, relationship with foreign agricultural investors in the area, conflict over water, water access and water pollution by agrochemicals applied by LSAIs. Research assistants were recruited and participated in questionnaire pre-testing and revision. Field guides who were fluent in the local languages in the study district were recruited to work with the research assistants. The LC 1 Chairpersons of villages in the study district helped the field guides to locate households that were randomly selected for the interviews. The research assistants were introduced by the LC 1 chairpersons to the respondents, the purpose of the study was explained and consent to be interviewed sought. The decisions of respondents who declined to be interviewed were respected and the next respondent selected. The research assistants administered the structured questionnaire in the local languages and wrote the answers in English. Where the respondent did not understand a question, the research assistant repeated it for clarity. The questionnaire was long and each interview lasted about one hour, thus each research assistant administered only five copies per day.

Key informant interviews

The key informants included the district agricultural officers, production officers, and local leaders especially LC 1 and LC 2 Chairpersons and members of the Local Area Land committees, LSAI representatives, local community members and the LSAI farm workers. The key informants were asked to explain the nexus between land tenure, large-scale agricultural investments, land and water pollution, access to water in their areas and the effects of LSAI on-farm agrochemical use on water. They were also asked to provide information on how water was used for irrigation and mixing of agro-chemicals for managing pests, weeds and diseases on the farms.

Observations

Activities observed were recorded to provide additional and triangulate information gathered through questionnaire and key informant interviews. Observations helped to confirm whether the investors used agrochemicals that polluted water. In addition, it also aided to affirm ways in which agrochemicals were washed into River Nyamukino. Furthermore, observations assisted to ascertain whether water sources were enclosed by LSAI and denied local communities access to collect water for domestic use and livestock watering.

Data Analysis

Questionnaire responses were edited, coded and entered in SPSS to create a data file and remove clerical mistakes associated with manual coding. In addition, responses from key informants were entered into NVivo for thematic analysis. NVivo is a data management tool that is deemed appropriate for analysis of large volumes of transcripts (Bazeley and Jackson, 2013; Kristi and Bazeley, 2019). The programme also facilitates content analysis as it creates patterns of related information that makes it possible to derive meaning from the interview transcripts. Furthermore, it facilitated coding and eased data retrieval as the data files were interlinked (Kristi & Bazeley, 2019). Furthermore, the programme helped to establish themes and facilitate qualitative data interpretation (Hilal & Alabri, 2013). The theme made it possible to compare different types of information. Data were also subjected to one-way ANOVA to establish whether smallholder farming households' proximity to the LSAI farms influenced their access to water sources and the time taken to access water sources. In addition, data were subjected to chi-square test to establish the relationship between the presence of LSAI farms and water quality. On top of that, qualitative data were subjected to narrative analysis to understand the local communities' perception of access to water and water quality.

Analysis of water samples

The water samples were analysed using the American Public Health Association's protocols (Rainwater & Thatcher, 1965). The pH and Oxidation Reduction Potential (ORP) were determined using a portable pH/ORP meter (Orion Model 115A, Thermal Fisher Scientific, and USA). Dissolved Oxygen (DO) was determined using a portable DO meter (Seven2Go Pro, Mettler Toledo, USA) and Chemical Oxygen Demand (COD) determined using a Hach DR5000 Colorimeter. Biochemical Oxygen Demand (BOD5) concentrations were determined using a manometric BOD5 apparatus (BODTrak II; HACH, USA) while the concentrations of ammonium were determined using the phenate method (NH_4^+/4500-NH_3). Furthermore, nitrite was determined using the colorimeter (NO_2^-/4500-NO_2 B), the orthophosphate phosphate (PO_4^{3-}) was determined using ascorbic acid method (PO_4^{3-}/4500-P E), Total Nitrogen (TN) and Total Phosphorus (TP) were determined using Persulfate method (TN/4500-N C) and (TP/4500-P) respectively in ultraviolet and visible spectrophotometers (Gold S54T; Lengguang Tech, China). Nitrate (NO_3^--N) was analysed based on 4500-NO_3^--N B method (APHA, 2005) in continuous flow colorimetry equipment (SEAL Autoanalyzer 3, UK).

Results

Questionnaire response rate

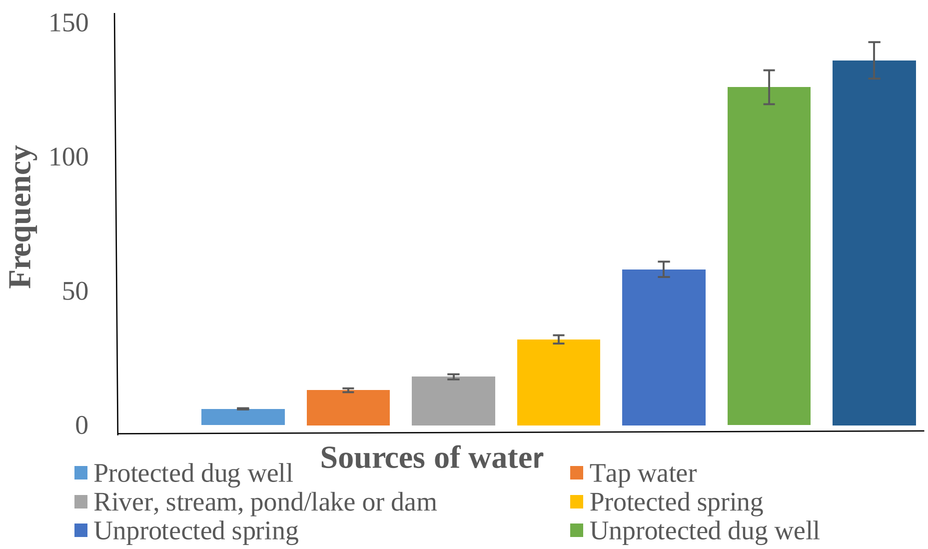
Out of 400 smallholder farming households and key informants who were expected to be interviewed, 389 (97.3%) were interviewed in the end.

Water access and quality

Respondents reported that they obtained water from rivers, dug wells, springs and boreholes. Majority of the respondents (88.9%) reported that they fetched water from sources located within their villages (Figure 2).

Figure 2

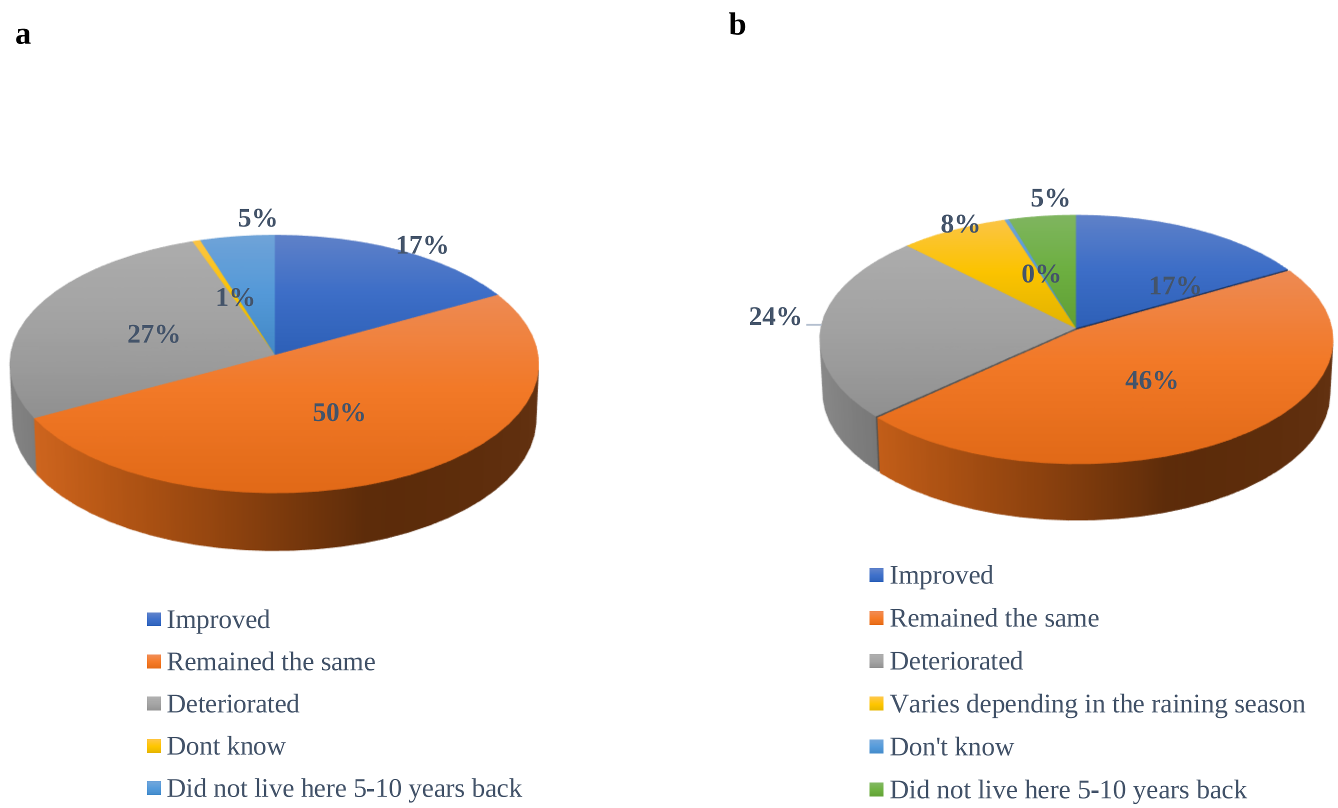
Sources of Water Accessible by the Local Communities.



Fifty percent of the respondents perceived the water quality from springs wells and streams to have remained the same, 27% perceived the water quality to have deteriorated, 17% perceived the water quality to have improved, 5% had no idea about water quality because they did not live near LSAI farms in the last 5-10 years while 1% also had no idea about change in water quality (Figure 3a). With regard to water quantity, 45% of the respondents indicated that it remained the same, 24% mentioned that it had deteriorated, 17% stated that it had improved, 8% mentioned that the quantity increased in the rainy season and dropped in the dry season, 5% did not express any opinion about water quantity as they had not lived in the area in the past 5-10 years whereas 0.5% did not know whether water quantity had changed (Figure 3b).

Figure 3

Respondents' views on water quality changes (a) and water quantity changes (b).

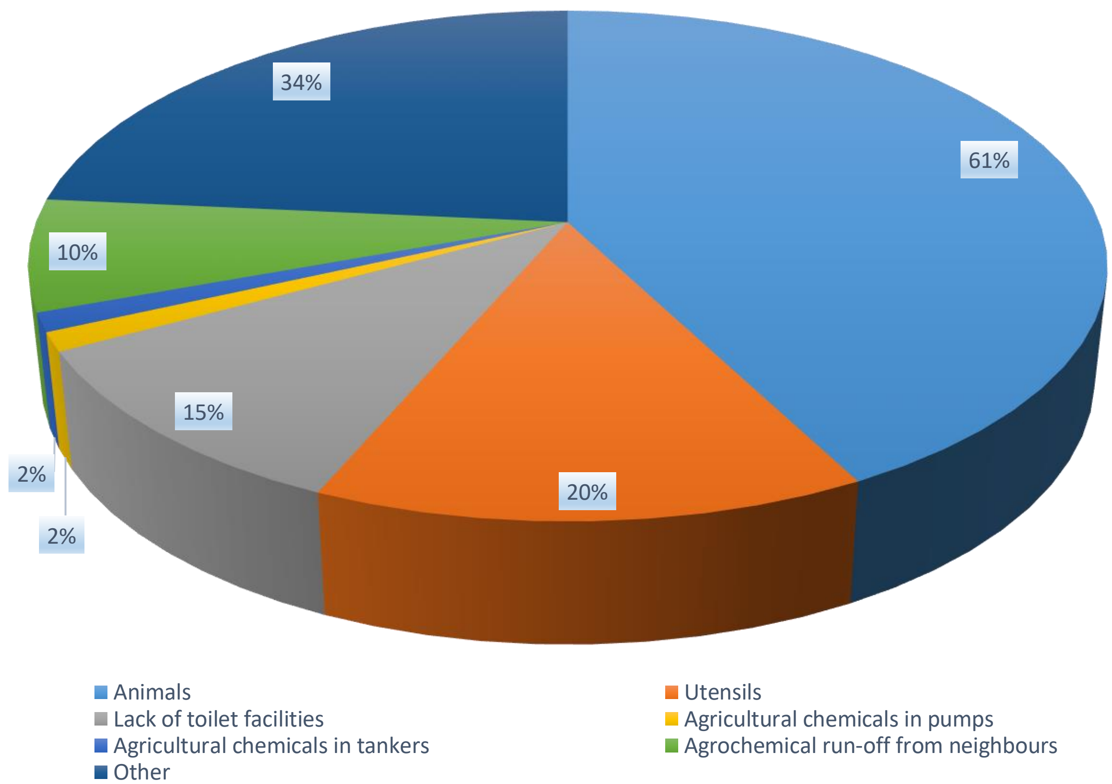


Causes of changes in water quality

The causes of changes in the water quality in the study area are presented in Figure 4. Sixty-one percent of the respondents mentioned that watering of livestock caused decline in water quality, 34% reported rusted water pipes, high concentration of water users, sediments sucked into the pipes after a burst, and high concentration of chlorine. Twenty percent indicated that washing of utensils by household members polluted the water, 15% stated that open defecation contaminated the water, 10% reported that agrochemicals carried by surface runoff from the farms polluted the water while 2% mentioned that washing of agrochemicals residues from the pumps and tankers after spraying the crops contaminated water in the rivers and streams.

Figure 4

Perceived causes of changes in water quality.



Key informants reported that it was common practice by LSAI farm workers to wash residues of agricultural chemicals from pumps and tanks at the wells and rivers which polluted water. In an oral account, the LC1 Chairman of Lebnec village reported that the practice was common in River Nyamukino where water quality had declined. He further added that, on some days, dead fish was seen floating in the river which he attributed to water pollution by agrochemicals. However, the practice was reported to have stopped after the district local government officers cautioned the perpetrators.

One-way ANOVA and Chi-square test results

Results of the statistical analysis presented in Table 1 show the relationships between the time taken by members of smallholder farming households to access water sources vis-a-vis distance from the LSAI farms. Results of the one-way ANOVA shows a statistically significant variation in the time taken to access water sources (F=3.34; p=0.0332). Members of the smallholder farming households located within <10 km radius from the LSAI farms took an average of 2.6 minutes to reach the water source, those who lived within 10-25 km radius took an average of 3.8 minutes while those who lived beyond 25 km radius took about 3 minutes.

Furthermore, there was a statistically significant relationship between the distance walked to the water source and washing of residues of agricultural chemicals from spray pumps (*F=9.9992; p=0.007*) and tanks (*F=43.8732; p=0.000*) at the water sources. This implies that the workers of LSAI farms that were located within <10 km radius, and had access to water sources, cleaned agrochemical residues that polluted water. Other activities that caused water pollution included livestock watering, washing of household utensils at the water sources and open defecation. Theses causes were not statistically significant as those who lived within 10 km radius (2.78% response) and 10-25 km radius (0% response) did not consider livestock watering as an activity that caused water pollution. Apart from these responses, 97.2% of the respondents who lived beyond 25 km radius from LSAI farms reported that livestock watering polluted the water sources.

A small proportion (8.33%) of the respondents who lived less than 10 km radius from the LSAI farms reported that washing of household utensils at the water source caused pollution while none (0% response) of them who lived 10-25 km radius from the LSAI farms indicated that washing of household utensils polluted water. The majority (91.67%) of the respondents who lived beyond 25 km radius from LSAI farms reported that washing of household utensils polluted water sources.

In terms of perceived changes in water quality in response to a question that sought a "yes" or "no" answer, a small proportion of the respondents (about 8%) who lived within a radius of < 25 km indicated that the water quality had declined and one of the village elders attributed the skin disease that affected her daughter in-law to use of the polluted water. The majority (about 92%) who lived beyond 25 km radius, concurred that the water quality had changed. In response to an open ended question on perceived water quality, 3% of the respondents who lived within < 25 km radius of the LSAI farms indicated that water quality had changed and the majority (97%) who lived beyond 25 km radius shared a similar view. There was a statistically significant relationship (χ^2=15.5772, P= 0.049) between perceived change in water quality and the distance of smallholder farming households' residences from the LSAI farms.

Other sources of water pollution reported by respondents, but were not statistically significant, included contamination of surface runoff by agrochemicals, use of rusted old water pipes, high concentration of users at a water source, sediments sucked into water pipes after a burst, and high concentration of chlorine used for water purification. A small proportion (16.7%) of the respondents who lived within < 10 km radius form LSAI farms reported that agrochemicals in surface runoff polluted water while none of the respondents who lived between 10-25 km radius did not consider contaminated surface runoff to pollute water. The majority (83.3%) of the respondents who lived >25 km radius mentioned that surface runoff laden with agrochemicals polluted water sources.

A small proportion (8.33%) of the respondents who lived within <10 km radius reported that high concentration of users at a water source caused water pollution. At the same time, none of the respondents who lived within 10-25 km radius reported that a large number of users at a water source was responsible for water pollution. About 92% who lived beyond 25 km radius stated that high concentration of users at a particular source polluted water. Less than 5% of the respondents who lived within 25 km radius mentioned that rusted water pipes, sediments sucked into burst pipes and high concentration of chlorine polluted the water. A large proportion (90-100%) felt that rusted water pipes, sediments sucked into burst pipes and high concentration of chlorine polluted the water.

Table 1

Causes of water pollution

Parameters	Distance between household home and water source				
	<10 km radius	10-25 km radius	>25 km radius	Statistic	P-value
Water access				**F-Value**	
Time taken to access water source (minutes)	2.59	3.78	3.09	3.44	**0.0332**
Perceived water quality (%)				**Chi-square**	
Water quality changes in relation to distance	6.18	1.69	92.13	3.0455	0.218
Perceived water quality changes	0.93	1.87	97.20	15.5772	**0.049**
Activities that polluted water (%)					
Livestock watering	2.78	0.00	97.22	2.7154	0.257
Washing household utensils at water source	8.33	0.00	91.67	1.5126	0.469
Open defecation	11.11	0.00	88.89	2.4283	0.297
Washing of agrochemicals from spray pumps	50.00	0.00	50.00	9.9992	**0.007**
Washing agrochemicals from spray tanks	100.00	0.00	0.00	43.8732	**0.000**
Other sources of water pollution (%)					
Agrochemicals in surface runoff	16.67	0.00	83.33	4.6846	0.096
High concentration of water users	8.33	0.00	91.67	0.7322	0.693
Rusted old water pipes	4.65	4.65	90.70	1.1765	0.555
Sucked-in sediments after water pipe burst	0.00	0.00	100.00	0.0720	0.965
High concentration of chlorine	0.00	0.00	100.00	0.2171	0.897

During key informant interviews, it was reported that the in Alingiri village, in Nwoya district where there are many LSAI farms, the water quality had declined. The key informants claimed that some of the residents suffered from skin diseases which they attributed to use of polluted water. During data collection, the LSAI farm workers were seen spraying crops with agro-chemicals that became a source of water pollution.

The LC 1 Chairman of Alingiri village also claimed that one of the LSAI companies washed agro-chemical residues from containers in one of the rivers on which dead fish and frogs were seen floating about 5 km downstream. It was also alleged that another company disposed agro-chemicals directly into River Nyamukino and polluted the water. However, further discussions with the community members revealed that the habit of LSAI companies to dispose agrochemicals into the river had reduced because the local community no longer complained about the practice as one of the causes of water pollution. During the interviews, the respondents stated that local community members who entered into agreements with LSAI companies to rent their land ensured that there was a clause to stop LSAI farms from polluting water used by humans and livestock.

Water quality parameters

In order to ascertain the pollution of River Nyamukino, results of the water quality tests presented in Table 2 were compared with the Uganda National Bureau of Standards (UBOS) potable water standards which is also aligned to International standards DUS ISO 24510:2007 (UNBS, 2019). Results revealed that all the tested parameters (except nitrites) were within the limits of the national potable water standards. This implies that the release of agro-chemicals from LSAI farms did not pollute River Nyamukino, as would be expected.

The pH and EC were determined in the laboratory and the values may not reflect field conditions. Water samples from all locations showed low levels of total dissolved solids. The levels of Biochemical Oxygen Demand (BOD5) and Chemical Oxygen Demand (COD) were indicative of trace amounts of oxygen demanding substances (organic matter) in the water. In addition, levels of BOD5 and COD were below the national effluent discharge standards (50 and 70 mg/L respectively). Levels of nutrients (Total phosphorus and ortho phosphorus) were minimal and suggested that application of fertilizers on the LSAI farms did not substantially pollute water. The levels of the following nutrients were below the national standards: potassium, nitrates and Ammonia. Samples 1, 2, A1, B1, and D1 had nitrite levels above the stipulated drinking water standards. Total nitrogen levels were also below the national standards for drinking water.

Table 2

Water quality parameters of River Nyamukino in Nwoya District

	Dry season sample				**Wet season sample**				
Sample ID Parameters	D1	D2	D3	D4	W1	W1	W3	W4	NDS
pH	8.09	7.68	8.32	8.37	7.32	7.18	7.39	7.05	6.5-8.5
EC (PS/cm)	198	166	174	184	96	97	99	90	1500
Total Dissolved Solids (mg/L)	160	132	142	142	94	82	68	84	700
BOD5 (mg/L)	nd	nd	nd	nd	nd	nd	nd	nd	ns
COD (mg/L)	nd	nd	nd	13	5	8	8	6	ns
Total Phosphorus (mg/L)	0.011	0.008	0.013	0.079	0.25	0.642	0.519	0.26	2.2
Ortho phosphorus (mg/L)	0.005	nd	0.005	0.032	0.115	0.322	0.257	0.132	ns
Potassium (mg/L)	nd	nd	nd	nd	0.03	0.01	0.02	0.94	ns
Nitrates (mg/L)	0.7	0.7	1.2	0.9	5.5	6.3	11.2	3.9	45
Nitrites (mg/L)	0.27	0.004	nd	nd	0.008	0.012	0.003	0.007	0.003
Ammonia (mg/L)	0.011	0.022	0.02	0.028	0.015	0.003	0.017	0.012	0.5
Total Nitrogen (mg/L)	nd	nd	nd	nd	0.81	1.02	1.08	0.4	ns

nd=not detected, National drinking water standards (NDS)

Despite the quality of water conforming to the UBOS' national water quality standards, there was a slight variation in the quantities of nutrients detected in the water samples obtained in the wet and dry seasons. The nutrient levels were slightly higher in the wet season implying that even if the water quality was not compromised, there was some level of pollution by inorganic fertilizers used on the LSAI farms.

There was a difference in the amounts of total phosphorus and nitrates detected in the water samples obtained in the dry and wet seasons. This is evidence of pollution although the amounts of nutrients are still generally too low. Potassium and total nitrogen were not detected in the dry season despite traces of them detected in the water samples obtained in the wet season. The amounts of ammonia, nitrites and orthophosphorus did not increase in the wet season.

Discussion

Access to safe drinking water is essential for health and it is a basic human right recognized by the United Nations Sustainable Development Goal (SDG) 6 (UNDP, 2015). Generally, availability of and access to safe water is critical for local community livelihoods in Africa (Bwire *et al.*, 2020). There is evidence that the populations of sub-Saharan Africa countries have the lowest access to safe drinking water (Santos *et al.*, 2017) and sanitation (Ohwo, 2019). Local people in Nwoya district depend on surface water for domestic and use and livestock watering and at the national level, 7% of Uganda's population depends on surface water (lakes, rivers, ponds) for domestic use (UBOS, 2012). These surface water sources are often vulnerable to contamination by human and livestock uses (Bwire *et al.*, 2020).

Apart from pollution by agro-chemicals applied on the LSAI farms that make water unsuitable for domestic and livestock use, there is also high risk of waterborne disease outbreaks in the communities (Pande *et al.*, 2018). Although it was not the main focus of the study, availability of adequate and safe water to the local communities is essential for prevention of enteric diseases in Nwoya district and access to safe drinking water is key to the wellbeing of the local communities. Water quality is defined in terms of physical, chemical and microbiological characteristics (Daud *et al.*, 2017). A less common but equally important parameter is the radiological characteristics that has not been examined in this study. In this research, 11 water quality parameters that are essential and impacts life were analyzed including pH, temperature, dissolved oxygen, conductivity and turbidity.

This study has revealed that the presence of LSAI in Nwoya district did not hamper local communities' access to water because the farms did not enclose the water sources contrary to reports by Sidibé & Williams (2016) in Mozambique and Zaehringer *et al*. (2021) in Kenya that LSAI farms denied local communities water use rights. Studies undertaken in Uganda and Madagascar by Cassivi *et al*. (2018) reported that local communities took 30 minutes to access water but this study found that members of the smallholder farming households took 3 minutes to access water and this improved with proximity to the LSAI farms. The study also revealed different time periods taken to reach water sources which varied from 2.6 to 3.8 minutes. However, these time differences were not proportionate to the distances covered to reach the water sources as the small holder farming households and the water sources were scattered within the 25 km radius. LSAI farms in Nwoya district use the water for spraying crops and did not compete for water with the local communities. LSAI companies also constructed boreholes that supplied drinking water for the adjacent households. This is an obligation stipulated in the land rent contracts signed by the investors and the local communities.

Although livestock watering did not have a statistically significant relationship with change in water quality, it is common knowledge that location of livestock farms near water bodies causes pollution. In this study, respondents who lived beyond 25 km radius from LSAI farms reported that livestock watering polluted water. This finding indicates that farmers who lived close to LSAI farms did not engage in livestock rearing unlike those who lived far away and reared livestock because land was available and watering the animals polluted water. Studies have shown that when livestock is concentrated in a particular place, they produce wastes that pollute surface water and groundwater (Mateo-Sagasta *et al.*, 2017). At the same time, location of livestock farms has been reported to pollute water sources by increasing the quantities of suspended materials, nitrates and phosphates (Cesoniene *et al.*, 2019). These substances decrease the pH and make surface water acidic. However, pollution of surface water is often more felt downstream than upstream which according to Chen *et al*. (2022) is over 20 km from the water source.

There was no statistically significant relationship between open defecation and water quality change and yet studies by Harris *et al*. (2017) and Okaali *et al*. (2021) reported that open defecation affects surface water quality by introducing fecal pathogens that affect human health. In the context of good hygiene practice, LSAI farms have provided boreholes to supply safe drinking water. However, there is a need for local community leaders to work with public health officials to encourage the community members to construct pit latrines and stop open defecation that affects human health.

In Uganda, the water coverage levels are considered to be low, and according to Naiga *et al.* (2015) national safe water coverage is estimated at 66% with 42% coverage in rural areas. This implies that rural communities utilize limited sources of water that are available to them and this can result in a high concentration of users gathered at one water source and cause pollution. This challenge is compounded if the same water sources are also used by livestock as reported in this study. Therefore, there is a need for long-term local collective action guided by national policy to increase rural communities' access to diverse and adequate sources of water in Nwoya district as this would help to reduce the concentration of users at few water sources and also minimize pollution. To ease access to water and minimize pollution in areas surrounding LSAI farms, it is important for government and development planners to take into account distance to a water source, time spent to collect water, water availability and water quality because, as reported by Aikowe and Mazancová (2021), these are critical determinants of local communities' choice of water source.

The farmers reported that rusted pipes, burst pipes that suck in sediment and high concentration of chlorine caused water pollution. This problem can be overcome by establishing a local community water users' committee whose roles and responsibilities would entail overseeing the operation and maintenance of water infrastructure and water quality. In this way water quality will be secured and the sources collectively owned, managed and used by the communities. To ensure sustainable water resources use, there is need for local community water users' committee to monitor the operations and functionality of the water infrastructure and to leverage the expertise of local mechanics to undertake regular repairs as reported by Nyaga (2020).

The local communities perceived that water quality had deteriorated since the arrival of LSAI in Nwoya district similar to a report by Zaehringer *et al*. (2021) based on a study undertaken in Kenya. Decline in water quality poses a risk to human health. Veolia and IFPRI (2015) reported that 1 in 3 people are likely to face a high risk of water pollution by 2050 from increased amounts of nitrogen and phosphorous and 1 in 5 people will be exposed to a high risk of water pollution due to increased levels of biochemical oxygen demand (BOD5) with dire consequences on human health. Furthermore, the perceived decline in water quality revealed by this study was linked to the fact that LSAI farms use herbicides and insecticides for crop protection and the chemicals pollute water hence making it unsafe for humans and livestock. Although application of agrochemicals is essential for ensuring crop health (Devi *et al*., 2022), they cause negative health and environmental effects (Nicolopoulou-Stamati *et al*., 2016). In view of this, there is need to pursue organic farming as an alternative cleaner and safer practice of food production guided by policies that emphasize drastic reduction in the use of agrochemicals.

Other than boreholes, the local people also used water from rivers and streams. However, the streams and rivers are vulnerable to pollution by agro-chemicals used on the LSAI farms. Reports by UNEP (2016); Khan *et al*. (2017) and Scanlon *et al*. (2007) affirm that continuous application of fertilizers and pesticides reduces water quality. The laboratory water quality test established that the water quality conforms to the national standards contrary to the above reports. However, there were variations in the amounts of nutrients between the wet and dry seasons that need to be investigated further and the cause established. A similar finding on seasonal disparity in water quality was reported by Huang *et al*. (2019) who attributed it to changes in land use and land cover caused by agricultural activities.

Local communities reported prevalence of a skin disease which they attributed to application of agrochemicals on the LSAI farms. In a study of large scale agricultural investments in Zimbabwe, Bwenje *et al*. (2017) reported disease outbreaks due to polluted local water sources. To address this challenge, there were efforts made by local leaders in Nwoya district in collaboration with the investors to reduce on the problem of water contamination.

Conclusions

This study provides empirical insights into the impacts of LSAI on water access and water quality in Nwoya district. The LSAI did not affect local communities' access to water because the water sources were not enclosed and the community members could access them in a short time within 25 km radius. The local communities that lived within 25 km radius did not feel that water quality changed unlike those who lived beyond this radius. Farmers who lived beyond 25 km radius reported that livestock watering and high concentration of users at water source polluted water which was perceived to cause health risks to the communities. The majority of farmers who lived beyond 25 km radius mentioned that open defecation was one of the main causes of water pollution. This presupposes that the local communities that lived far away from the LSAI farms lacked pit latrines for human waste disposal although the budget framework paper for Nwoya district local government for the financial year 2021/20222 indicates that pit latrine coverage in the district is 88% (Nwoya District Local government, 2020) and open defecation would not be a major environmental health concern.

Furthermore, the application of agro-chemicals on LSAI farms polluted water and the pollution was linked to prevalence of skin disease among some local community members. Apart from skin diseases, there is also high risk of waterborne disease outbreaks in the communities that use polluted water. Availability of adequate and safe water to the local communities complemented by boreholes provided by the investors is, therefore, essential for prevention of the alleged skin disease and other related waterborne diseases in Nwoya district. Studies are needed to establish the cause-effect relationship between agro-chemical pollution of water sources and the skin disease to guide future LSAI on-farm application of agro-chemicals.

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