Smallholder farmers' perceived evaluation of agricultural drought adaptation technologies used in Uganda: constraints and opportunities

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Abstract

Many smallholder farmers in semi-arid areas continue to face increasing threats of agricultural drought exacerbated by a rapidly changing climate. This calls for increased understanding of farmers' drought response experiences and perceptions for better agricultural production. This study assessed the smallholder farmers' perceived evaluation of drought adaptation technologies, constraints and opportunities in drought prone districts of Uganda. A cross-sectional survey was conducted using semi-structured questionnaires. The evaluation indicators of the technologies included efficiency, effectiveness, equity, acceptability, urgency and institutional compatibility performance measures. The findings show that among the irrigation technologies, drip irrigation systems were the most efficient, effective, acceptable and urgent performance measures ($p<0.05$). The rainwater harvesting technologies used were perceived to be significant for all the considered performance measures ($p<0.05$). In the agroforestry category, agrisilviculture and agrosilvopastoral were significant ($p>0.05$) for the assessed indicators. The significant constraints were unreliable rainfall, high technology operational costs, limited labour and technical support ($p<0.05$). This study reveals that market prices, efficient use of water, improved labour and time saving are important for adoption and use of drought adaptation technologies. This study provides insights for policy and development planning processes geared towards drought risk reduction measures that are either structural or non-structural.

Keywords

Drought, Adoption, Adaptation, Irrigation, Rainwater Harvesting, Agroforestry, Uganda

Acknowledgement

This study was financially supported by USAID and implemented through FHI 360 and Makerere University Centre for Climate Change Research and Innovations (MUCCRI). We highly acknowledge a team of dedicated research assistants who collected data in the nine study districts. Great thanks also go to the local government officials who introduced us to study sub-counties in respective districts.

Declaration of interest statement
No potential conflict of interest was reported by the authors.

Author contributions

David

Conceptualized and led the process of research design, data collection and management

Bernard

Led the process of analysis and text compilation and also participated in research design

Nicholas

Participated in research design and review

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Data collection and manuscript drafting

John Paul

Data collection conceptualization

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Abstract

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1. Introduction

Drought is a major problem facing agricultural production in semiarid regions of the world (Mir et al., 2012; Lipiec et al., 2013; Stanke et al., 2013; Rolli et al., 2015; Guo et al., 2019). Globally, historical records of precipitation and drought indices show increased aridity since 1950 (Dai, 2013). Drought is further expected to increase in frequency and severity in the future as a result of climate change (Sheffield et al., 2012; Trenberth et al., 2014). Drought can reduce crop yield by as much as 50% (Sapeta et al., 2013) and limit water supply in agriculture (Tabari et al., 2012; Kasim et al., 2013). The prevalence of drought conditions over the last 50 years has significantly contributed to increased demand for water in the agricultural sector (Reyhani et al., 2017). Drought and water scarcity pose enormous impacts on the livelihood and welfare of farmers highly dependent on natural resources (Eslamian & Eslamian, 2017). Tropical agricultural areas bear more crop yield losses associated with drought episodes (Teixeira et al., 2013).

Droughts and prolonged dry spells are common in Uganda's semiarid areas (Ogwang et al, 2012; Barasa et al., 2013). Overall drought episodes have been on the increase leading to crop failure, and human and livestock mortality, among others (Akwango et al., 2016). Maize production has been the most affected especially in the parts of south west, north and north eastern, mid-western and central Uganda (Epule et al., 2017). Smallholder farming is among the most vulnerable livelihood systems due to its great social and economic sensitivity (Lindoso et al., 2014; Sietz et al, 2012). Droughts are largely responsible for food and nutritional insecurity in many of such areas of Uganda (Nabikolo et al., 2012; Sabiiti et al., 2018).

Although water stress threatens sustainable agricultural production, evidence shows that agrarian societies can overcome the associated constraints through building socio-ecological resilience (Eslamian & Eslamian, 2017; Maleksaeidi et al., 2017; Reyhani et al., 2017). This can be achieved through development, adoption, evaluation and learning from adaptation technologies necessary to reduce drought risk for improved production and livelihoods of smallholder agriculture dependent rural communities (Teixeira et al., 2013; Bhargava & Sawant, 2013). In this study, drought adaptation technologies refers to "the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change" (UNFCCC, 2005). Rainwater harvesting (RWH) is one of the technologies that hold significant potential for improving rainwater-use efficiency and sustaining agricultural production (Biazin et al., 2012). In addition, agroforestry (in home and forest gardens) has been used to adapt to drought because of its dynamic, ecological and natural resource management benefits (Nguyen et al., 2013; Atangana et al., 2014). Such technologies can easily be supported and widely adopted to improve food security and incomes of the rural poor because of the associated equity, acceptability and productivity benefits in semiarid land agriculture (Kahinda & Taigbenu, 2011).

In East Africa, smallholder farmers have generally utilised short season crops, drought-resistant crops, irrigation, and tree planting to adapt to realised and potential negative impacts of drought (Komba & Muchapondwa, 2012; Okonya et al., 2013; Nyaga et al., 2015; Mfitumukiza et al., 2017a). However, cultural factors and perceptions shape how people adopt interventions, and their motivation to respond to drought (Adger et al., 2013). Option selection from available drought adaptation technologies by farmers has been associated with performance measures such as efficiency, effectiveness and equity, (Molden & Gates, 1990; Gorantiwar & Smout, 2005; Mendicino et al., 2008). Other considerations are technology constraints such as finance which affect farmers' access to adequate supply of quality inputs (Mdemu et al., 2017). Moreover, use of drought adaptation technologies such as expansion of smallholder irrigation face a number of challenges including; land tenure issues, lack of access to appropriate technologies, credit services, research support, poor irrigation water management, poor extension systems, and the over-dependence on national governments, Non-Governmental Organisations and donors for support which is usually not consistent (Barbier & Tesfaw, 2013; Nakawuka et al., 2017).

Understanding prevailing opportunities that can facilitate improvement of access to and use of appropriate drought adaptation technologies is important for adoption and upscaling of such efforts. For example, rainwater harvesting in South Africa is founded on government buy-in and the knowledge gathered for over 15 years of RWH research (Kahinda & Taigbenu, 2011). As a result, there is a more efficient distribution of water supported by "free of charge" required infrastructure available for farmers to use varied rainwater harvesting technologies (Hatibu et al., 2006). In Tanzania, rainfall variability, runoff quality and quantity, local skills and investment capacity, labour availability and institutional support have been found to be significant in influencing sustainability of rainwater harvesting systems for drought management (Pachpute et al., 2009). On the other hand, agroforestry, has been easily adopted in many areas due to its low-cost, minimal input requirements, and the diversity of immediate benefits (Inocencio et al., 2003; Kiptot & Franzel, 2012).

It is apparent that smallholder farmers use a range of drought adaptation rainwater harvesting, agroforestry and irrigation technologies. However, there is scanty evaluation based information, especially on farmers' perceived performance of such technologies' intervention outcomes. Yet, perceptions and attitude are important in determining the processes and actions aimed at dealing with drought including for technologies and strategies (Knowler and Bradshaw, 2007). In addition, location specific information on the constraints and opportunities prevalent on the use of drought adaptation technologies (rainwater harvesting, agroforestry and irrigation) does not explicitly exist. Only single drought adaptation technologies have been investigated by most researchers with very limited comparison basis across available options (Gorantiwar & Smout, 2005; Rodrigues et al., 2009). Such information is important in guiding farmers and those involved in supporting them to manage drought risk to either deal with such perceptions or support interventions that are likely to be adopted. Therefore, the purpose of this study is to specifically increase understanding around performance of selected drought adaptation technologies used in Uganda based on farmers' experiences and perceptions. The objectives were to: 1) evaluate the drought adaptation technologies (irrigation, rainwater harvesting and agroforestry) used by smallholder farmers, and 2) ascertain the opportunities and constraints to the use of drought adaptation technologies.

2. Study area and methods

2.1 Study area description

This study was conducted in nine districts of the south-western, central and mid-western regions of Uganda. Most parts of these regions lie in the semiarid belt of Uganda, often referred to as the 'cattle corridor' (Figure 1). The nine districts covered included: Hoima, Isingiro, Kiboga, Luweero, Masaka, Mubende, Nakaseke, Nakasongola and Sembabule. The districts were chosen because of their proneness to drought and their characteristic erratic rainfall distribution in space and time

(Zziwa et al., 2012; Nimusiima et al., 2013, Twongyirwe, et al. 2019; Kakeeto et al. 2019; Nakabugo et al., 2019). Rainfall is highly variable and sporadic with mean annual rainfall ranging between 500 mm and 1,600 mm (Makuma-Massa et al., 2017; Turyagyenda et al. 2013). Generally, rains are usually expected during the months of March to April and September to November of each seasonal calendar year. The average temperatures range from 25°C to 30°C. The potential evapotranspiration in the area remains high throughout the year (~130 mm/month and ~1586 mm/annum). The area is characterized by intermittent drought episodes (Akwango et al., 2016; Akwango et al., 2017; Makuma-Massa et al., 2017). The area is known for the historical reliance on nomadic pastoralism as a strategy to cope with climate variability (Makuma-Massa et al., 2012; McGahey & Visser, 2015; Chaplin et al., 2017; Egeru et al., 2019).

The cultivatable soil layer is mainly composed of pale-yellow fine sands (Gleyic arenosols) common in Nakasongola district; yellow-red clay loams (Dystric Regosols) in Hoima and Isingiro, reddish brown sandy loams (Petric Plinthosols) in Nakaseke and yellow-red loams (Acri Ferralsols) common in Luwero District. The central districts are characterized with central plateau lying between 1000m and 1400m above sea level; while the southern districts are topographically characterized by gentle hilly slopes, low land areas and steep hills (1800 meters above sea level). Metamorphic rock type spreads astride all the districts characterized by undifferentiated gneisses, argillites and arenites with some basal meta calcareous rocks (Taylor and Howard, 1998).

The area is mainly covered with bushlands and thickets, savannah grasslands, wetlands, and woodlands. Fresh water lakes and rivers of international importance drain the districts (Brian et al., 2009). The notable lakes include Lakes Victoria, Wamala, Albert, Kyoga, and Nakivale. Rivers include Rugaga, Katonga, Mayanja, Sezibwa, Kafu, Nkuse, and others. Agriculture is the main economic activity for most of the households (Francis & James, 2003). Subsistence rain fed crop growing and livestock rearing characterize the landscape. The key crops grown include maize, bananas, coffee, beans, cassava, etc. Livestock includes cattle, goats, sheep, pigs and poultry, among others. The secondary sources of income include fishing, formal employment, and small-scale businesses.

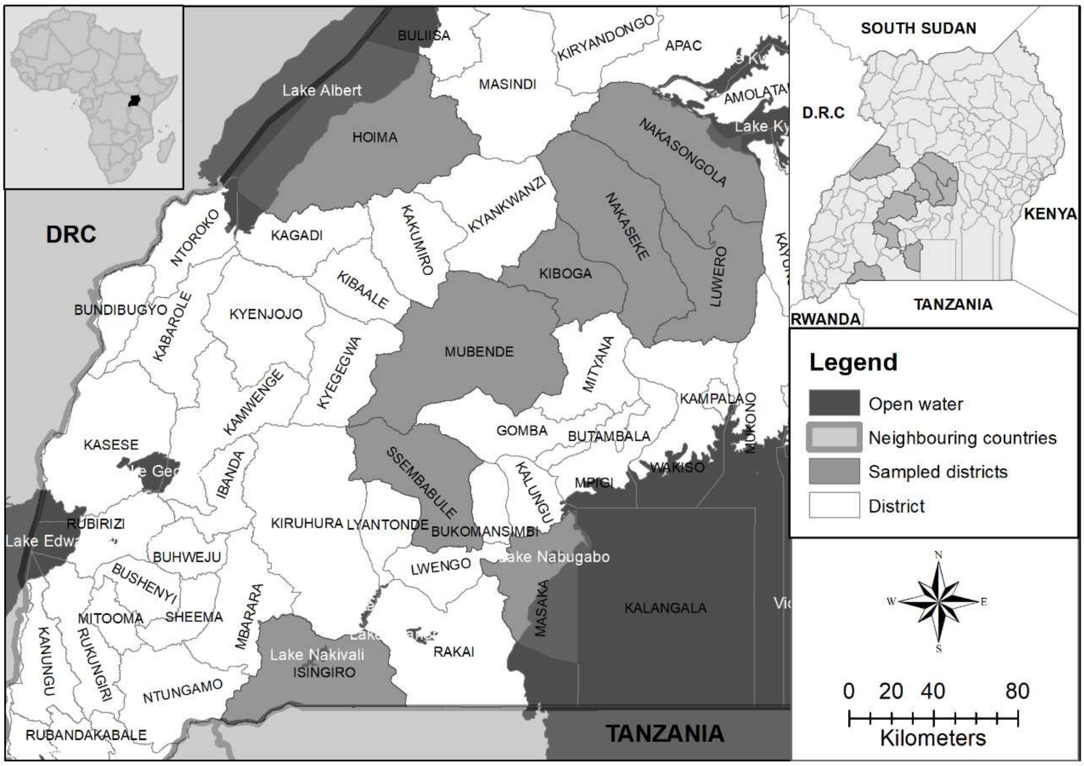

Figure 1: Location of study area

2.2 Methods

A holistic technological evaluation was used in this study covering planning, implementation and assessment aspects (Gorantiwar & Smout, 2005). The evaluation of technologies used by the smallholder farmers was based on performance indicators/measures including efficiency, effectiveness, equity, acceptability, urgency and institutional compatibility. These indicators appropriately defined the aims farmers attached to the adoption of drought adaptation technologies over the years. The evaluated drought adaptation technologies were categorised into major and sub categories prior to their evaluation. Irrigation was subcatergorised as drip, sprinkler, watering cans, treadle pumps, solar pumps. Rainwater harvesting technologies were sub grouped as valley dams, valley tanks, surface and subsurface water tanks; while agroforestry as silvopastoral, apiculture, agrisilviculture and agrosilvopastoral.

Table 1: Description of performance indicators/measures

Performance indicators	Description
Efficiency	Assessment of the costs, benefits, risks and timeline of the technology
Effectiveness	Achievement of drought adaptation goals and objectives
Equity	Effects and benefits of the technology for the different social groups
Acceptability	Technology acceptance in society
Urgency	Period taken to implement the required technology

Institutional compatibility	Technology supported by the institutions (government, civil, local and local communities)

To understand the perceived evaluation of drought adaptation technologies, a cross-sectional survey was carried out using a questionnaire administered at household level. In addition, key informant interviews and focus group discussions were also undertaken. This study was conducted between July and October of 2017. The smallholder farmers involved in the study were selected using multi-stage sampling design, from district, sub-county, parish and village administrative strata. The household survey focused on understanding the past and current utilisation and experiences with drought adaptation technologies. A total of 461 smallholder farmers was randomly and proportionally sampled from the target population in the selected villages (Bartlett et al 2001). The questionnaire targeted data and information on drought adaptation technologies, perceived evaluation of the technologies, constraints and opportunities. Gender inclusive focus group discussions comprising of 10-15 farmers who included elders, youths and community leaders were conducted to supplement information obtained using the questionnaire (Kumar et al., 1993; Grootaert, 2004).

Purposively selected key informants were interviewed and their responses recorded. The interviewees were selected based on expected knowledge, experience and insights on responding to drought impacts, water for production and awareness of the technologies practiced by farmers/households in the study districts. Those selected included climate change champions (community-based agents of climate change adaptation information dissemination), district environment and/or /natural resources officers, representatives of non-governmental organisations involved in promoting drought adaptation technologies.

3. Results

3.1 Socio-economic and Farm characteristics of respondents

Table 2 below shows the characteristics of the smallholder farmers that were interviewed. On average, the respondents' age ranged between 40 and 50 years. The majority of the respondents were generally literate. This study also found out that most of the interviewed farmers were farming on freehold, customary and leasehold, mostly, individually owned land tenure. Most of the interviewed farmers had been engaged in smallholder farming (crop growing and rearing of livestock – animals and birds) for an average of 22 years. Majority of the respondents were married, and on average each household had 7 members.

Table 2: Socio-economic and farm characteristics

Social-economic/farm characteristics		**N=461, n (%); Mean**								
Sampled districts		Hoima N=51	Isingiro N=51	Kiboga N=56	Luweero N=50	Masaka N=50	Mubende N=52	Nakaseke N=50	Nakasongola N=50	Sembabule N=51
Respondent age		46.4	45.1	39.7	41.1	41.9	38.1	46.3	50.1	44.1
Family size		7.2	6.5	6.3	6.9	7.2	6.4	7.6	10.8	7.3
	Female	25(49)	31(60.8)	31(55.4)	22(44)	18(36)	30(57.7)	24(48)	21(42)	22(43.1)
Gender	Male	26(51)	20(39.2)	25(28.8)	28(56)	32(64)	22(42.3)	26(52)	29(58)	29(56.9)
Marital status	Co-habiting	36(70.6)	0	30(5.4)	24(48)	0	12(23.1)	0	0	1(2)
	Divorced	1(2)	0	1(1.8)	0	0	0	3(6)	0	1(2)
	Married	6(11.8)	50(98)	38(67.9)	13(26)	40(80)	31(59.6)	41(82)	45(90)	41(80.4)
	Separated	4(7.8)	0	4(7.1)	4(8)	0	1(1.9)	0	1(2)	1(2)
	Single	4(7.8)	1(2)	6(10.7)	4(8)	10(20)	6(11.5)	0	0	2(3.9)
	Widowed	0	0	4(7.1)	5(10)	0	2(3.8)	6(12)	4(8)	5(9.8)
Education levels	No-formal	11(21.6)	7(13.7)	2(3.6)	1(2)	2(4.0)	7(13.5)	6(12)	0	4(7.8)
	Primary	20(39.2)	24(47.1)	19(33.9)	17(34)	21(42)	26(50)	31(62)	33(66)	27(52.9)
	Secondary	13(25.5)	18(35.3)	26(46.4)	26(52)	18(36)	16(30.8)	13(26)	17(34)	17(33.3)
	Tertiary	7(13.7)	2(3.9)	9(16.1)	6(12)	9(18)	3(5.8)	0	0	3(5.9)
Farm characteristics										
Land tenure	Mailoland	0	0	1(1.8)	44(88)	0	0	5(10)	8(16)	5(9.8)
	Freehold	25(49)	31(60.8)	39(69.6)	6(12)	50(100)	31(59.6)	6(12)	0	17(33.3)
	Leasehold	8(15.7)	3(5.9)	1(1.8)	0	0	5(9.6)	2(4)	42(84)	26(51)
	Customary	17(33.3)	17(33.3)	13(23.2)	0	0	0	37(74)	0	3(5.9)
	Public	1(2)	0	2(3.6)	0	0	16(30.8)	0	0	0
Years involved in farming (mean)		26.6	27.3	19.3	18.8	18.4	23.2	22.2	34.1	25.2
Cultivated land owned (acres)		16.7	4.8	6.9	13.8	5.6	3.8	4.6	12.1	5.6
Cultivated land rented (acres)		6.4	3.3	4.6	3.4	5.3	1.2	0.2	4.0	2.0
Number of family labour used on cropped own land		1.2	1.0	1.0	1.0	1.0	1.2	1.0	1.0	1.0
Number of hired labour used on cropped own land		1.5	1.6	1.8	1.4	1.1	1.5	1.5	1.8	1.6
Number of labour on grazing land		1.9	1.9	2.0	1.9	2.0	1.9	2.0	2.0	2.0
(acres)		17.5	3.8	5.9	10.0	1.2	1.6	1.3	6	1.5

3.2 Drought adaptation technologies

Table 3 below, shows results of the non-parametric signed rank sum test for the level of use of different drought adaptation technologies in the study area. Watering cans, drip irrigation, valley dams, surface water tanks, sub-surface water tanks and agrisilviculture were the most significant drought adaptation technologies utilized by the farmers ($p<0.05$). Under irrigation, watering cans were the most used followed by drip irrigation, sprinklers, treadle and solar pumps. Among the rainwater harvesting systems, valley dams were the most utilized technologies. Surface water tanks were the most utilized followed by sub-surface water tanks. For the agroforestry based technologies, agrisilviculture and agrosilvopastoral were the most used technologies.

Table 3: Distribution of drought adaptation technologies in the study area

Category	Sub category	(%, n=461)									Signed rank sum test
	Districts	Hoima	Isingiro	Kiboga	Luweero	Masaka	Mubende	Nakaseke	Nakasongola	Sembabule	P-value
Irrigation	Drip irrigation	26	25	15	24	4	0	14	45	0	0.0156*
	Sprinkler	11	0	7	8	15	0	0	0	0	0.1250
	Watering cans	63	75	70	48	81	100	81	55	96	0.0039*
	Treadle pumps	0	0	7	16	0	0	5	0	4	0.1250
	Solar pumps	0	0	0	4	0	0	0	0	0	0.9999
Rainwater harvesting	Valley tanks	19	0	13	17	17	0	62	2	100	0.0156*
	Surface water tanks	74	100	48	48	43	55	22	84	0	0.0078*
	Valley tanks	4	0	29	28	26	0	7	0	0	0.0625
	Subsurface water tanks	4	0	9	7	13	45	9	14	0	0.0156*
Agroforestry	Agrisilviculture	21	100	84	74	100	88	100	100	86	0.0039*
	Silvopastoral	0	0	3	0	0	8	0	0	2	0.9999
	Apiculture	0	0	0	5	0	4	0	0	5	0.9999
	Agrosilvopastoral	79	0	13	21	0	0	0	0	7	0.1250

* = Significant at 5% significance level

3.3 Evaluation of drought adaptation technologies

Table 4 below, shows results of the perceived usability and performance evaluation of drought adaptation technologies based on efficiency, effectiveness, equity, acceptability, urgency and institutional compatibility criteria. For irrigation category, watering cans and sprinklers were the significant drought adaptation technologies based on the performance measures. Efficiency, effectiveness, acceptability and urgency were the most significant performance measures for drip irrigation ($p<0.05$). For the use of treadle pumps, efficiency, equity, acceptability and urgency were the significant performance measures ($p<0.05$). The rainwater harvesting technologies (valley dams, valley tanks, surface and sub-surface water tanks) used were perceived to be significant for all the considered performance measures ($p<0.05$). In the agroforestry category, agrisilviculture and agrosilvopastoral had the significant ($p>0.05$) performance measures. Overall, rainwater harvesting and irrigation related drought adaptation technologies were rated highly because of wider usability and high performance.

Table 4: Evaluation of drought adaptation technologies (irrigation, RWH and agroforestry)

Category	Sub category	Performance measures					
		Efficiency	Effectiveness	Equity	Acceptability	Urgency	Institutional compatibility
Irrigation	Drip irrigation	0.013*	0.002*	0.401	0.039*	0.034*	0.067
	Sprinkler	0.001*	0.001*	0.028*	0.015*	0.001*	0.019*
	Watering cans	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
	Treadle pumps	0.048*	0.060	0.020*	0.025*	0.020*	0.457
	Solar pumps	0.411	0.411	0.411	0.411	0.411	0.411
Rainwater harvesting	Valley dams	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
	Surface water tanks	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
	Valley tanks	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
	Sub-surface water tanks	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
Agroforestry	Agrisilviculture	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
	Silvopastoral	0.532	0.93	0.532	0.470	0.470	0.532
	Apiculture	0.329	0.559	0.564	0.246	0.554	0.114
	Agrosilvopastoral	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*

Notes: * = Significant at 5% significance level

3.4 Constraints to the use of drought adaptation technologies

The correlation Table 5, reveals that out of 17 constraints reported by respondents, the high technological operational costs, limited labour, limited information on technologies, water scarcity, limited technical support, unreliable rainfall, inadequate funds and scarcity of materials were the significant perceived constraints ($p<0.05$) that hindered use of drought adaptation technologies. Other constraints included resource use conflicts, vandalism, nature of soils, limited storage capacity, limited accessibility, land fragmentation, sub-standard technologies, land tenure and price fluctuations. Use of watering cans and drip irrigation were the most constrained irrigation related drought adaptation technologies. Performance and usability for the of irrigation category was primarily constrained by sub-standard technologies, limited labour, scarcity of materials, high operational costs, limited storage capacity, price fluctuations, water scarcity and inadequate funds (Figure 2). For rainwater harvesting, most of constraints were around valley dams and surface water tanks. The perceived constraints included: limited accessibility, resource use conflicts, limited storage capacity, unreliable rainfall, water scarcity and vandalism (Figure 3). On agroforestry, agrisilviculture and Agrosilvopastoral systems stood out as the most constrained drought adaptation technologies. The major constraints that hampered the use of agroforestry related technologies included land fragmentation, land tenure, limited information on the use of the technology and scarcity of materials (Figure 4).

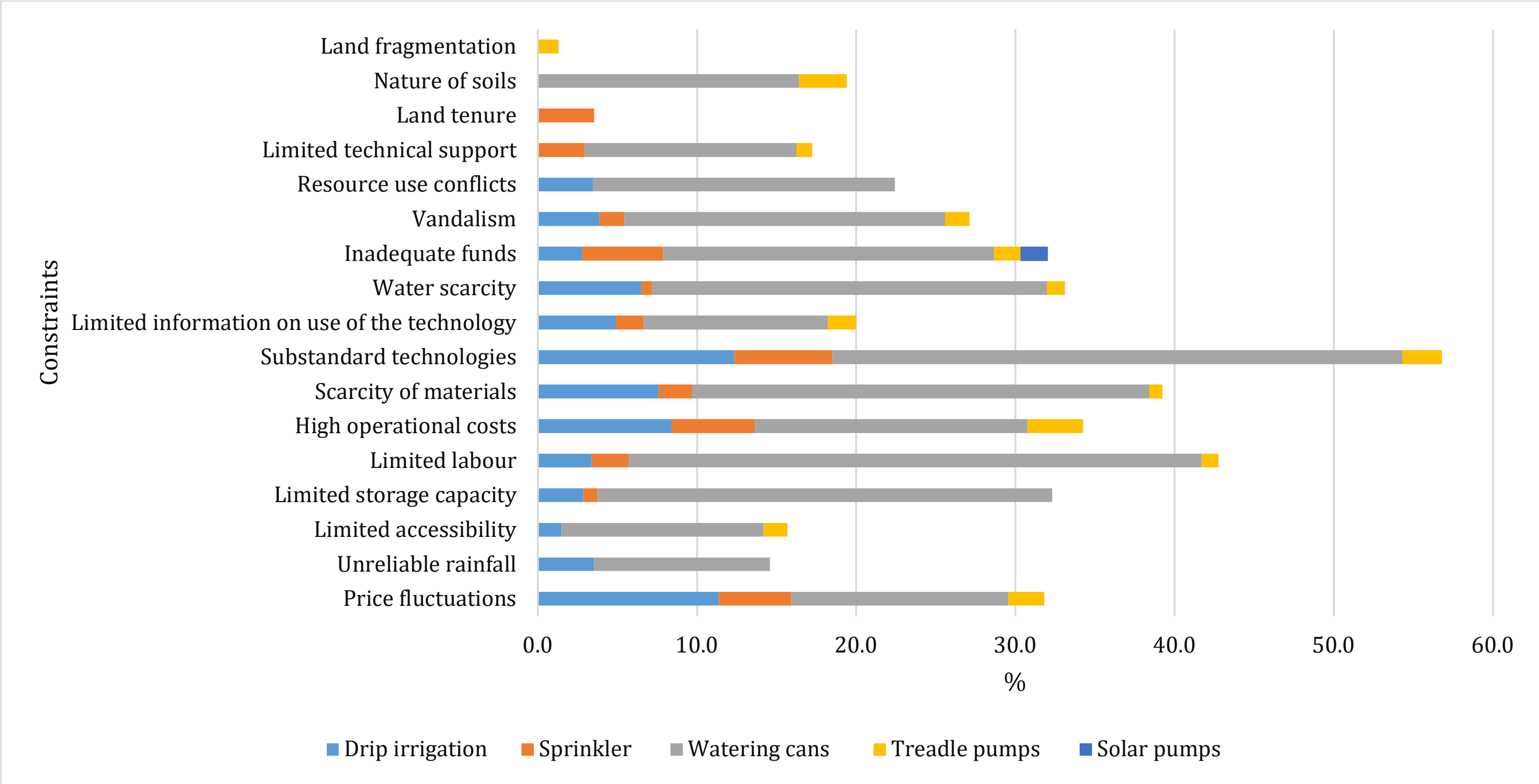

Figure 2: Constraints in the use of irrigation drought adaptation technologies

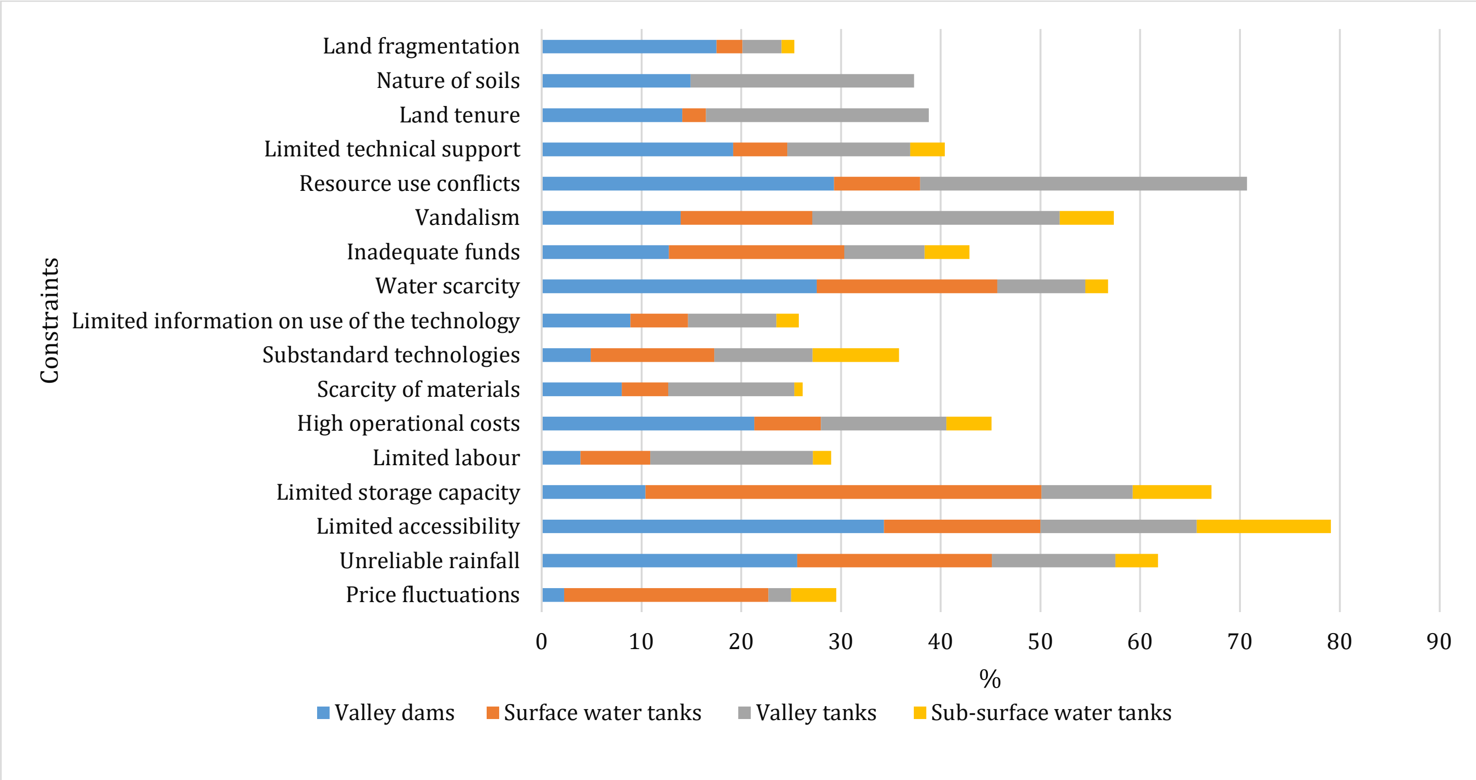

Figure 3: Constraints in the use of rainwater harvesting drought adaptation technologies

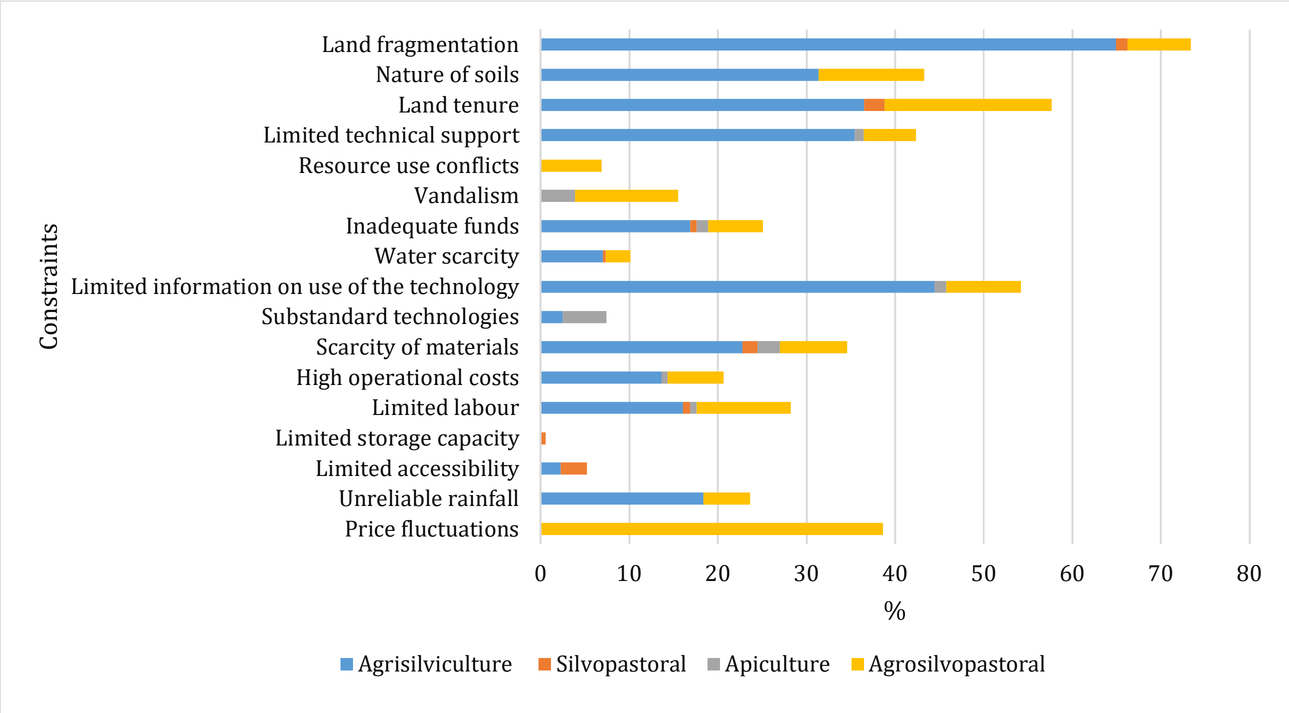

Figure 4: Constraints in the use of agroforestry drought adaptation technologies

1		0.885	0.933	0.847	0.917	0.875	0.771	0.781	0.825	0.723	0.628	0.730	0.755	0.518	0.576	0.388	0.497
2	0.885		0.939	0.943	0.865	0.887	0.904	0.895	0.663	0.587	0.828	0.426	0.513	0.582	0.429	0.539	0.382
3	0.933	0.939		0.875	0.849	0.858	0.817	0.888	0.742	0.632	0.712	0.574	0.567	0.450	0.550	0.458	0.393
4	0.847	0.943	0.875		0.781	0.887	0.821	0.894	0.730	0.659	0.760	0.495	0.457	0.467	0.510	0.545	0.528
5	0.917	0.865	0.849	0.781		0.860	0.837	0.725	0.737	0.635	0.608	0.605	0.741	0.708	0.394	0.548	0.352
6	0.875	0.887	0.858	0.887	0.860		0.857	0.749	0.664	0.609	0.616	0.611	0.529	0.438	0.532	0.452	0.524
7	0.771	0.904	0.817	0.821	0.837	0.857		0.761	0.547	0.544	0.818	0.359	0.515	0.675	0.246	0.632	0.227
8	0.781	0.895	0.888	0.894	0.725	0.749	0.761		0.692	0.558	0.758	0.394	0.391	0.393	0.440	0.518	0.269
9	0.825	0.663	0.742	0.730	0.737	0.664	0.547	0.692		0.885	0.500	0.700	0.613	0.340	0.513	0.337	0.506
10	0.723	0.587	0.632	0.659	0.635	0.609	0.544	0.558	0.885		0.373	0.727	0.586	0.206	0.648	0.133	0.597
11	0.628	0.828	0.712	0.760	0.608	0.616	0.818	0.758	0.500	0.373		0.068	0.349	0.618	0.033	0.588	-0.003
12	0.730	0.426	0.574	0.495	0.605	0.611	0.359	0.394	0.700	0.727	0.068		0.793	0.053	0.796	0.021	0.505
13	0.755	0.513	0.567	0.457	0.741	0.529	0.515	0.391	0.613	0.586	0.349	0.793		0.500	0.471	0.240	0.136
14	0.518	0.582	0.450	0.467	0.708	0.438	0.675	0.393	0.340	0.206	0.618	0.053	0.500		-0.250	0.785	0.006
15	0.576	0.429	0.550	0.510	0.394	0.532	0.246	0.440	0.513	0.648	0.033	0.796	0.471	-0.250		-0.207	0.527
16	0.388	0.539	0.458	0.545	0.548	0.452	0.632	0.518	0.337	0.133	0.588	0.021	0.240	0.785	-0.207		-0.015
17	0.497	0.382	0.393	0.528	0.352	0.524	0.227	0.269	0.506	0.597	-0.003	0.505	0.136	0.006	0.527	-0.015	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Table 5: Correlation table (Spearman rank correlation - non-parametric)

Key: 1=Water scarcity; **2**=Limited information on use of the technology; **3**=High operational costs; **4**=Limited labour; **5**=Unreliable rainfall; **6**=Inadequate funds; **7**=Limited technical support; **8**=Scarcity of materials; **9**=Resource use conflicts; **10**=Vandalism; **11**=Nature of soils; **12**=Limited storage capacity; **13**=Limited accessibility; **14**=Land fragmentation; **15**=Substandard technologies; **16**=Land tenure; **17**=Price fluctuations

3.5 Opportunities for drought adaptation technologies

Table 6 shows opportunities for uptake and use of drought adaptation technologies. These include availability of water (runoff and rivers), technological accessories, and cheaper technological options. The availability of water was perceived to be an important opportunity for the use of watering cans, valley dams and surface water tanks. The availability of materials was perceived to play an important role in the use of watering cans and agrisilviculture. The presence of cheaper options was perceived to be an opportunity for the use of watering cans, surface water tanks and agrisilviculture. Availability of technical support was considered to be an important opportunity for using valley dams and agrisilviculture. The farmers reported that there were a number of policies that favoured use of valley tanks, valley dams and agrisilviculture. Availability of government/development partners (e.g. Food and Agriculture Organization) funding was perceived to be an opportunity for construction and use of valley tanks, valley dams and surface water tanks. Some farmers also considered land availability to be an opportunity for the use of agrisilviculture, watering cans, valley dams and Agrosilvopastoral. Agrisilviculture, valley dams and use of watering cans had the highest number of perceived opportunities for adoption and use.

Table 6: Opportunities for drought adaptation technologies

Opportunities	Drip irrigation	Sprinkler	Watering cans	Treadle pumps	Solar pumps	Valley dams	Surface water tanks	Valley tanks	Sub-surface water tanks	Agri-silviculture	Silvo-pastoral	Apiculture	Agro-silvopastoral	Signed rank sum test
Availability of materials and accessories	1.5	0.6	25.1	0.2	0.4	15.8	12.4	9.6	3.2	23.9	0.0	0.6	6.8	0.0005*
Availability of cheaper technological options	0.7	0.0	21.4	0.0	0.0	4.8	21.8	17.4	4.5	24.1	0.0	0.9	4.4	0.0039*
Availability of technological support	0.3	0.3	17.3	0.2	0.2	27.3	9.5	4.0	3.2	31.7	0.0	1.8	4.2	0.0005*
Availability of inputs	2.9	0.6	34.3	0.0	0.0	3.5	6.9	2.6	4.9	38.6	0.0	1.4	4.3	0.0020*
Favourble policies	1.9	0.0	15.3	0.0	0.0	24.8	10.8	17.2	4.5	19.1	1.3	1.3	3.8	0.0030*
Availability of funding	1.1	0.0	16.8	0.2	0.0	39.7	5.0	4.6	2.4	27.5	0.9	1.3	0.4	0.0010*
Tax exemptions	0.0	0.5	13.6	0.5	0.0	24.3	14.6	18.4	3.4	13.6	1.9	3.4	5.8	0.0040*
Availability of communal land	3.2	1.5	23.8	0.0	0.2	10.7	6.1	4.1	3.9	32.8	1.9	1.2	10.5	0.0005*

Note: The values are presented as percentage of responses
* = Significant at 5% significance level

4. Discussion

4.1 Socio-economic and Farm characteristics

This study considered smallholder farmers' social economic characteristics to be important determinants of the extent to which adaptation technologies can be used to realize the desired performance outcomes. The smallholder farmers' average age ranged between 40 and 50 years. Age is an important factor that can influence the use of drought adaptation technologies because it is a primary latent characteristic in the choice of use decisions (Akudugu et al., 2012). The working age group is able to sustain the usability of drought adaptation technologies on their farmlands. On the other hand, the size of a household determines the use of labour-intensive technologies. For example, Nakaseke, Sembabule, Masaka and Hoima which had the highest numbers of household members (seven to ten) were using more labour-intensive technologies such as watering cans and agrisilviculture than other districts. The majority of the respondents were literate. Reimers & Klasen (2013) argued that literate and educated farmers on average are more willing to use new drought adaptation technologies and therefore have a first-mover advantage.

Land tenure is also an important factor that influences smallholder farming practices including use of drought adaptation technologies (Byenkya et al., 2014; Mayanja et al., 2015). This study found out that most of the interviewed farmers settled on land owned through freehold, customary and leasehold land tenure systems. Farmers perceive these systems to have provided secure land access and use. Sebukyu & Mosango (2012) show that higher levels of personal land ownership contribute to the use of agroforestry systems to promote long-term agricultural production systems. However, this finding is in contrast with Amone & Lakwo (2014) who reported that customary land ownership is positively related to agricultural underdevelopment such as the low implementation of practices, leading to food insecurity. The average land owned by individual smallholder farmer in the study area was above the Uganda national average of 1.2 acres. Farmers who owned the largest pieces of cultivatable land were from Hoima (16.7 acres), Luweero (13.8 acres) and Nakasongola (12 acres). Availability of relatively more land presents an opportunity for uptake and use of drought adaptation technologies as was similarly expressed during interviews and group discussions.

4.2 Drought adaptation technologies

The use of watering cans, agrisilviculture, surface water tanks, drip irrigation, valley dams, sub and surface water tanks were the most significant drought adaptation technologies utilized. This finding in view of rainwater harvesting and irrigation is to some extent surprising because of the limited capacity and size of catchments, storage capacity of technologies and the unreliable amount of rainfall received as was established during data collection. The rainwater harvesting and irrigation systems are the most preferred drought adaptation technologies. However, the availability and demand of rainwater harvesting and irrigation systems are known to be affected by both changes in temperature and evapotranspiration in such areas (Kurukulasuriya & Rosenthal, 2013).

In the rainwater harvesting systems, valley dams were the most highly utilized technologies. The districts directly receive local government support for excavating valley dams to facilitate smallholder farming. Valley dams were perceived to be more reliable because the water does not easily dry out. This was dependent on the main economic activity, and as such dams were mainly found to be preferred in districts that are predominantly rainfall dependent, such as Nakasongola, Nakaseke, Sembabule and Isingiro. The dams were also perceived to be easily accessible and can be utilized by a large number animals. Agrisilviculture was the most utilized agroforestry practice in most of the districts. The higher uptake of agroforestry adaptation technologies is attributed to immediate benefits (food and firewood), availability of cultivatable land, government support (provision of tree seedlings). According to focus group discussions, the technologies were perceived to be significant contributors to promoting smallholder farming activities throughout the year.

4.3 Evaluation of drought adaptation technologies

Watering cans and sprinklers were considered to be the most important drought adaptation technologies based on the assessed performance measures (efficiency, effectiveness, equity, acceptability, urgency and institutional compatibility). The watering cans are widely used by the farmers because of the low acquisition cost, easy use and time saving. Zziwa & Kabirizi, (2015) also a reported similar finding that watering cans are widely adopted in Uganda`s farming systems because of time and labour saving. The sprinklers were highly adopted because of the availability of water from river diversions and their water use efficiency. Discussions with farmers generally showed that they perceived mobile sprinkler systems can be easily moved within the field and not labour intensive. They also considered farming based on sprinkler irrigation to be profitable. Similarly, Drechsel et al. (2006) also argue that farmers involved in year-round irrigation can earn twice more than those engaged in rainfed farming.

Efficiency, effectiveness, acceptability and urgency were the most significant performance measures considered by farmers for drip irrigation. Related findings were also reported by Nyasimi et al. (2016) in their study in Nakasongola District where they reported the importance of drip irrigation in vegetable growing during drought. Kabirizi et al. (2014) in their study in Masaka District found out that the application of goat, cattle and poultry manure with drip irrigation significantly increased cabbage yield. For the use of manual treadle pumps, efficiency, equity, acceptability and urgency were the most significant performance measures. The equity and acceptability could be attributed to the fact that the technology used is supported by government and non-governmental Organisations. Similar observations were made by Nakawuka et al. (2017), that in East Africa, the use of certain technologies such as treadle pumps was mainly creating a positive impact because of wide ranging support by national governments, NGOs and donors. A study in a similar semiarid environment in Nigeria by Tambo & Abdoulaye (2013) also found out only 4% of the surveyed farmers used some form of irrigation inclusive of treadle pumps for better agricultural productivity and production. The use of solar pumps was least valued because the technology is inaccessible, has limited technical support and expensive to purchase and maintain for an ordinary smallholder farmer. This is also in regard with the findings of Giordano & Clayton (2012) who found out in Tanzania that the motor pumps provide the best return when used to irrigate during drought, however, most farmers lack the technical expertise to use and maintain their pumps.

The use of valley dams, valley tanks, surface and sub-surface water tanks had significant and positive perceived performance on efficiency, effectiveness, equity, acceptability, urgency and institutional compatibility. These technologies are widely spread and highly supported by the Ugandan government through agricultural and drought adaptation programmes since 1986

(Wanyama et al., 2017). The tanks are major sources of water for both smallholder farming and domestic water uses. Similar observations have been reported by Mfitumukiza et al. (2017b); Zziwa et al. (2012) in Uganda's dryland areas. However, Wanyama et al. (2017) in their review of irrigation and rainwater harvesting systems in Uganda argue that such water resources are at risk of degradation because of rapid urbanisation, industrialisation, water pollution and poor land use practices. A similar report was made by Wandiga (2015) in his study of critical water issues in Africa.

In the agroforestry category, agrisilviculture and agrosilvopastoral had the most significant perceived positive performance on efficiency, effectiveness, equity, acceptability, urgency and institutional compatibility. Higher farmer awareness of agroforestry benefits and distribution of tree seedlings by various organisations, government and development partners are among factors that could be responsible for such high level of perceived importance. Sebukyu & Mosango (2012), in their study carried out in Masaka district in Uganda, show that agrosilvopasture, agrosilviculture and silviculture were among the most preferred agroforestry systems by smallholder farmers. These agroforestry systems were more preferred because of the multiple benefits such as food, fodder, erosion control and soil fertility enrichment (Zake et al. 2015; Abebe et al., 2013; and Tumwebaze et al, 2013) in Uganda and Ethiopia. Siriri et al. (2013) found out that the success of agroforestry in semi-arid areas depends on efficient use of available water and effective strategies to limit tree/crop competition and maximise productivity.

4.4 Constraints to drought adaptation technologies

Despite benefits of using drought adaptation technologies, a range of constraints are experienced by the smallholder farmers. This study found out that high operational costs, limited labour, limited information on accessibility and availability of adaptation technologies, water scarcity, limited technical support, unreliable rainfall, inadequate funds and scarcity of materials were the most significant constraints that hindered realization of the desired outcomes of using the drought adaptation technologies.

The irrigation technologies were primarily constrained by sub-standard equipment, limited labour, scarcity of materials, high operational costs, limited water storage capacity, unstable prices of technologies, water scarcity and inadequate financial resources. Capital constraint stand out to limit farmers from investing in irrigation technologies. This finding is consistent with what was reported by Burney et al. (2013) in the Sub-Saharan Africa; Namara et al. (2014) in Ghana and Nakawuka et al. (2017) in East Africa., Xie et al. (2014) emphasise that irrigation technological expansion amongst farmers largely depends on costs and commodity price developments. Rainwater harvesting technologies were primarily constrained by limited accessibility to the technology and its accessories, water resource use conflicts, limited water storage capacity of harvesting options, unreliable rainfall, water scarcity and vandalism of infrastructure. Land tenure issues, communal technological ownership and prolonged droughts were found to be important factors in the usability of rainwater harvesting technologies.

4.5 Opportunities for drought adaptation technologies

There are opportunities for adoption and use of irrigation, rainwater harvesting and agroforestry drought adaptation technologies. These include availability of water sources (runoff and rivers), technological accessories, cheaper technological options, among others. Specifically, the availability of water sources was perceived to be an important opportunity for the use of watering cans, valley dams and surface water tanks. The country's bimodal rainfall pattern, and terrain have favoured the use of these technologies because runoff is the main source of water into valley dams and tanks (Turyagyenda et al. 2013).

Agrisilviculture, valley dams and use of watering cans had the highest number of perceived opportunities by the respondents. Treadle pumps, solar pumps registered the least consideration for opportunities of adoption and use. Results from focus group discussions showed that interest by government in the technologies was the main explanation for these perceived opportunities. Studies by Furley (2000); Muhereza (2001); Inselman (2003) show that the Ugandan government has provided basic smallholder crop and livestock infrastructure to support such technologies including valley dams and dip tanks.

5. Conclusions

This study has enriched our understanding of drought adaptation technologies used in Uganda, their considered value by farmers and the prevailing challenges and opportunities to drought risk management. . The use of watering cans, drip irrigation, valley dams, surface water tanks, sub-surface water tanks and agrisilviculture are the most significant perceived high performance drought adaptation technologies. Rainwater harvesting (valley dams, surface water tanks, valley tanks, sub-surface water tanks) and irrigation (drip irrigation, sprinkler, watering cans, treadle pumps, solar pumps) related drought adaptation technologies are perceived to be associated with high level of performance. The major constraints that limited the use of drought adaptation technologies are: the high operational costs, limited labour, limited information on use of the technologies, water scarcity, limited technical support, unreliable rainfall, inadequate funds and scarcity of materials. Generally, the availability of water, technology materials and respective accessories, cheaper technological options, technical support, and funding were the most considered important opportunities for drought adaptation technologies by the farmers.

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