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Characterisation of ecosystem-based adaptations to drought in the central cattle corridor of Uganda§

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Ecosystems provide climate-change adaptation opportunities including ecosystem services, adaptation benefits and livelihood improvement especially for natural resource dependent communities. To contribute to the understanding of location specific adaptation processes of predominantly agro-pastoralists, a study was carried out in the central cattle corridor of Uganda to characterise ecosystem-based drought Adaptations. A cross sectional survey using semi-structured questionnaires, focus group discussions and key informant interviews were employed among 183 randomly selected households. The ecosystem-based adaptations (EbAs) to perceived drought impacts were characterised basing on ecosystem services, adaptation benefits to drought and livelihood improvement categories unveiling the different proportions of each EbA under each category. Water shortage and intense heat were the major perceived drought impacts. The use of drought resistant shade trees, water reservoirs and dams, and alternative ecosystem-based livelihoods were the majorly utilised EbAs. The alternative ecosystem-based livelihoods were the mostly used EbA dominating all the three categories. The utilisation of drought resistant shade trees dominated the ecosystem services and adaptation benefits categories, whereas the use of water reservoirs and dams were the mostly used EbA for livelihood improvement. These EbAs should be incorporated in climate-change adaptation policies and initiatives, while considering their subsequent dominating categories to enhance farmers' resilience.

Keywords: agro-pastoral farming, adaptation benefits, biodiversity, climate change, livelihood, rangeland

Introduction

The global climate is continuously changing and becoming variable, which is posing a serious threat to the natural resources, livelihoods, social and economic development most especially in developing countries (Westerman et al. 2012; Intergovernmental Panel on Climate Change 2012). Climate change and variability in Uganda is for example manifesting through unreliable rainfall, severe and more frequent droughts that are negatively affecting agricultural productivity and livestock production (Zake et al. 2010). Uganda is ranked as one of the most unprepared and vulnerable countries in the world in respect to drought and its impacts (Zake and Hauser 2014). Drought, defined by prolonged moisture deficiency, is a climate change hazard that is perceived to be triggered by anthropogenic practices like deforestation, swamp reclamation, overstocking of livestock among others (Mfitumukiza et al. 2017a). Besides having unpredictable access to pasture and water in their rangeland ecosystem, Uganda´s agro-pastoralists in the central cattle corridor are even more vulnerable to drought impacts because they are unable to access information and respond in a timely and appropriate manner including planning and using technologies that may be available (Zake et al. 2015; Waiswa et al. 2019). In addition, the presence of several policies and programs does not provide an effective safety net for these farmers against drought risks, which policies could miss addressing such climate change effects, because of inadequate policy implementation, because of limited resources allocation and logistics to support effective service delivery at different levels (UNDAC 2008; NDP 2010).

Amidst the many constraints, agro-pastoralists in the rangeland areas try out various actions and innovations to enhance their resilience and adaptation to drought (Adger et al. 2003). The IPCC (2014) defines adaptation as the process of adjustment to actual or expected climate and its effects. In addition, adaptation refers to the initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects (IPCC 2014). The agro-pastoral farmers therefore may opt for drought adaptation strategies like sale of livestock, construction and use of water from boreholes, use of inorganic fertilisers for subsistence farming among others (Mfitumukiza et al. 2017a; Waiswa et al. 2019). Such adaptation strategies may be limited in terms of cost and sustainable ecosystem management (Mfitumukiza et al. 2017a). Other adaptation strategies could be derived from the existing ecosystems for their cost effectiveness and availability (Osano et al. 2013; IPCC 2014). Ecosystem services are known to be foundational for many successful

§ Submitted for consideration in the Special Issue: Droughts in South African savannas adaptation and resilience strategies especially for agro-pastoralists (Rao et al. 2007). The agro-pastoral farmers utilise ecosystem services, as well as biodiversity, as part of an overall adaptation strategy to negative impacts of climate change including drought. This adaptation strategy, known as ecosystem-based adaptation (EbA) has proved to be one of the most effective and sustainable adaptation strategy for farmers to climate change including drought (Convention on Biological Diversity 2009; Munang et al. 2014). EbA involves sustainable utilisation of ecosystems and biodiversity to help agro-pastoral farmers adapt to climate change effects including drought (Munang et al. 2014; Mfitumukiza et al. 2017a).

EbA may also involve sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural benefits for local communities (CBD 2010). EbA approach provides a basis for harnessing natural resources for ecosystem services and adaptation benefits to climate change impacts, as well as livelihood improvement for farmers (Uy and Shaw 2012; Vignola et al. 2015). For example, in Kenyan Masailand, the sustainable management of grasslands and rangelands to enhance pastoral livelihoods and the conservation of wildlife habitats is one example of EbA reported to be utilised in the rangeland that can provide multiple benefits. These multiple benefits include socio-cultural (recreation and tourism), economic (income for local communities), and biodiversity (forage for grazing animals and wildlife habitats) (CBD 2009; Osano et al. 2013). In Nakasongola district, an agro pastoral region in the cattle corridor of Uganda, some of the EbA practices reported during drought are fresh water and grassland ecosystem utilisation (Mfitumukiza et al. 2017a). The former provides alternative livelihood sources for farmers through provisioning ecosystem services like water, fish and craft raw materials, whereas the later enhances pasture availability for the livestock (Mfitumukiza et al. 2017a). The sustainable availability of ecosystem services from different ecosystems reduces on time and cost of living among the agro-pastoral households. The preceding examples of EbA not only reveal the relevance of EbA to climate change adaptation, but also the utilisation of the ecosystem services, as well as livelihood improvement of the agro-pastoral farmers.

The few studies on EbA that are available have proved it to be an effectual and sustainable climate change adaptation strategy for agro-pastoral farmers (Munang et al. 2013; Munang et al. 2014; Vignola et al. 2015; Mfitumukiza et al. 2017a). Results from these studies reveal the opportunities of EbA use that include biodiversity conservation, improvement and or maintenance of farm production, buffering of biophysical impacts of climate change, increase of food security and livelihood diversification. More importantly, it is best that EbA practices are based on ecosystem services, adaptation benefits to drought and improvement of livelihoods of farmers (Vignola et al. 2015). It is on this basis that this study sought to specifically characterise the ecosystem-based adaptations used in response to perceived drought impacts in the central cattle corridor of Uganda. The study attempted to address the following questions: What are the perceived impacts of drought on agro-pastoral farmer households? What are the ecosystem-based adaptations used to respond to the perceived drought impacts? How are these EbAs to perceived drought impacts characterised basing on ecosystem services, adaptation to drought and livelihood improvement of the agro-pastoral farmers? The information from this study highlights the ecosystem-based adaptations that agro-pastoral farmers could use to enhance their resilience and adaptive capacity to drought impacts, in order to optimise sustainable production in their agro-pastoral farming systems.

Materials and methods

Study area

The study was conducted in the central cattle corridor of Uganda where changes in climate have been reported including drought (National Environment Management Authority 2010). According to the Uganda National Climate Change Policy (2015), the cattle corridor of Uganda reportedly receives less rainfall compared to the rest of the country, therefore resulting in water stress challenges (Ministry of Water and Environment 2015). In terms of climate, there is usually a dry season from June to July and December to February of every year, though these have been fluctuating with time (Mfitumukiza et al. 2017b). The rainfall in the central cattle corridor has decreased, become less reliable and unevenly distributed, resulting in stressed agricultural landscapes (NEMA 2010). In addition, there are fluctuating temperature patterns in the central cattle corridor that have been linked to drought and consequent increment in cattle deaths (Ministry of Water and Environment 2015). There is also low ground water supply in the central cattle corridor, which is exacerbated by drought, therefore affecting agricultural production (NEMA 2006). The population growth in the central cattle corridor results in farm insecurity, as people struggle for land, as well as putting pressure on the existing ecosystems, thereby increasing their vulnerability to climate change and variability (Department of Relief, Disaster Preparedness and Mangement 2016). According to Rugadya (2006), the cattle corridor is majorly a rangeland providing a diversity of habitats and land uses including livestock forage, wildlife habitat, water, wood products, recreation and natural beauty. Rangelands are customarily communal cattle grazing areas characterised by pastoralism with varying intensity depending on the culture. However, because of population increase, a variety of socio-economic activities has brought about some changes in the cattle corridor (Rugadya 2006). For instance, more land has been opened up for crop farming, including the marginal areas, consequently making the rangeland ecosystem fragile with low and unreliable rainfall coupled with sparse vegetation cover (Rugadya 2006).

Ddwaniro and Lwamata subcounties, located in Kiboga (Figure 1), a rural district in the central cattle corridor region of Uganda, were purposively selected because they were the mostly drought stricken areas at the time of the study. In addition, they were predominantly occupied by livestock and crop farmers, respectively (FAO 2016). Kiboga is originally a pastoral region, but upon a reconnaissance study it was discovered that there were some crop farming activities dominating Lwamata. In the study area's pastoral production system, mobility in search of water and fodder was initially an

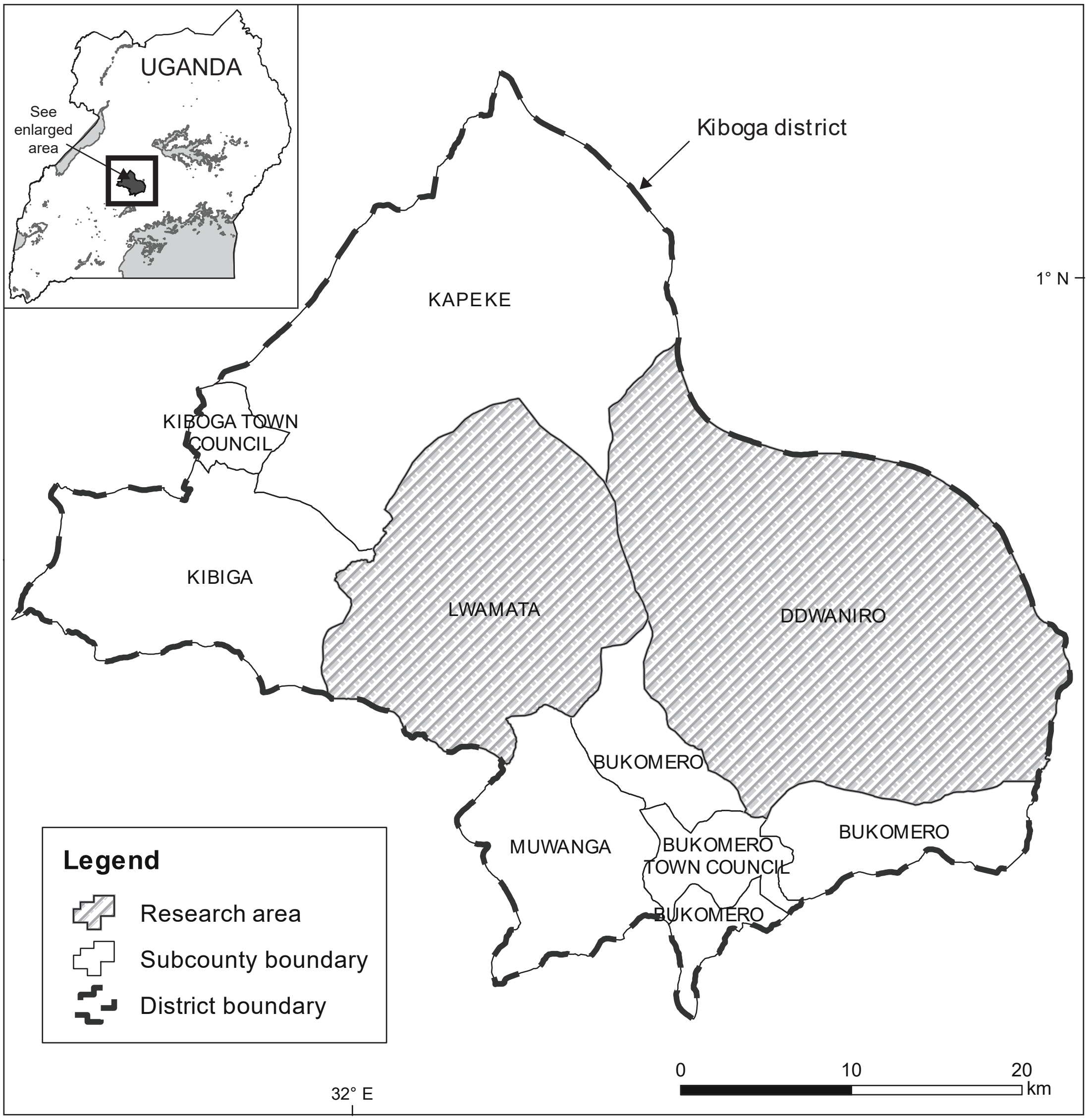

Figure 1: Map of Kiboga district showing the location of the study subcounties

exclusive survival strategy for the farmers and their livestock (Ruhangawebare 2010). However, most pastoralists have settled and started growing crops though livestock farming remains their major source of basic needs of milk, meat, income and savings. The agro-pastoral farmers not only graze their livestock on communal land in the rangeland, but also give them crop residues. Nevertheless, they move the livestock in the dry season in search of fodder and water (Ruhangawebare 2010). This history of agro-pastoralism reveals the relevance of ecosystems to such natural resource dependent communities. The study area's selection therefore was based on aforementioned farming predominance, which would help to obtain information about the ecosystem-based drought adaptations from both livestock and crop farming.

Sampling and data collection

The sample size (n = 183) was derived based on the approach of Roscoe (1975) that provides a proportionate sample size to that of the overall population in a location. Data were collected using a mixed method approach using semi-structured questionnaires, key informant interviews and gender specific focus group discussions. A reconnaissance study was conducted to test the questionnaire and obtain prior information that could be essential in data collection. For instance, it was found out that some crop farming activities were dominating Lwamata subcounty despite the pastoral nature of the study area. Such information could be vital in providing EbAs among crop farmers in an originally pastoral region. Considering the study area's low literacy levels, guided interviews using the questionnaires were conducted to allow establishment of trustworthiness with the respondent hence providing validation of the responses (Morton 2007; Mbolanyi et al. 2017). The questionnaires sought to obtain information on the socio-demographic characteristics of the respondents, perceived drought impacts and the possible ecosystem-based adaptations they used to adapt to the drought impacts. The questions on the perceived drought impacts in the questionnaire were under the humans, crop and livestock categories. The EbAs used to adapt to the impacts also followed the same categories so that specific responses were obtained for humans, crop and livestock. Each of the questions had responses from which the respondents would choose from with an opportunity of mentioning any other impact or EbA if they existed and were not among those in the questionnaire. The respondents were interviewed from their randomly sampled homesteads, in order not to interfere with their work. The household head was the major target of the interview although the spouse offered the immediate alternative in the event that the former was absent. The questionnaires were administered to the randomly selected households using the local language of the region. In case of language barrier, a field guide known in the area was used as an interpreter.

To supplement that information and ensure quality control check of the collected data, four focus group discussions and five key informant interviews were conducted. The focus group discussions were gender specific to allow free sharing of information and were conducted from both subcounties (two in Ddwaniro and Lwamata, respectively). For both subcounties, the representative group of either males or females were selected with the help of the subcounty veterinary (Ddwaniro) or agricultural (Lwamata) officer. Each group had five to ten participants. The key informants were purposively selected basing on their farming experience, knowledge of EbA and leadership position in Ddwaniro and Lwamata (Marshall 1996). They included the Kiboga district environment officer, two local government council leaders (one from Ddwaniro and another from Lwamata), one veterinary officer from Ddwaniro and one agricultural officer from Lwamata).

Data analysis

All the data that were collected in the questionnaire was first coded and entered into SPSS software. Then the perceived drought impacts on the farmers (humans), crops and livestock were categorised following the four classifications of drought i.e. meteorological, agricultural, hydrological and socio-economic (Keyantash and Dracup 2002; Yuan and Zhou 2004; Mishra and Singh 2010). The frequencies of all the perceived drought impacts were obtained and transferred to Excel software. The frequency of each perceived drought impact was expressed as a percentage of the overall total of all frequencies. The perceived drought impacts were presented according to the classified drought types in percentages (Figure 2).

The coded responses on the EbAs used to adapt to the perceived drought impacts were entered in SPSS software. The mean and frequency of each EbA were obtained first. The frequency of each EbA was expressed as a percentage of the overall total of all frequencies. All these (percentages and mean) were presented in Table 3. The ecosystem-based adaptations were then characterised according to the model documented by Vignola et al. (2015). With reference from this model, each of the EbAs was classified based on three categories i.e. ecosystem services, adaptation benefits to drought and livelihood improvement of agro-pastoral farmers. For instance, if there was a response to why an EbA was used in a given household and it corresponded with the description under the 'based on ecosystem services' category, as described in Table 1, then the frequency of that response would be put under that 'based on ecosystem services' category of that EbA. The same frequency tallying would be done for 'provides adaptation benefits to drought' category and 'improves the livelihoods of agro-pastoral farmers' category of that particular EbA. The aforementioned frequency tallying analysis was applied for the rest of the EbAs obtained proportionate to the three EbA categories, as described in Table 1. The frequency of each response in a given category was expressed as an overall percentage of all responses in that respective category.

Results

Socio-economic characteristics of agro-pastoral farmers

The results reveal that the majority of the interviewed respondents were female (60.1%) who mainly carried out both crop and livestock farming (63.4%), a practice 83.2% of them learned through indigenous knowledge transfer. On average, a household had 6.0 ± 3.31 persons with an average crop and livestock acreage of 3.63 ± 8.51 and 5.91 ± 18.29 acres, respectively (Table 2).

Perceived drought affects on the agro-pastoral farmers

The most prevalent drought impact perceived by the agro-pastoral farmers was water shortage (15.3%) an agricultural impact followed by intense heat (13.7%) a meteorological impact, affecting the farmers themselves. The least perceived drought impacts were farm insecurity, which includes theft and straying of livestock (0.7%) and reduced income (1.0%) both of which are socio-economic impacts (Figure 2).

Characterisation of ecosystem-based adaptations in response to perceived drought impacts based on ecosystem services, adaptation benefits to drought and livelihood improvement

The results reveal that the agro pastoral farmers majorly utilised ten ecosystem-based adaptations to adapt to the perceived drought impacts (Table 3) with the mostly used being drought resistant shade trees (20%), water reservoirs and dams (19%) and alternative ecosystem-based livelihoods (18%). The least ecosystem-based adaptations utilised by the agro-pastoralists included use of cover crops and mulching (4%), rotational grazing within rangeland (3%) and use of already established drought resistant live fences (2%).

Table 4 shows how the ecosystem-based adaptations (each in response of the perceived drought impacts) were characterised based on ecosystem services, adaptation to drought and livelihood improvement categories. The drought resistant shade trees (33%) and the alternative ecosystem-based livelihoods (25.1%) were the mostly used EbAs based on ecosystem services. Similarly, the use of drought resistant shade trees (32.9%) and alternative ecosystem-based livelihoods (19.6%) were the mostly utilised EbAs for providing adaptation benefits to drought. The alternative ecosystem-based livelihoods (25.8%) and use of water reservoirs and dams (19.5%) dominated the livelihood improvement category (Table 4).

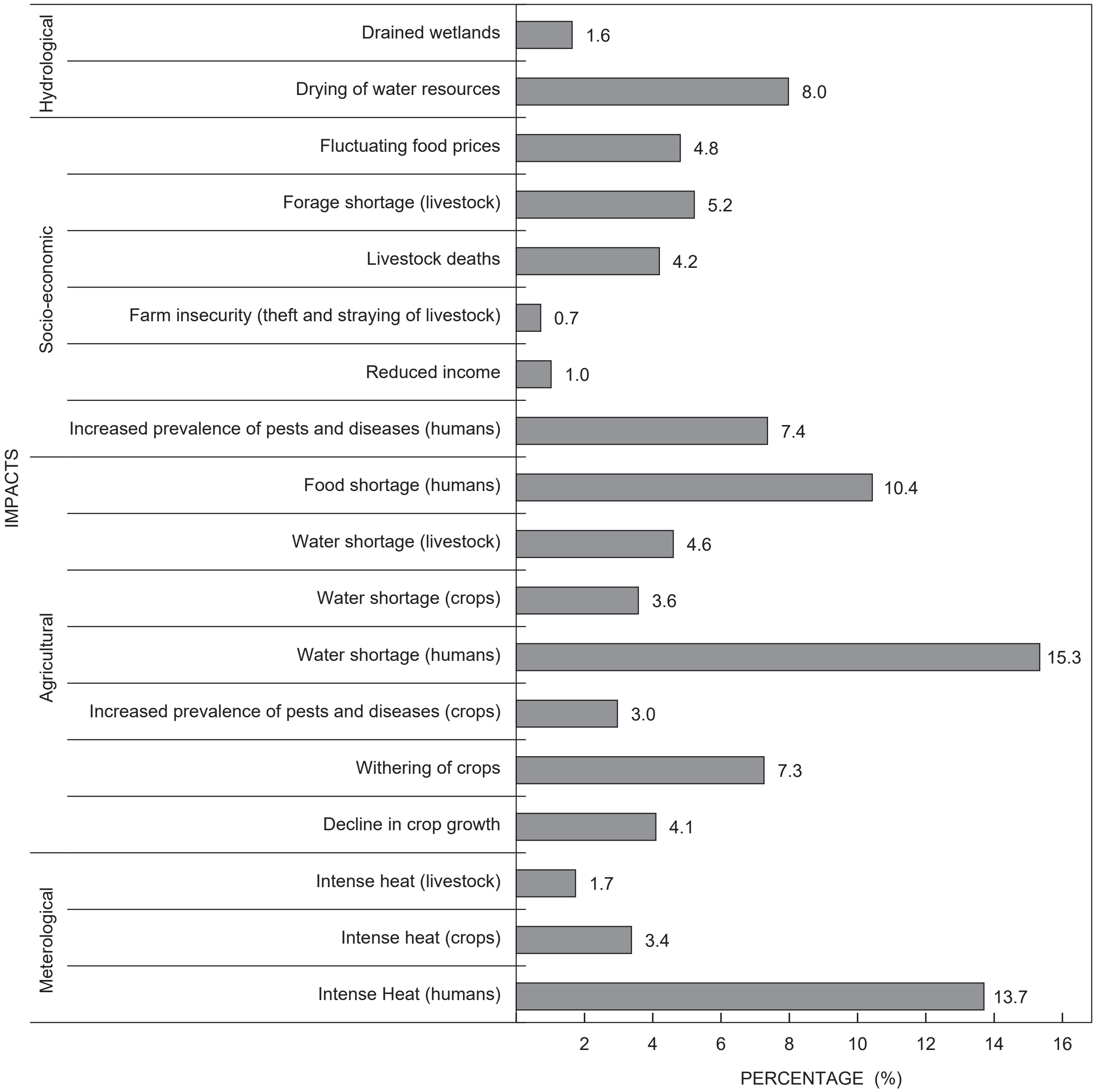

Figure 2: The perceived drought impacts on the agro-pastoral farmers

Discussion

Socio-economic characteristics of agro-pastoral farmers

The socio-economic characteristics of the agro-pastoral farmers in the central cattle corridor depict their vulnerability and adaptive capacity at household level. All the sampled households were highly dependent on farming. Despite the study area being an originally pastoral region, the majority of the farmers practiced both crop and livestock farming mainly using indigenous knowledge transferred to them by their ancestors. This indicates that there has been a shift from pastoral to agro-pastoralism in the central cattle corridor of Uganda. The standard deviation of land size under livestock farming was very far from the mean, which implies that the farmers have varying land sizes on which they keep their livestock. There could be a possibility of them diversifying the land into other activities like crop farming. Diversification of farm land (especially with crop farming) plays a significant role in increasing household income and food security of pastoral farmers, consequently reducing their vulnerability to climate change including drought (Tiwari et al. 2014; Waiswa et al. 2019).

Perceived drought affectson the agro-pastoral farmers

The perceived drought impacts on the agro-pastoral farmers were expected. However, the most prevalent (water shortage) was an agricultural impact followed by intense heat, a meteorological impact. This finding seemed to

Table 1: Summary of criteria used in characterisation of EbAs (adopted from Vignola et al. 2015)

Category 1: Based on ecosystem services	Category 2: Provides adaptation benefits to perceived drought impacts	Category 3: Improves the livelihoods of agro-pastoral farmers
Criterion 1: Is based on the conservation, restoration and sustainable management of biodiversity (e.g. genetic, species and ecosystem diversity)	Criterion 1: Maintains or improves crop, animal or farm productivity in drought	Criterion 1: Increases food security of agro-pastoral households
Criterion 2: Is based on the conservation, restoration and sustainable management of ecological functions and processes	Criterion 2: Reduces the biophysical impacts of extreme drought events and high temperatures on crops, animals or farming systems	Criterion 2: Increases or diversifies income generation
	Criterion 3: Reduces pest and disease outbreaks, because of drought	Criterion 3: Takes advantage of local or traditional knowledge of agro-pastoral farmers
		Criterion 4: Uses local, available and renewable inputs
		Criterion 5: Have affordable labour and implementation costs

Table 2: Socio-economic characteristics of agro-pastoral farmers

Variable	Mean ± standard deviation	Percentage (%)
Gender of household head		Female 60.1% Male 39.9%
Major agricultural activity of household		Livestock farming only 2.7% Crop farming only 33.9% Both crop and Livestock farming 63.4%
Use of indigenous knowledge as major source of farming knowledge		83.2%
Alternative source of income		44.8%
Access to extension services		21.3%
Awareness of policy related to EbA		8.2%
Membership to farmer organisation		24%
Household number	6.02 ± 3.31	
Number of farming years of household	25.37 ± 17.88	
Time spent on farm daily by famers (hours)	4.69 ± 2.16	
Land size under crop farming (acres)	3.63 ± 8.51	
Land size under livestock farming (acres)	5.91 ± 18.29	
Number of family members working on farm	3.16 ± 2.836	
Number of hired farm labourers	2.04 ± 1.18	

Table 3: Ecosystem-based adaptations to drought utilised by the agro-pastoral farmers

EbA options	Percentage (%)	Mean ± SD
Use of drought resistant shade trees	20	0.90 ± 0.306
Use of water reservoirs and dams	19	0.85 ± 0.361
Alternative ecosystem-based livelihoods	18	0.80 ± 0.403
Use of home or kitchen gardens	13	0.58 ± 0.495
Crop diversification	9	0.39 ± 0.489
Use of grass thatched granaries	8	0.37 ± 0.483
Use of drought resistant fodder crops	6	0.27 ± 0.444
Use of cover crops and mulching	4	0.19 ± 0.390
Rotational grazing within rangeland	3	0.13 ± 0.338
Use of already established drought resistant live fences	2	0.08 ± 0.275
Total	100	

contradict with Enfors and Gordon (2008) who reported that meteorological drought impacts (defined as precipitation/rainfall shortage) are the most prevalent ones and usually result in other drought impacts. In this case, the intense heat caused by the drought would be the most perceived impact and consequently result in a water shortage. This finding depicts that water availability during drought is indeed compromised during drought, consequently affecting the

Table 4: Characterisation of EbAs in response to perceived drought impacts based on ecosystem services, adaptation benefits to drought and livelihood improvement

Perceived drought impacts	EbA in use	Based on ecosystem services	%	Provides adaptation benefits to drought	%	Improves livelihoods of agro-pastoral farmers	%
Intense heat (humans, crops, livestock)	Use of drought resistant shade trees	Already established multipurpose trees on farm are conserved and their existence maintains ecological functions like pollination	31.1	Tree shades reduce excessive heat, because of drought on (farmers themselves) humans	22.5	Source of other tree products e.g. poles, fuel wood, fruits, traditional medicine, etc.	4.1
		Recreation purposes	1.5	Trees on farm provide shade to crops therefore reduce effect of heat	4.1		
		Habitat for biodiversity (e.g. pet doves, pollinators)	0.4	Farm animals cool off drought heat under tree shades	6.3		
Water shortage (humans, crops, livestock)	Use of water reservoirs and dams	Conservation and sustainable management of farm biodiversity and entire household during long dry spells	13.9	Water fetched is used for irrigating crops in drought periods (using plastic bottles technique learnt in farmer field schools)	3.6	Water availability for domestic use	15.9
Drained wetlands				Maintains/improves livestock production through water availed to them at water sources	3.9	Less labour is required in case of moving near the water reservoirs	0.1
Drying of water sources						Fetching water is a source of income for the youth	3.5
Reduced income	Alternative ecosystem-based livelihoods	Harvesting only ready materials ensures, conservation and sustainable management of involved ecosystems	18.6	Maintains farm productivity	19.6	Diversifies income through: -	
Farm insecurity (theft and straying of animals)						handcraft making for sale e.g. mats, baskets for sale, papyrus mats	5.3
						non-baked brick making	0.2
						baked brick making	0.4
Increased prevalence of pests and diseases (humans)		Establish harvest regulations especially in the farmer field schools ensures sustainable management	0.2			ecotourism	0.3
						recreation e.g. board games	0.3
						making fuel efficient cook stoves from clay	0.3
						charcoal production	0.6
Increased prevalence of pests and diseases (crops)		Use of domesticated sources fosters conservation	1.2			agribusiness i.e. sale of farm produces like ghee, milk, maize	1.0
		Involve women	1.9			herbal medicine production for use and sale	0.5
		Involve youth	3.0				
		Ask for permission from authorities	0.2			build houses or huts for pastoralists, also requires affordable labour and implementation costs	0.3
						make local wine	0.2
						offer labour on farm for wages	1.2
						educate youth about ecosystems with aid of local knowledge	0.3
						herbal medicine boosts human health and is affordable	8.7
						sale of livestock increases food security	4.8
						game hunting increases food security	0.4
						offering labour on farms in exchange for food entails low implementation costs	0.1
						make cooking oil from palm trees increases food security and income of farmers	0.1

Table 4: cont.

Perceived drought impacts	EbA in use	Based on ecosystem services	%	Provides adaptation benefits to drought	%	Improves livelihoods of agro-pastoral farmers	%
						Uses local knowledge through: -	0.3
						recreation e.g. keeping dove pets	0.3
						educational services about ecosystems	0.2
						spiritual/religious practices	
Death of crops Decline in crop growth Decline in crop growth Fluctuating food prices Increased prevalence of pests and diseases (humans)	Use of home or kitchen gardens	Kitchen or home gardens ensure sustainable management of biodiversity (crops, local herbs, vegetables)	8.6	Local medicine from the gardens boosts immunity of the farmers, therefore maintaining productivity	8.6	Increasing food security	3.9
		Conservation of domesticated local plants	5.5			Makes use of indigenous knowledge	1.6
						Domesticated local herbs in home gardens are source of medicine for the farmers	4.4
						Requires locally available raw materials like dung	3.0
						Diversifies income	3.8
Reduced income Farm insecurity (theft and straying of animals)	Crop farming diversification	Ensures sustainability of involved crop species	5.5	Maintains farm productivity	3.6	Increase food security	15.2
Food shortage (humans) Fluctuating food prices	Use of grass thatched granaries	Storing food in granaries preserves genes of crop species	1.2	Avails food for farmers during drought, therefore maintains farm productivity	11.2	Storing food in granaries increases food security, requires less labour, entails locally available inputs,makes use of indigenous knowledge	5.7
Forage shortage (livestock)	Use of drought resistant fodder crops	Allows regeneration of rangeland species	2.7	Fodder crops are alternative forage sources for livestock, therefore maintains/increases production during dry spells	1.9	Source of income for youth to obtain the forage	0.4
						Entails affordable labour	0.3
						Increase forage security	0.3
Water shortage (crops)	Drought resistant cover crops and mulching	Conservation of soil biodiversity	0.2	Maintain soil moisture	5.8	Uses locally available renewable inputs	3.0
						Entails affordable labour and implementation costs	3.3
						Takes advantage of indigenous knowledge	3.0
Forage shortage (livestock)	Rotational grazing within rangeland	Rotational grazing allows regeneration of plant species	2.7	Improves animal production by availing fodder at different times	4.6	Requires less labour for implementation	2.3
		migration to distant grazing lands ensures regeneration of rangeland forage species	0.2				
Farm insecurity (theft and straying of livestock)	Use of already established drought resistant live fences (*lukoni/nkoni*)	Sustainable source of medicine too (e.g. warts)	1.1	Prevents straying of livestock, therefore reduce pests and disease transfer	4.6	Live fences are locally available and require low costs to establish and maintain	0.3
		Recreational purposes	0.2				
Total			100		100		100

agro-pastoral farmers in the Uganda cattle corridor. Although the farmer respondents complained of extremely hot weather during drought that made them sweat profusely and reduced their workability, the scarcity of water had a greater toll on them. This could be because water being a necessity for forage, crop and livestock sustainability was prioritised by the farmers, as opposed to having a cool microclimate. Similar perceptions on drought impacts have also been reported in Nakasongola, Uganda (Mfitumukiza et al. 2017a) and Zambezi valley, Zimbabwe (Mahvura et al. 2015), which are also agro-pastoral regions. These studies showed that drought negatively affected the agro-pastoralists through water scarcity, accordingly affecting their food security and forage availability.

Characterisation of ecosystem-based adaptations in response to perceived drought impacts based on ecosystem services, adaptation benefits to drought and livelihood improvement

The characterisation of the ecosystem-based adaptations to the perceived drought impacts were based on ecosystem services, adaptation benefits to drought and livelihood improvement, which resulted in respective proportions of each EbA in each category. They were majorly ten EbAs utilised by the agro-pastoral farmers to adapt to the perceived drought impacts with the prevalent ones being drought resistant shade trees, water reservoirs and dams and alternative ecosystem-based livelihoods. The utilisation of the major EbAs was expected considering the perceived drought impacts in the study area. The least EbAs utilised by the agro-pastoralists were use of cover crops and mulching, rotational grazing within rangeland and use of already established drought resistant live fences. The least use of these EbA practices could be attributed to the rangeland ecosystem and culture of the region as livestock are grazed on expanse communal lands. A study by Harvey et al. (2017) reported that cover crops were among the rarely used EbA practices despite their promotion among agro-pastoralists. This was attributed to the additional cost and labour required to establish them and could result in a change in the management of farm practices (Harvey et al. 2005; Harvey et al. 2017). The farmers in the study area use a live fence species locally known as *lukoni/nkoni* to reduce theft and straying of animals. Though use of live fences as an EbA was the least, the farmers that utilise them report that *lukoni/nkoni* helps to restrict livestock from straying, therefore preventing pests and disease transfer. The farmers testify that *lukoni/nkoni* is locally available and requires low establishment and maintenance costs. The farmers in the central cattle corridor also say that they use *lukoni/nkoni* for recreation and as a medicinal remedy for warts. A study by Tugume et al. (2016) documented *lukoni/nkoni* (*Europhobia tirucalli* L.) as medicinal plant that cures warts. The use of live fences in cattle landscapes is essentially for their cost-effectiveness and significance in field demarcation, barrier creation to livestock movement, and provisioning services like fodder, firewood, fruits, timber and medicine (Tugume et al. 2016; Harvey et al. 2017).

The alternative ecosystem-based livelihoods subjugated all the three categories (ecosystem services, adaptation benefits to drought and livelihood improvement). The agro-pastoralists used alternative ecosystem-based livelihoods to adapt to perceived drought impacts of reduced income, farm insecurity, increased prevalence of pests and diseases (among crops and humans). They adopted a wide range of livelihoods mainly to diversify their income and boost their health using local knowledge. These included handcraft making, brick making, making fuel-efficient cook stoves from clay, charcoal production, agribusiness (i.e. sale of farm produces like ghee), herbal medicine production for use and sale, herbal medicine boosts production, game hunting, among others. The aforementioned livelihoods increased food security of the agro-pastoralists, diversified their income, involved use of local or traditional knowledge, required use of locally available inputs, and entailed affordable labour and implementation costs (Vignola et al. 2015). In this way, the productivity of their households was maintained. The utilisation of alternative ecosystem-based livelihoods based on ecosystem services category involved harvesting ready products, establishing harvest regulations, domestication, involvement of women and youth, and obtaining authorities' permission to harvest ecosystem products like firewood. These practices ensured conservation, restoration and sustainable management of biodiversity, ecological functions and processes in the Uganda's central cattle corridor (Vignola et al. 2015).

The utilisation of drought resistant shade trees dominated the ecosystem services and adaptation benefits categories. The drought resistant shade trees were already established multipurpose trees on farmland or rangeland that were utilised to adapt to the intense drought heat on the crops, livestock and farmers themselves through providing a cool microclimate. They provided ecosystem services like maintenance of ecological functions like pollination, recreation and habitat for biodiversity, such as pollinators and pet doves. A study by Harvey et al. (2017) reports that the predominance of shade trees exceeds their exclusive use for adaptation benefits to climate change. In addition to being locally used and widely recognised EbA practices, they are being generally promoted by extension service providers, climate-change project developers and farmer groups, because of their capacity to improve farm sustainability, maintain and diversify farm production, enhance income generation and livelihoods of the agro-pastoral farmers (Harvey et al. 2017). The conservation of such multipurpose plants is therefore of great importance to farmers in the central cattle corridor and could be a significant source of diversified EbA for natural resource dependent communities in changing climatic conditions (Reid and Alam 2017).

The use of water reservoirs and dams were the mostly used EbA for livelihood improvement. The agro-pastoral farmers utilised this EbA to adapt to water scarcity during drought. According to the results, they obtained water from the reservoirs and dams mainly for domestic use. Fetching of the water from the dams was a source of income for the youth. However, less labour was required in the event of moving to nearby water reservoirs. The water reservoirs were mainly dams established in high water table regions and therefore able to withstand the long dry spells. Aside from domestic use, water stored in dams and reservoirs raises the ground water table through seepage, which fosters vegetation regrowth (Munang et al. 2014).

All the EbAs in the study have proportions in the ecosystems, adaptation and livelihood improvement categories. EbA, as a climate-change adaptation strategy should entail all the three components. However, EbA, appropriate for natural resource dependent communities like agro-pastoralists should improve their livelihoods, in order to enhance their resilience to climate change (Vignola et al. 2015). In addition, there ought to be proper adaptive management of EbA measures, in order to avoid maladaptation cases in the long run (Taylor et al. 2014).

Conclusion

Understanding the agro-pastoral farmers' perception about drought presents a significant basis on how they utilise existing ecosystems and biodiversity to adapt to climate change. The major perceived drought impacts affecting the farmers were water shortage, an agricultural impact and intense heat, a meteorological impact that threatened their water availability and microclimate.

This study highlights the ecosystem-based adaptations that agro-pastoral farmers can use for drought. These include the use of drought resistant shade trees, water reservoirs and dams, alternative ecosystem-based livelihoods, home or kitchen gardens, crop diversification, grass thatched granaries, drought resistant fodder crops, cover crops and mulching, rotational grazing within rangeland and already established drought resistant live fences. However, the use of drought resistant shade trees, water reservoirs and dams, and alternative ecosystem-based livelihoods dominated the ecosystem services, adaptation benefits to drought and livelihood improvement categories. These ecosystem-based adaptations should, in consideration of the categories they dominated, be given greater importance in climate change adaptation policies and initiatives to enhance the resilience of agro-pastoral systems.

Although the results of this study show the prevalence of EbAs in agro-pastoral systems, they would possibly be compatible with other farming systems in the event of other climate change hazards besides drought. Therefore the broader use of EbA in all farming systems should be encouraged by practitioners, policy makers and funders, in order to increase their climate change resilience.

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