

The effect of climate information in pastoralists' adaptation to climate change

A case study of Rwenzori region, Western Uganda

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Abstract

Purpose – This paper aims to investigate the effect of using indigenous forecasts (IFs) and scientific forecasts (SFs) on pastoralists' adaptation methods in Rwenzori region, Western Uganda.

Design/methodology/approach – Data were collected using a household survey from 270 pastoralists and focus group discussions. The multivariate probit model was used in the analysis.

Findings – The results revealed that pastoralists using of IF only more likely to be non-farm enterprises and livestock sales as adaptation strategies. Pastoralists using both SF and IF were more likely to practise livestock migration.

Research limitations/implications – Other factors found to be important included land ownership, land tenure, gender, education level, non-farm and productive assets, climate-related risks and agricultural extension access.

Practical implications – Increasing the number of weather stations in pastoral areas would increase the predictive accuracy of scientific climate information, which results in better adaptive capacity of pastoralists. Active participation of pastoral households in national meteorological dissemination processes should be explored.

Social implications – A two-prong approach that supports both mobile and sedentary pastoralism should be adopted in rangeland development policies.



Originality/value – This study has shown the relevance of IFs in climate change adaptation methods of pastoralists. It has also shown that IFs compliment SFs in climate change adaptation in pastoralism.

Keywords Uganda, Climate change adaptation, Climate information, Indigenous forecasts, Pastoralists, Scientific forecasts, Indigenous knowledge

Paper type Research paper

1. Introduction

Despite access to climate information and implementation of sedentary pastoral development interventions such as the construction of valley dams and boreholes (Muchuru and Nhamo, 2017), pastoralists are still vulnerable to climate variability. This is a major challenge in pastoral development because poor adaptation to climate-related risks has led to low milk yields and high livestock mortality, contributing to high poverty rates and destitution among pastoralists. Use of climate information improves resilience against climate-related risks. As has been observed, “managing climate variability and climate risk is not new to pastoralism” (Eriksen *et al.*, 2013, p. 71). Opportunistic grazing habits and mobility of pastoralists have been some of the adaptive mechanisms to climate variability and change in fragile ecologies with high temporal and spatial variations in rainfall (Catley and Akilu, 2013; Sandford, 1983; Westoby *et al.*, 1989; Sandford and Scoones, 2006). The debate continues as to whether sedentary pastoralism, as opposed to mobile pastoralism, improves the adaptive capacity of pastoral households. This study investigated the effect of climate information on the pastoral adaptation methods.

Climate information is one of the essential factors for effective adaptation to climate variability in pastoralism (Kedir and Tekalign, 2016). Pastoralists use indigenous forecasts (IFs) (Nganzi *et al.*, 2015) and scientific forecasts (SFs) in their adaptation to extreme weather events (Luseno *et al.*, 2003; Lybbert *et al.*, 2007). Indigenous knowledge is widely used in different parts of the world in predicting weather and seasonal events (Roncoli *et al.*, 2002; Orlove *et al.*, 2000; Green *et al.*, 2010; Kalanda-Joshua *et al.*, 2011). Pastoralists change their original beliefs on forecasts related to rainfall distribution for the coming seasons upon receiving SFs (Lybbert *et al.*, 2007). The challenge of using IFs arises from the effect of climate variability on their reliability (Ingrama *et al.*, 2002), while unreliable forecasts have rendered SFs not be trusted by pastoralists (Demeritt *et al.*, 2007). Due to weaknesses of using IFs or SFs exclusively, some pastoralists have resorted to using a combination of the two. A study done in Kenya investigated agro-pastoralists’ use of climate information in their adaptation strategies (Bryan *et al.*, 2013). The findings revealed that the use of weather forecasts positively influenced adaptation. Another study revealed that the use of weather forecasts increased the likelihood of livestock migration among pastoralists in Kenya (Silvestri *et al.*, 2012).

Further, climate information is a key factor in weather index-based livestock insurance. For instance, the rainfall index has been used in the implementation of weather index-based agricultural insurance in Kenya, Malawi, Rwanda, Ethiopia, Ghana, India and Thailand (Carter *et al.*, 2014; Gine and Yang, 2009; Takahashi *et al.*, 2016; Karlan *et al.*, 2014; Cole *et al.*, 2017). Due to challenges with rainfall data, the weather index-based livestock insurance programme among pastoralists in Kenya used satellite data in the form of normalised difference vegetation index (Jensen *et al.*, 2017).

The Uganda National Meteorological Authority (UNMA, 2017b, 2016) has been very active in the dissemination of SFs in Uganda’s rural areas, including the cattle corridor. There has been an increase in the use of SFs due to the proliferation of local radio stations and the translation of SFs in local languages (Ziervogel, 2004; Jost *et al.*, 2015). IFs are widely used in

the pastoral households in Uganda (Orlove *et al.*, 2010; Nganzi *et al.*, 2015). However, there is a knowledge gap on the effect of the use of IFs only or both SFs and IFs on pastoralists' adaptation strategies. This study attempts to address this knowledge deficiency.

Land scarcity and human population growth has led to an increase in sedentary pastoralism in pastoral areas in Uganda (Wurzinger *et al.*, 2009). Sedentary pastoralism involves transforming pastoralists into mixed farmers in settled communities. This increases their access to social services such education, health and water for livestock production. More importantly, the Uganda Government uses the approach in reducing violent conflicts between pastoralists and the neighbouring farming communities, as is the case, for example, with the Karamojong in the North East (Ide *et al.*, 2014). Mobile pastoralism involves practising opportunistic grazing and extensive herd mobility in the rangelands of Uganda as an adaptation to climate-related risks.

This paper investigates the influence of the use of IFs and/or SFs on climate change adaptation among pastoralists in Rwenzori region in Western Uganda. The research question was "do IF and/or SF have an effect on pastoralists' adaptation strategies?" The study's objective was to generate empirical evidence that could be used by policymakers, development partners; non-governmental organisations to support pastoralists' adaptation to climate variability and change. The study findings also have implications for pastoral-meteorology policies in sub-Saharan Africa.

2. Materials and methods

2.1 The study area

Data on pastoralists was gathered from Kasese and Ntoroko districts in the cattle corridor of Western Uganda (Figure 1). These two districts have rangelands that are suitable for both

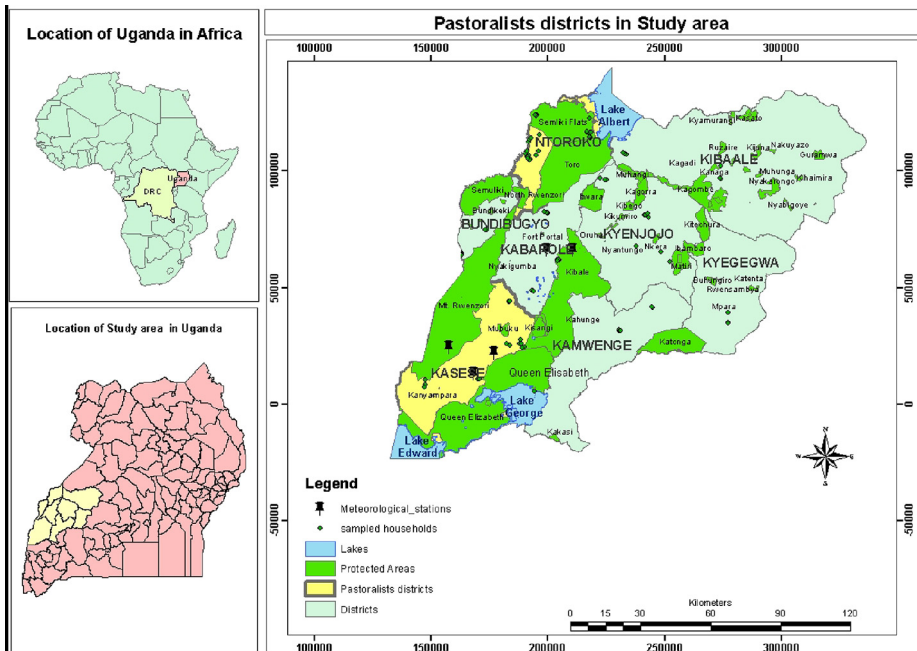


Figure 1.
Location map of
study area

livestock and wildlife. The wildlife protected areas (WPA) found in this part of the cattle corridor include Queen Elisabeth National Park in Kasese district and Toro-Semiliki game reserve in Ntoroko district (Figure 1). Other natural resources found in this area include fisheries resources in Lake Edward, Lake Albert, Lake George and River Semiliki. Mobile pastoralism is practised, with migration from Ntoroko district to the Eastern part of the Democratic Republic (DR) of Congo through River Semiliki. The Eastern part of the DR of Congo has abundant forage resources. However, conflicts in Eastern DR Congo have resulted into migration into Uganda (KRC and RFPJ, 2012). Sedentary pastoral policies led to the drop in the number of pastoralists in the cattle corridor in Uganda, especially in Kasese district (Wurzinger *et al.*, 2009; Wurzinger *et al.*, 2006). The Rwenzori region experiences bimodal rainfall distribution from March to May and July to November. Climate-related risks such as droughts and floods have resulted into pastoralists encroaching on the WPA. As a result of pastoralists' encroachment into protected areas, the Uganda wildlife authority imposes heavy penalties on the culprits such as prosecution through courts of law. Climate-related risks are prevalent in the region, with increased frequency and severity due to climate variability (NAPA, 2007). The common pastoral adaptation methods include livestock diversification, herd mobility and migration (RTT, 2011; Oxfam, 2008). In line with sedentarisation[1] of pastoralists, the Uganda Government has embarked on infrastructure development[2] in the cattle corridor[3]. However, pasture scarcity during the long dry spells and droughts has remained a challenge for pastoralists. The meteorological station density in the pastoral areas is low (Figure 1).

2.2 Sample size

A two-stage stratified approach was used in the sampling of the respondents (Cochran, 1963). The first stage units were the agro-ecological systems (Table I) and second stage units were households. The sampling took into consideration pastoralism and arable farming in the selection of the respondents. The 2014 Uganda population census report gave the number of households in the area to be 102,496 households. Raosoft (2004), a sample size calculator, showed that a statistically acceptable sample size for this population of households at 95 per cent confidence level and margin of error of 3.5 per cent was 778. However, to allow for replacement in the sample of those who might back out of the study, 19 per cent of the statistically selected sample was included giving a total study sample of approximately 924. This was also to ensure good size for sub samples (for those who use IF only, and both SF and IF). After data cleaning, 17 incomplete questionnaires were eliminated from the final analysis. At the end of the study 907 questionnaires were completely answered giving a response rate of 98 per cent comprising of 580 arable farmers, 270

Agro-ecological zone	Arable farmers	Pastoralists	Agro-pastoralists	Total
Forested	122	0	0	122
Mountainous	97	0	0	97
Wetland	82	0	0	82
Lowland	197	270	57	524
Mountainous and forested	82	0	0	82
Total	580	270	57	907

Source: Survey data (2015)

Table I.
Sample size

pastoralists and 57 agro-pastoralists. This paper limits itself to the 270 pastoralists in the sample. Random sampling was used in the selection of survey respondents.

2.3 Data collection methods

Data were gathered from August to October 2015. The household survey was used to gather data on adaptation methods, household characteristics, use of IF and SFs, institutional access and land tenure. Focus group discussions[4] and key informant interviews[5] were used to triangulate[6] the information from the survey. Two focus discussion groups (FDGs) were conducted at Rwebisengo village found in Rwebisengo sub-county in Ntoroko district. One focus group consisted of 14 female pastoralists, while the second comprised of 18 male pastoralists. This gender separation ensured a conducive environment for expression. The key informants included the technical officials from the district local government service commissions of Kasese and Ntoroko from the departments of agricultural production, wildlife officers and a meteorologist from UNMA. Data were analysed using Stata 12 statistical software.

2.4 Econometric estimation of climate change adaptation methods

The probit model has been used in pastoralists' climate change adaptation analysis (Silvestri *et al.*, 2012). In using univariate models such as probit or logit the assumption is that the pastoralists' decision to, for instance, destock is not influenced by their decision to adopt livestock diversification as an adaptive strategy. Some studies have used the multinomial model in the analysis of pastoralists' adaptation to climate change (Bryan *et al.*, 2013). Multinomial models, namely, multinomial probit and multinomial logit have an assumption of no relationship between adaptation strategies (Young *et al.*, 2009). This suggests that adaptation strategies are incompatible, yet pastoralists use the strategies concurrently in their rangeland management practices. Failure to consider unobserved factors[7] and interrelationships[8] in the use of adaptation strategies results into biased and inefficient estimates (Greene, 2003). This suggests simultaneous modelling provides for the relationship between adaptation strategies. The multivariate probit (MVP) model is suitable in providing for the interrelationships in the use of strategies. The MVP analyses the effect of independent variables on the use of each of the adaptation strategies, while it provides for the unobserved and unmeasured factors (error terms) to be freely correlated (Asfaw *et al.*, 2014). There are complementarities and substitutability (Mehtar *et al.*, 2016) between the strategies. The MVP has been used in adaptation studies (Kpadonou *et al.*, 2017; Ali and Erenstein, 2017; Yegbemey *et al.*, 2013; Mehtar *et al.*, 2016; Asfaw *et al.*, 2016; Piya *et al.*, 2013; Tesfaye and Seifu, 2016). Therefore, MVP was used in this study.

The empirical model specified as follows:

$$Y_i = \beta + \pi \text{ indigenous forecasts} + \varphi \text{ Scientific forecasts} + \theta \text{ Household characteristics} + \mu$$

where Y represents the adaptation methods, β is the constant term and μ is the error term. π , φ , φ and θ are parameter estimates for IFs only, SFs and IFs, control variables, respectively.

Where Y_i ($i = 1, 2, 3, 4, 5$ and 6) representing the adaptation methods for pastoralists $Y_{1i} = 1$, if the pastoralists adapts to herd mobility[9]; $Y_{2i} = 1$, if the pastoralists adapts to livestock diversification; $Y_{3i} = 1$, if the pastoralists adapts to livestock migration[10]; $Y_{4i} = 1$, if the pastoralists adapt to selling livestock; $Y_{5i} = 1$, if the pastoralists adapts to water pan and

well excavation; and $Y_{6i} = 1$, if the pastoralists adapt to switching from farm to non-farm enterprises. The exogenous control variables were: household characteristics (H): the level of education, age, sex and farming experience; (I): access to agricultural extension, credit access and non-farm access; institutional arrangements on land (Q): purchased and inheritance; land tenure (T): freehold and customary; climate-related risks (C): flood experience and drought experience; wealth (W): number of local produced in the past 12 months; ownership of productive assets (O): sprayers; ownership of transport assets bicycle, vehicle and motor cycle (V); and non-farm engagement fishnets (N). The expected signs for the variables are indicated in [Table II](#).

Using the MVP model, coefficients β , φ and π were estimated. After estimating the coefficients and level of significance, the determinants of pastoralists' adaptation methods were ascertained.

3. Results

3.1 Descriptive statistics

The results show that respondents were mostly male (59 per cent). The average number of local cows produced in the past 12 months was 70, a proxy for wealth status of pastoralists in the area. Over half (59 per cent) used both IFs and SFs, 41 per cent used IFs only and only one respondent used SFs only in their climate change adaptation strategies. Less than half (47 per cent) had attained primary education and 38 per cent had no formal education. The most important adaptation methods were livestock migration (83 per cent), herd mobility (55 per cent), livestock diversification (54 per cent) and livestock sales (51 per cent). Climate-related risks were very important in pastoralists' climate change adaptation methods ([Table III](#)). The key factors that enhanced participation in non-farm enterprises included land ownership, level of education and transportation assets such as motor cycle and bicycle, non-farm engagement assets such as fishnets and boats. Production assets such as sprayers and transportation assets such as bicycles, and access to hired labour were very important in livestock-related adaptation methods. Use of both forecasts was very important in livestock migration. Access to land through purchasing facilitated adaptation, implying that land markets were functional in the study area. Pastoralists not only used range resources but also fisheries resources in the lakes and rivers found in the study area, as is evidenced by ownership of boats and fishnets. Over three-quarters of the households used onset and cessation forecasts, implying their relevance in pastoralism.

3.2 Econometric results

3.2.1 The effect of using climate information on pastoralists' climate adaptation methods. The study shows that use IFs had a positive effect on pastoralists' climate change adaptation. Pastoralists using of IFs only were more likely to be engaged in non-weather related activities such as non-farm enterprises and livestock sales ([Table IV](#)). This establishes the significance of IFs in pastoralism. The results also suggest that using IFs only influences decision making under sedentary pastoralism. Distress livestock sales are commonly done by the onset of rains for weak livestock that may not be fit for migration over long distances such as crossing over to the Eastern part of DR Congo. The incomes from livestock sales are then invested in non-farm enterprises. Pastoralists use the climate information in planning for the search for water and pastures for their livestock. It was interesting to note that IF only short-range forecasts had a negative effect on livestock migration ([Table IV](#)).

The findings also show that the use of both IFs and SFs had a significant positive effect on pastoralists' climate change adaptation. Pastoralists using both SFs and IFs were more

Table II.
Explanatory
variables for
adaptation methods

Description	Expected sign	Cited literature
Farming experience	-	Bryan <i>et al.</i> , (2013)
Education level	+/-	Yegbemey <i>et al.</i> (2013); Nkonya <i>et al.</i> (2011); Bryan <i>et al.</i> (2013); Gbetibouo (2009)
Use of climate information	+/-	Nkonya <i>et al.</i> (2011); Bryan <i>et al.</i> (2013); Gbetibouo (2009)
Gender	+/-	Yegbemey <i>et al.</i> (2013); Nabikolo <i>et al.</i> (2012); Bryan <i>et al.</i> (2013); Ali and Erenstein (2017)
Assets	+/-	Nabikolo <i>et al.</i> (2012); Ali and Erenstein (2017)
Credit access	+/-	Yegbemey <i>et al.</i> (2013); Nkonya <i>et al.</i> (2011); Ali and Erenstein (2017); Bryan <i>et al.</i> (2013); Gbetibouo (2009)
Agricultural extension access	+/-	Yegbemey <i>et al.</i> (2013); Nkonya <i>et al.</i> (2011); Bryan <i>et al.</i> (2013); Ali and Erenstein (2017); Gebrehiwot and van der Veen (2013)
Access to non-farm enterprises	+	Gebrehiwot and van der Veen (2013)
Local cows produced in the past 12 months	-/+	Tambo (2016)
Assets	+	Nabikolo <i>et al.</i> (2012); Ali and Erenstein (2017); Tambo (2016)
Flood experience	+	Bryan <i>et al.</i> (2013)
Drought experience	+/-	(Alauddin and Sarker (2014)
Land tenure	+/-	(Nkonya <i>et al.</i> (2011); Gbetibouo (2009)
Institutional arrangements on land (purchased, inheritance and grabbed)	+/-	(Yegbemey <i>et al.</i> (2013)
Access to climate change information	+	(Gebrehiwot and van der Veen (2013); Tambo (2016); Deressa <i>et al.</i> (2008)
Government programmes on climate change	+	

Source: Authors specification

Variable	Herd mobility (N = 149) %	Livestock diversification (N = 145) %	Migrate livestock (N = 223) %	Selling livestock (N = 138) %	Water pan and well excavation (N = 84) %	Non-farm (N = 21) %
Both IF and SF	59	63	62	58	57	62
No school	38	34	39	38	37	24
Primary	48	49	49	48	49	62
Secondary education	12	15	11	12	12	15
Own land	78	77	83	77	83	91
Own sprayer	77	77	77	79	76	57
Own bicycle	52	46	46	45	36	33
Owens cycle	28	34	27	30	24	47
Owens fishnet	9	14	10	8	4	43
Owens boats	8	15	11	10	5	43
Hired labour access	51	53	43	54	29	48
Agri ext access	17	21	17	23	7	24
Credit access	41	41	34	29	24	24
Inheritance	38	42	40	41	46	38
Purchased	33	26	34	31	24	24
Drought experience	96	97	98	96	98	95
Flood experience	81	84	88	83	83	81
Govt climate change programme access	20	25	21	26	18	33

Source: Survey data (2015)

Table III.
Descriptive summary of adaptation methods of pastoralists

likely to practise livestock migration (Table V). This suggests that using both SFs and IFs influences decision making under mobile pastoralism. The study has established that pastoralists did not use short-range forecasts (Table IV) but rather used seasonal climate forecasts in their decision making in the search for water and pastures (Table V). The results reveal that IF enhances SF in pastoralism.

The results of the MVP model (using robust standard errors) for investigating the influence of using IFs only and both SFs and IFs on pastoralists' adaptation methods are shown in Tables IV and V. The likelihood ratio statistics [Wald chi-square (χ^2)] for the use of IFs only and both SFs and IFs (Tables IV and V) are significant ($p = 0.0000$), signifying the relevance of the model in explaining the influence of use of IFs only and both SFs and IFs in pastoralists' adaptation methods. This justifies the use of simultaneous modelling with MVP instead of single probit models. The correlation coefficients of the error terms for IFs only and both SFs and IFs are significant (Tables VI and VII) for any two equations, which indicates that there are adaptation methods, which complemented each other and some adaptation methods, which substituted one another.

The results (Table VII) of the complementarities and substitutes between adaptation methods for pastoralists who used both SFs and IFs were similarities and differences to those of IFs only (Table VI). For pastoralists using both SFs and IFs, herd mobility significantly complemented well excavation. Herd mobility involves livestock movement over distances that enable the livestock to return to the homestead that very day while livestock migration involves long distance where the livestock do not return to the homestead that very day. Herd mobility involves the search for pastures and wells are usually excavated in the neighborhood of the homestead. For pastoralists using both SFs and IFs, well excavation significantly substituted livestock sales.

Table IV.
Determinants of
pastoralists’
adaptation methods
using IF only: MVP
model parameter
estimates

Variable	Herd mobility		Livestock diversification		Migrate livestock	
	Coef	Robust sth. err	Coef	Robust sth. err	Coef	Robust sth. err
Male	0.385**	0.182	0.080	0.176		
Female						
IF only onset	0.389	0.396				
IF only 5 day	-0.285	0.417			-0.451**	0.222
IF only seasonal						
Local cattle produced the past 12 months	-0.001	0.001				
No school						
Advanced level						
Farm experience	0.004	0.006				
Own land						
Own sprayer						
Own bicycle	0.505***	0.170				
Owens cycle	-0.342*	0.195				
Owens fishnet	0.992*	0.511	1.029***	0.289		
Owens boats	-1.125**	0.488				
Hired labour access	0.319*	0.178	0.397**	0.176		
Agri ext access			0.348	0.233		
Non-farm access						
Inheritance			0.177	0.165	-0.280	0.262
Purchased					-0.504*	0.299
Grabbed					-0.383	0.341
Customary						
Freehold	-0.575***	0.187	-0.344	0.262		
Drought experience			-0.656**	0.259	0.949**	0.391
Flood experience			0.127	0.240	1.071***	0.300
_cons	0.102	0.261	-0.038	0.268	-0.055	0.442

Notes: ***, ** and * denote that significance at the 1, 5 and 10% levels, respectively. Log pseudo likelihood = -661.97; Wald χ^2 (58) = 352.67; Prob > χ^2 = 0.0000; N = 233, cessation was used as the reference category for the forecasts

Sources: Survey data (2015)

(continued)

Variable	Selling livestock		Water pan and well excavation		Non-farm	
	Coef	Robust sth. err	Coef	Robust sth. err	Coef	Robust sth. err
Male						
Female					0.343	0.307
IF only onset					1.336**	0.649
IF only 5 day		0.259	-0.182	0.270	-1.526**	0.680
IF only seasonal	-0.485*	0.284	-0.273	0.302		
Local cattle produced the past 12 months	-0.001	0.001	-0.002	0.001		
No school					-0.517	0.391
Advanced level					1.296*	0.676
Farm experience					0.018	0.014
Own land					1.425**	0.613
Own sprayer	0.314	0.223			-1.139***	0.324
Own bicycle					-0.345	0.265
Owns cycle					0.473	0.329
Owns fishnet					1.354***	0.387
Owns boats						
Hired labour access			-0.465**	0.187		
Agri ext access	0.680***	0.240				
Non-farm access	0.287	0.225				
Inheritance					-1.797***	0.437
Purchased					-1.588***	0.474
Grabbed					-0.851	0.892
Customary					1.188**	0.460
Freehold	-0.388**	0.180			0.619	0.474
Drought experience						
Flood experience	0.115	0.238	-0.389	0.273		
_cons			-0.163	0.337	-2.420**	0.929

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Table IV.

Table V.
Determinants of
pastoralists’
adaptation measures
using both IF and
SF: MVP model

Variable	Herd mobility		Livestock diversification		Migrate livestock	
	Coef	Robust sth. err	Coef	Robust sth. err	Coef	Robust sth. err
Male	0.302*	0.182	0.077	0.181	0.238	0.216
Female						
IF and SF onset						
IF and SF 5 day						
IF and SF seasonal	0.158	0.182	0.288	0.197	0.575**	0.293
Local cattle produced the past 12 months					0.004	0.003
Primary						
Ordinary level						
Advanced level						
Farm experience	0.005	0.006			-0.072	0.295
Own land						
Own sprayer						
Own bicycle						
Owns cycle						
Owns fishnet	0.767	0.499	0.974***	0.292		
Owns boats	-1.076**	0.453				
Hired labour access	0.413**	0.174	0.433**	0.187		
Agri ext access			0.344	0.241		
Non-farm access					-0.282	0.297
Credit access						
Inheritance			0.149	0.173		
Purchased	0.307*	0.184				
Grabbed						
Customary	-0.246	0.251	-0.350	0.266		
Freehold	-0.550**	0.248	-0.659**	0.262		
Drought experience					1.120***	0.425
Flood experience			0.181	0.256	0.851***	0.280
Govt climate change programme access	-0.260	0.201	0.048	0.214		
_cons	0.009	0.279	-0.094	0.287	-1.135**	0.520

Notes: ***, ** and *denote that significance at the 1, 5 and 10% levels, respectively. Log pseudo likelihood = -665.79; Wald χ^2 (64) = 322.13; and Prob > χ^2 = 0.0000, Cessation was used as the reference category for the forecast

Source: Survey data (2015)

(continued)

Variable	Selling livestock		Water pan and well excavation		Non-farm	
	Coef	Robust sth. err	Coef	Robust sth. err	Coef	Robust sth. err
Male	0.129	0.171			0.148	0.286
Female					-0.531	0.387
IF and SF onset	-0.233	0.176			0.091	0.321
IF and SF 5 day					0.340	0.404
IF and SF seasonal						
Local cattle produced the past 12 months			-0.003*	0.002		
Primary					0.566	0.360
Ordinary level					0.555	0.590
Advanced level					1.523**	0.762
Farm experience			-0.010	0.007		
Own land	-0.371	0.333			0.970*	0.546
Own sprayer	0.198	0.212			-1.020***	0.291
Own bicycle			-0.483**	0.193	-0.236	0.290
Owns cycle					0.445	0.344
Owns fishnet			-1.219***	0.390	1.088***	0.380
Owns boats						
Hired labour access						
Agri ext access	0.730***	0.248	-0.398	0.281	0.148	0.335
Non-farm access	0.320	0.215				
Credit access	0.176	0.303	-0.462**	0.209		
Inheritance	0.099	0.304	0.558***	0.194	-1.469***	0.418
Purchased					-1.364***	0.413
Grabbed			1.709***	0.430		
Customary			-0.331	0.211	1.123**	0.453
Freehold					0.446	0.515
Drought experience						
Flood experience			-0.137	0.256		
Govt climate change programme access	0.183	0.206	0.487	0.370	0.082	0.325
_cons	-0.064	0.289			-1.943***	0.681

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information

Table V.

3.2.2 *Other determinants of pastoralists' adaptation methods.* Pastoral households with non-farm assets such as fishnets were more likely to diversify their livestock and to engage in non-farm enterprises (Tables IV and V)[11]. The incomes from fish enterprises were invested in buying livestock and in non-farm enterprises. This could be due to pull factors associated with wealthy pastoralists investing in other natural resource ventures or push factors for the poor pastoralists spreading their risks against possible livestock losses due to climate-related risks such as droughts, floods or disease epidemics. The latter has implications on the poverty reduction strategies while the former has the implication of over-exploitation of the fisheries by overfishing through the increase of a number of fishnets used. Thus, on one hand, managers of fisheries limit the number of fishers, fishnets and boats on Uganda water bodies as a strategy to control over-fishing; and on the other hand poverty reduction strategies are promoting rural livelihood diversification among livestock farmers through the utilisation of other natural resources such as fisheries. This is a catch 22 for national policymakers in developing countries like Uganda. Boat ownership decreased the likelihood of herd mobility. This suggests that owning a boat necessitates one to go fishing or have close supervision of the catch at the landing site; and a lifestyle, which conflicts with herd mobility.

Pastoral households with transportation assets such bicycles were less likely to be involved in the water pan and well excavation but more likely to adapt using herd mobility (Tables IV and V). Well excavation is done in the neighborhood of the homestead or land owned by the pastoralist. Therefore, the pastoralist did not need a bicycle to access wells

Table VI.
Covariate matrix for those who used both SF and IF

	Livestock diversification	Migrate livestock	Selling livestock	Water pan and well excavation	Non-farm enterprises
Herd mobility	0.462***	0.163	0.190*	0.239**	0.005
Livestock diversification		0.224*	0.081	0.045	0.170
Migrate livestock			-0.010	-0.012	-0.357
Selling livestock				-0.300***	-0.080
Water pan and well excavation					0.168

Notes: ***Significant at 1%; **Significant at 5%; and *Significant at 10%. Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho32 = rho42 = rho52 = rho62 = rho43 = rho53 = rho63 = rho54 = rho64 = rho65 = 0. χ^2 (15) = 47.2445; Prob > χ^2 = 0.0000

Table VII.
Covariate matrix for those who used IF only

	Livestock diversification	Migrate livestock	Selling livestock	Water pan and well excavation	Non-farm enterprises
Herd mobility	0.503***	0.108	0.198*	0.139	-0.062
Livestock diversification		0.211*	0.120	0.006	0.297**
Migrate livestock			0.018	-0.012	-0.277
Selling livestock				-0.126	-0.120
Water pan and well excavation					-0.070

Notes: ***Significant at 1%; **Significant at 5%; *Significant at 10%. Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho32 = rho42 = rho52 = rho62 = rho43 = rho53 = rho63 = rho54 = rho64 = rho65 = 0. χ^2 (15) = 44.61666; Prob > χ^2 = 0.0001

and water pans. It is probable that milk obtained from the lactating animals during herd mobility is transported using bicycles to the local markets.

Pastoral households with productive assets such as sprayers were less likely to be engaged in non-farm enterprises (Table V). Sprayers are instrumental in the control of livestock diseases. The results suggest that non-farm assets and productive assets promote sedentary pastoralism but do not enhance mobile pastoralism.

The study also reveals that access to hired labour increased the likelihood of herd mobility and livestock diversification but decreased the likelihood of water pan and well excavation (Tables IV and V). The water pans and wells are usually dug next to the homesteads and family labour is mostly employed. Pastoralists hired young men as herdsmen in search for water and pastures to River Semiliki flood plains and the neighbourhood of Toro-Semiliki wildlife protected area. The results suggest that access to hired labour enhances mobile pastoralism.

The results of the study demonstrate that access to agricultural extension increased the likelihood of adapting to climate change (Table V). Pastoralists with access to the agricultural extension were more likely to be engaged in destocking. During periods of pasture and water scarcity, pastoralists were advised by extension agents to take on destocking to maintain a manageable number of livestock according to the availability of pastures.

The study also reveals that climate-related risks increased the likelihood of livestock migration (Tables IV and V). Pastoral households, which had flood and drought experiences were more likely to practice livestock migration. Participants in both male and female FDGs reported that “they cross to Congo”. Floods limit the movement of livestock; and reduce access to pastures by reducing the quality of and access to safe water for livestock and humans. One male FGD participant reported that “when it floods, we even fail to get clean water to drink”. The rangelands in Ntoroko are found in the flood plain of River Semiliki. Seasonal climate forecasts provide information on early warning for impending floods and droughts. Furthermore, pastoralists use their indigenous knowledge to predict the trend of floods in the rangeland. Floods significantly affect pastoralist livelihoods due to the associated human and livestock diseases such as foot rot, which could trigger diversifying into the less vulnerable small stock, such as goats. This was supported by responses from female FGD participants of the who reported that “the children get sick from worms, since the children play in the mud so they pick the worms”[. . .] “People suffer from malaria due to mosquito bites”[. . .] even the cows’ nails fall out. Seasonal forecasts (both scientific and indigenous) inform measures taken to mitigate disaster risks associated with floods and droughts. The results suggest that climate-related risks promote mobile pastoralism.

Pastoral households who acquired land through inheritance were more likely to practice well excavation (Table V). This is because land ownership rights gives them the liberty to use the land as they wish. Pastoral households, which acquired land through inheritance and purchase were less likely to be engaged in non-farm enterprises (Tables IV and VII). The land was acquired primarily for providing pastures, especially during the wet season. The male focus group participants reported that landlords graze their livestock in the commons during long dry spells and droughts. Although the land was acquired for pasture provision, which is important to well excavation (Table V), it limits the mobility and flexibility in pastoralism. Mobility and flexibility contribute to an increase in livestock numbers that are sold to invest in non-farm enterprises.

The study revealed mixed results about the effect of land tenure on pastoral adaptation strategies. Customary land tenure had a significant positive effect on non-weather based adaptation measures such as non-farm enterprises but freehold land tenure had a significant

negative effect on herd mobility, livestock diversification and destocking (Tables III and VI). Customary land tenure permitted open access grazing and the returns from milk and beef sales were invested in non-farm enterprises. Freehold promotes sedentary pastoralism while mobile pastoralism that involves herd mobility tends to enhance livestock diversification and destocking of weak and old animals.

Being a male pastoralist increased the likelihood of herd mobility (Table IV). The search for pastures and water for livestock over long distances is a very strenuous activity and tends to mainly involve herdsman in pastoral communities. This was supported by the response from a participant in the female focus group discussion who said that “the men migrated with the cattle and went away to look for where to graze”. The results suggest that being male pastoralist enhances mobile pastoralism.

Pastoral households with land ownership were more likely to be engaged in non-climate-related ventures such as non-farm enterprises (Tables IV and V). Pastoralists who owned land invested in pasture development and improved livestock management practices. This led to an increase in return on investments from the livestock enterprises through participation in the local milk and beef markets. The returns could then be invested in non-farm enterprises. According to one key informant, some pastoralists had secured support in infrastructure development such as fencing from the defunct National Agricultural Advisory Services. A key informant and the male focus group participants revealed that there had been a reduction in the amount of land under open access due to land acquisition in customary lands. This has led to a reduction in the mobility of pastoralists due to an increase in sedentary human and livestock populations. The results suggest that land ownership promotes sedentary pastoralism.

The study shows that education level increased the likelihood of adapting to climate change (Table V). Pastoralists with an advanced level of education were more likely to be engaged in non-climate-related ventures such as non-farm enterprises. The results suggest that education level promoted sedentary pastoralism.

4. Discussion

The study revealed that pastoralists using of IFs only were more likely to be engaged in non-farm enterprises and livestock sales. During onset, there is a spread of water-borne diseases and worms (Bett *et al.*, 2009; Woods, 1988; Munyua *et al.*, 2010). This results into livestock sales involving weak animals. Livestock farmers invest the incomes from destocking in non-farm enterprises (Nkuba and Sinha, 2014; Nkuba, 2006). Pastoralists make grazing decisions related to mobility using long range rather than short-range forecasts (Luseno *et al.*, 2003). Short range forecasts provide information about dry spells, which influence pastoralists' decisions on destocking. A study done in Kenya showed that weather forecasts positively influenced the selling of livestock, although the influence was not statistically significant (Bryan *et al.*, 2013). Scientific climate seasonal forecasts provide advisories about climate-related risks such as droughts and floods. UNMA provides information on disaster risk reduction and climate risks during the dissemination of seasonal climate outlooks in February and August (UNMA, 2017a, 2017b). Pastoralists had confidence in long-range scientific climate forecasts for their livestock migration planning decisions because they are based on good forecast skills (Goddard *et al.*, 2010). The mobility of pastoralists using rangelands is based on long-range forecasts (Luseno *et al.*, 2003). The study reveals that the use of IFs only for onset was associated with non-farm enterprises while long-range forecasts for IFs and SFs were associated with livestock migration. This is consistent with an earlier study in Kenya that revealed that pastoralists had a high interest in onset forecasts for they influenced decisions pertaining to migration patterns

(Luseno *et al.*, 2003). The study findings support the integration of IFs in the national meteorological services in Africa (Ziervogel and Opere, 2010). The findings show that for the two categories of use of forecasts, herd mobility significantly complemented with livestock diversification and livestock sales. Small stock such as goats are browsers while large stock such as cattle are grazers resulting into good utilisation of range resources in mobile pastoralism. This is consistent with pastoral literature (Blench, 2001; Huho *et al.*, 2009). The study shows that for the two categories of use of forecasts, livestock diversification significantly complemented livestock migration. The literature on pastoralism has shown that herd mobility and livestock sales are some of the mechanisms that pastoralists use in sustainable rangeland management (Morton and Barton, 2002; Blench, 2001; McPeak, 2004; Berhanu and Beyene, 2015). The results show that pastoralists in Rwenzori region use a non-equilibrium model of range management that makes use of herd mobility, livestock migration and livestock sales as climate adaptation strategies. This is consistent with the range management literature that discusses opportunistic management (Behnke, 1994; Elliot *et al.*, 1999; Thomas and Twyman, 2004). Non-farm enterprises are associated more with sedentary pastoralism than mobile pastoralism (Table II). This is consistent with earlier studies that revealed that settled pastoralists had better income diversification than those engaged in migration (Haji and Legesse, 2017; Elliot *et al.*, 1999). Studies have shown that although settled pastoralists have more income sources than mobile pastoralists, they had less welfare (Berhanu and Beyene, 2015; Elliot *et al.*, 1999). Wealthy pastoralists (using both forecast systems) with large heads of cattle do not use well excavation as a coping mechanism but livestock migration (Table V). A study done in Kenya revealed destocking as one of the coping strategies for wealthy pastoralists (Bryan *et al.*, 2013) while poorer pastoralists were hesitant about destocking (Silvestri *et al.*, 2012). Well excavation is associated with poorer pastoralists to address water scarcity during long dry spells. Studies have shown that incomes from fish sales are reinvested in livestock and non-farm enterprises (Olale and Henson, 2013; Nkuba and Sinha, 2014; Nkuba, 2006). Fish incomes reinvested in fish business such as an increase in the number of fish nets has sometimes led to overfishing and degradation of fisheries (Hartwick and Olewiler, 1998). Pastoralists derive their livelihoods from natural resources such as rangelands and fisheries; however, there is the danger of over-exploitation of fisheries by overfishing beyond the sustainable maximum yield of the water bodies (Nkuba and Sinha, 2014). Studies have reported over-exploitation of Uganda fisheries due to increase in the fish market prices as a result of market liberalisation (Nunan, 2006; Nkuba and Sinha, 2014; Nkuba, 2006; Balirwa *et al.*, 2003; von Sarnowski, 2004). Pastoralists with large livestock numbers are more likely to practice herd mobility and migration in search for water rather than well excavation (Berhanu and Beyene, 2015). During droughts and long dry spells, scarcity of pastures results into herd mobility as a coping mechanism. This is consistent with earlier studies that reported large herd owners practicing dual grazing rights in Botswana, Ethiopia and Niger (Perkins, 1996; Snorek *et al.*, 2014; Berhanu and Beyene, 2015). In pastoral communities, herd mobility is assigned to men and the boy child. This was the case in the study area and is consistent with findings of earlier studies (Brockhaus *et al.*, 2013). Having an advanced level of education increased the likelihood of adopting non-farm enterprises. Registration of micro-enterprises and payment of taxes to local councils requires education. This is consistent with earlier studies (Frank and Bahiigwa, 2003). The returns to labour from herd mobility were worth the investment. This is consistent with earlier studies in Ethiopia and Ivory Coast (Megersa *et al.*, 2014; Basset, 2009).

Although freehold tenure gives one good benefits from the land, herd mobility is a coping mechanism during long dry spells and droughts. A study done in Ivory Coast revealed that

herders practice mobile pastoralism because of higher productivity and better health of their livestock than that under sedentary pastoralism (Bassett, 2009). The availability of nutritious pastures during herd mobility is linked to forage selection by livestock resulting into higher fertility and productivity, which yields higher economic returns (Idibu *et al.*, 2016; Cañas *et al.*, 2003; Baumont *et al.*, 2000). Research has shown that controlled grazing results into grazing less nutritious forage especially during the dry season resulting into lower productivity (Idibu *et al.*, 2016). On one hand granting tenure security under customary land through titling would improve pastoralists' welfare by investing in infrastructure such as fencing, dip tanks and pasture development on private property. On the other hand, it would limit mobility and flexibility in rangelands. There is a need for the tradeoff. The World Bank strongly advocates for land titling while the new range ecologists advocate for common property regime in rangelands (Bassett, 2009). In Botswana, for example, some mobile pastoralism was transitioned into sedentary pastoralism through the tribal grazing land policy with support from the World Bank (Perkins, 1996). This policy has produced mixed results. On the one hand, the policy helped Botswana improve its access to EU beef markets. On the other hand, the policy did not lead to significant improvements in range conditions as dual grazing rights contributed to the continued degradation of communal rangelands (Perkins, 1996; Magole, 2009; Darkoh and Mbaiwa, 2002). The land tilting in Botswana has led to commercial farmers having access to both their ranches and the communal lands hence dual grazing rights (Darkoh and Mbaiwa, 2002). The establishment of fences in the rangelands not only limited livestock migration but also wildlife mobility, resulting in heavy losses during droughts (Perkins, 1996; Mbaiwa and Mbaiwa, 2006). Due to the limitation of mobility, droughts have very adverse effects on livestock farmers (Kgathi *et al.*, 2007). Mobile pastoralism is used to adapt to climate-related risks. This is consistent with earlier studies (Huhó *et al.*, 2009; Okoti *et al.*, 2014; Berhanu and Beyene, 2015).

5. Conclusion and recommendations

The study has established that the use of SFs and/or IFs had a significant effect on how pastoral households adapt to climate variability and change. Explicitly, the findings have revealed that pastoral households using IFs only were more likely to be engaged in non-weather related ventures such as non-farm enterprises and livestock sales, suggesting that the use of IFs was associated with sedentary pastoralism. The use of both SFs and IFs increased the likelihood of livestock migration, suggesting that mobile pastoralism was associated with both indigenous and scientific forecast systems, especially for long-range forecasts. The research has demonstrated that IFs complements SFs in pastoral adaptation to extreme weather events. Other factors found to be important in adaptation included gender, land ownership, education level, non-farm and productive assets, land tenure, agricultural extension and climate-related risks.

Climate-related risks were associated with mobile pastoralism. Non-farm assets and education level tend to promote engagement in non-weather related livelihood activities and enhance sedentary pastoralism. Livestock diversification significantly complemented herd mobility, implying that mobile pastoralism used opportunistic management of rangelands for climate change adaptation. Pastoral development policies addressing climate change adaptation should take cognizant of natural resource policies like fisheries and rangeland policies that take into account the poverty reduction strategies. Pastoral development policies addressing climate change adaptation should promote the integration of IFs in national meteorological services. A two-pronged approach that supports both mobile and sedentary pastoralism should be adopted in national rangeland policies.

IFs will continue to be part and parcel of pastoral societies in Uganda and sub-Saharan Africa. We do not challenge the use of SFs among pastoralists but confidence will improve with

an increase in the number of weather stations in pastoral areas. This would reduce spatial variation and increase the precision of predictions of meteorological forecasts. Investments in more weather stations (especially automatic weather stations) in pastoral areas may lead to more accurate scientific climate information in the future. Accurate scientific climate information is the bedrock for the weather insurance index and agricultural production insurance in improving the adaptive capacity of pastoralists. Thus, there is need to replicate this study in the future when there is a significantly higher density of weather stations in the Rwenzori region of Western Uganda and compare its results to those of this baseline study.

Notes

1. The strategy limits the mobility of pastoralists and transforms them into settled farmers that practise crop and livestock husbandry.
2. Social infrastructure such as schools, health units and water development infrastructure such as valley dams have been built in pastoral areas in Kasese district.
3. Region of pastoral districts in Uganda stretching from North East (of the Karamojong ethnic group) across to South East (of the Banyakole ethnic group).
4. To provide information on the community perceptions on importance of IK and SF in climate change adaptation.
5. To provide expert knowledge on climate change adaptation.
6. The focus groups and household survey were done concurrently during the data collection period.
7. A household may consider a particular factor important, which may not be important to another household. Factors considered by a farmer for a particular strategy may not be the same for another strategy. The consideration of these factors is not observed.
8. Decision making of which strategies to use from the various options is done concurrently not in isolation. For example, the decision to sell livestock can be influenced by engagement in non-farm enterprise in case incomes from sale of livestock are to be invested in non-farm enterprises. Hence, there is a correlation. Some strategies could be reinforcing each other or counter-productive. Pastoralist does not use only one strategy but a number of them at the same time that maximises the expected utility. Taking these decisions as not being correlated yet there are, can lead to biased estimates.
9. Herd mobility involves short distances of 1-20 km and returning to homestead at the end of the day.
10. Livestock migration involves long distances of 21-100 km and spending weeks or months away from the homestead.
11. The covariates in the MVP (Tables IV and V) differ because of precision concerns. Covariates with standard errors larger than the coefficients, high standard errors almost equivalent to the coefficient or larger than the coefficient indicate a poor estimation (Gujarati, D. N. 2013. *Basic Econometrics*, Boston, USA, McGraw-Hill companies) and were therefore not included in the models.

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