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ORIGINAL ARTICLE

Rural household vulnerability to climate risk in Uganda

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Abstract Vulnerability assessment is fundamental for informing adaptation to climate change policy. The aim of this study is to evaluate the vulnerability of rural subsistence farmers in Uganda to climate risk. A mixed methods approach used semi-structured and guided interviews, and participatory techniques to explore perception, livelihood response and socio-economic status. Perception of climate risk varied, with wealthier farmers perceiving drought as highest risk, whilst poorer farmers perceived extreme heavy rainfall. Farmers implemented many general livelihood coping and anticipatory responses (54.7 %) to perceived impacts from drought, rainfall variability and extreme heavy rainfall. Examples included food storage, livestock maintenance and planting drought-resistant varieties. Other responses (45.3 %) were specific to individual climatic events, and farmers had no response to cope with rainfall variability. Climate risk was not the only driver of vulnerability. Soil infertility, pests and diseases, and economic instability also sustained decreasing trends in income. Adaptive capacity of households differed with external and internal attributes of sensitivity. Farmers with more land, education, access to governmental extension, a non-farm livelihood, larger households and older age had more capacity to buffer shock through increased assets and entitlements than poorer farmers who were more likely to engage in opportunistic behaviour like casual labouring. Few livelihood responses associated with perceived threat from the climate indicating response to a broader range of stressors. Conclusions determined inequality in livelihood response as a fundamental driver in households' ability to cope and adapt to climate risk.

Keywords Vulnerability · Adaptive capacity · Livelihoods · Climate risk · Uganda

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Introduction

It is well recognised that climate change will intensify the vulnerability of human–environment systems (Wheeler and von Braun 2013). Constraints such as food insecurity, poor infrastructure and services, and weak governance are likely to exacerbate already vulnerable situations (Adger et al. 2006; McCord et al. 2015). Uganda the focus of this research has already witnessed an increase of 1.3 °C since 1960, and observed annual rainfall has decreased at an average rate of 3.5 % per decade (McSweeney et al. 2010). Projections foresee further increases in temperature, and increases in both extreme rainfall events and annual rainfall (McSweeney et al. 2010). These projections present serious risks for Ugandan livelihoods characterised predominantly by rain-fed subsistence agriculture (Berman et al. 2015). Fundamental to avoiding adverse consequences is effective adaptation policy to support vulnerable livelihood systems (IPCC 2014). Key to this process is the assessment of

vulnerability to target support programmes and other interventions (Singh and Nair 2014).

In recent decades, there has been considerable progress in both the conceptualisation and measurement of vulnerability, its roots embedded in geography and natural hazards research focusing on disasters (Adger 2006; Füssel 2007a; McDowell et al. 2016). Conceptual thinking gradually progresses from the risk-hazard framing of vulnerability to include scale, politics, economic, social and internal components (Eakin and Luers 2006; Füssel 2007a; Tucker et al. 2015). The most widely accepted conceptual framing for vulnerability to climate change integrates the latter thinking and comprises: exposure, sensitivity and adaptive capacity (Shah et al. 2013; IPCC 2014; Wang et al. 2014). Exposure addresses 'the degree of exposure of the system to climate hazards', referring to the magnitude of climate stress on a system, including long- and short-term climatic events. Sensitivity refers to 'the degree to which a system will respond to given change in climate, including beneficial and harmful effects' and the third component: adaptive capacity, defined as 'the potential or capability of a system to adapt to (to alter to better suit) climatic stimuli or their effects or impacts' (Adger et al. 2007; Shah et al. 2013). Adaptive capacity comprises a vital component of adaptation, linking vulnerability to adaptive action (Smit and Wandel 2006; Engle 2011; Pelling 2011).

Many approaches and methodologies exist to measure vulnerability, stemming from different disciplines; the inherent dynamic nature of vulnerability; and the wide range of contexts, systems and hazards, and normative interpretations of vulnerability (Brooks 2003; Eakin and Luers 2006; Füssel and Klein 2006; Füssel 2007b; Djoudi et al. 2013; Antwi-Agyei et al. 2014). Approaches include models and holistic approaches such as sustainable livelihood analysis (SLA) which links livelihood strategies to the broader environment (Eakin and Luers 2006; Antwi-Agyei et al. 2014). Useful are proxies or attributes serving as indicators of vulnerability, for example the Livelihood Vulnerability Index (LVI) developed by Hahn et al. (2009), derived from the SLA which uses household data to inform community-focused projects and policy (Shah et al. 2013).

Analysis at the household scale evaluates livelihood assets and wealth, proposed as key determinants of exposure, sensitivity and adaptive capacity to shock including climate risk (Cooper et al. 2008; Below et al. 2012; Wood et al. 2014). This asset-based approach builds on Sen's endowments and entitlement approach; a concept devised in the early 1980s. Endowments refer to: 'the assets owned and personal capacities which an individual or household can use to establish entitlement for food', and entitlements refer to: 'the relationships through which an individual or household gains access to food' (Elliot 1999: 109; Heltberg et al. 2009). Also important is the context-specific nature of vulnerability, which includes the broader drivers of threats to households and the embedding of households in the dynamic *milieu* of multi-scalar processes (Shah et al. 2013). Changes in temperature and increased variability in rainfall and extreme events which constitute climate risk are just a few of a multitude of stressors which a household has to respond and may not be perceived as the most important (Mertz et al. 2009). A household's vulnerability varies according to access to resources, options to diversify sources of income and social status (Adger and Kelly 1999; Berman et al. 2015). Households use these assets to buffer shock, but these strategies frequently present risk and trade-offs as they impact on the ability of households to maximise production, thus compromising future livelihood security (Heltberg et al. 2009).

Research into livelihood response to climate risk generally differentiates between two types of household responses. Coping responses referring to short-term (reactive) responses which households undertake to survive and spread risk from negative exposure to shocks (Corbett 1988; Cooper et al. 2008; Berman et al. 2015), and adaptation or anticipatory strategies, referring to responses with purposefulness to offset risk in the future over a longer timescale (Challinor et al. 2007; Antwi-Agyei et al. 2014). Coping is nothing new to farmers whom for generations have autonomously adjusted their livelihoods to offset risk to climate variability, but as stressors become more severe, the longer-term anticipatory strategies will become more important (Lee et al. 2014; Berman et al. 2015). There is much literature dedicated to the evaluation of these responses and variables influencing these responses (Eriksen and Silva 2009; Quinn et al. 2011; Trærup and Mertz 2011; Gebrehiwot and van der Veen (2013); Antwi-Agyei et al. 2014; Wood et al. 2014; Berman et al. 2015). For example, Antwi-Agyei et al. (2014) examine household adaptation strategies and perception of climate change of farmers stratified by wealth, and Berman et al. (2015) evaluate household responses to different climatic parameters. This paper also focuses on both coping and anticipatory strategies to different climatic parameters and the influence of household wealth on these strategies, but also extends the investigation to evaluating perception of risk from the climate and its influence on livelihood response.

Ultimately, it is the ability of a household to undertake these responses which determines its adaptive capacity, capacity which is frequently unequal and influenced by capital assets and attributes (Corbett 1988; Heltburg et al. 2009; Tschakert 2007; Eriksen and Silva 2009; Saroar and Routray 2012). Determinants of this inequity equate to the conceptual notion of sensitivity to climate change discussed earlier and can be categorised into external and internal attributes (Eakin and Luers 2006). External

attributes represent externalities such as assets, entitlements and institutional interaction, and internal attributes as innate features such as gender, age, education, household size and culture (Eakin and Luers 2006; Below et al. 2012). All these attributes combine and interact to determine a household's ability to cope, adjust and adapt to exogenous shock (Eakin and Luers 2006). For example, assets such as land and livestock equate with increased adaptive capacity through increased income, contingency and a source of savings (Mortimore and Adams 2001). Internal attributes are endogenous components of a household which influence adaptation including goals, values, risks, perceptions and social choices (Adger et al. 2009).

Risk perception is another internal aspect of vulnerability and significant because perceptions of risk from the climate influence farmers' decisions and behaviour relating to coping responses and adaptation strategies, thus presenting implications for the success of adaptation policies (Meze-Hausken 2004; West et al. 2008; Rao et al. 2011; Antwi-Agyei et al. 2014). For example, farmers make decisions every year on crops, technologies and management strategies (Rao et al. 2011). For marginalised farmers, this is a risky endeavour, as seasonal variation in rainfall can affect productivity and profitability. Generally, farmers tend to be risk averse; therefore, elevated perceived risk from the climate could result in avoiding beneficial agricultural investments which give better returns (Hansen et al. 2007; Rao et al. 2011).

Uganda could be one of the most vulnerable countries to climate change with 88 % of the population dependent on rain-fed agriculture (Apuuli et al. 2000). Without adaptation, climate change will inevitably result in insurmountable challenges in the security of food, water and livelihoods leading to hunger, poverty, migration and conflict over dwindling natural resources (May et al. 2012). Given the context-specific nature of vulnerability, this analysis makes a significant contribution to mapping out vulnerability in a specific region of Uganda to inform national adaptation policy. The principle aim of this paper is to evaluate the vulnerability of rural subsistence farmers in Uganda to climate risk. The research questions: (1) what are the anticipatory and coping responses to climate variability and change, and (2) what are the determining factors and issues that enable or constrain the adaptive response to climate change were used to guide this research.

Data Collection

The conceptual framing promoted by the IPCC was used to guide the research and is illustrated in Fig. 1. Here, sensitivity is divided into its internal and external aspects. The internal aspects comprise the innate features of an exposure unit. The exposure unit in this research was a household, and the external aspects refer to the magnitude of exposure and the externalities which affect sensitivity (Eakin and Luers 2006; Shah et al. 2013). Proxies were selected to represent both aspects. The arrows represent not only the influential links between the two aspects and adaptive capacity (extent of livelihood response) which determine vulnerability but also represent the dynamism and shifting of these components over time.

Fieldwork took place over 7 months between January and August 2010 in Mbarara District located in south-western Uganda. Topography lies between 1200 and 2100 m and is characterised by a mixture of rolling hills with dry vegetation (GoU 2004; Nyende et al. 2007). Agriculture is mostly subsistence, pertaining to the perennial banana and coffee system. Small numbers of livestock are also kept, and annual crops such as maize and sweet potato are common (Nyende et al. 2007). Land holdings are small (generally 0.5–1.0 ha) due to high population and land fragmentation; therefore, intensive agriculture is common. Agriculture is predominantly rain-fed, with two distinct rainfall seasons. First season's rainfall occurs between March and May, and the shorter second season falls between September and November (Basalirwa et al. 2006; Goulden 2006; Toulmin 2009). The major urban centre nearest to the study region is Mbarara Town, serving as a major transport and economic hub, located 180 km from Kampala. One of the country's major highways passes through constituting a major trading route to Rwanda and the Democratic Republic of Congo (Spilsbury et al. 2002). A major river, the Rwizi flows through the town constituting an important water source in the region.[1] Two study sites were selected for the presence of active institutional governmental and non-governmental extension and development projects and their proximity to a weather station in Mbarara Town. Nyanja Parish in Bukiro Sub-County is located 40 km from Mbarara Town and 6 km from the nearest sealed road and town: Bwizibwera. Rukindo Parish in Nyakayojo Sub-County is located just 15 km from Mbarara Town with the major road connecting Kampala with Rwanda running centrally through the parish and the nearest town Ruti (2 km). As a result, farmers here were better connected, with more options for livelihood diversification and market access.

Full details of data collection and methods are given in Cooper and Wheeler (2015). A mixed methods research approach was used to achieve a balance between

[1] Proximity to a weather station was selected to benefit other related research. The sampling of study sites did not use location as a selection factor; however, location was used in the study to assist comparative analysis.

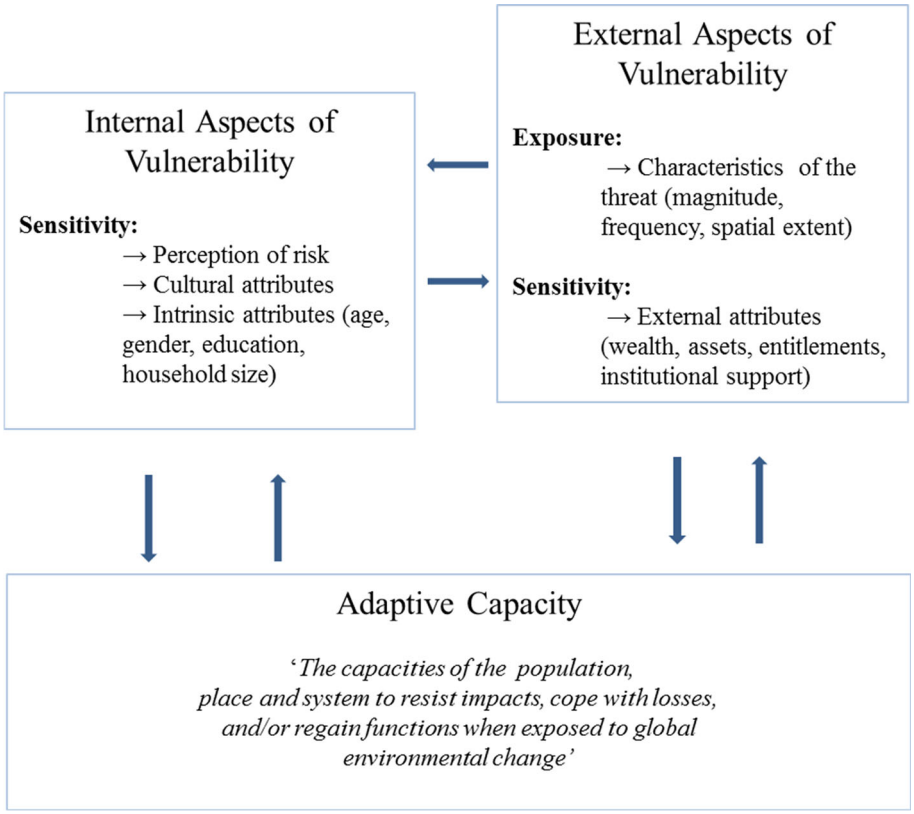

Fig. 1 Conceptual framework for analysing vulnerability to climate risk *Source* (Eakin and Luers 2006; Adger et al. 2007)

quantitative robustness and the qualitative exploration of process and dynamics (Cresswell 1994; Yin 2003; Bryman 2008). Semi-structured questionnaires (SSI) were used for their structure but also to give respondents the flexibility to express opinions and ask questions. One hundred and sixty farmers (80 in each parish) were randomly sampled using the strata of gender and participation in agricultural extension. Male farmers tended to be the head of household, whilst female farmers were either head of household or married. Households were selected as they were the scale at which livelihood decisions are made (Antwi-Agyei et al. 2014). Farmers were questioned on how exposure to three climatic parameters impacted on their livelihoods. Parameters selected were drought (including inter- and intra-seasonal dry spells), rainfall variability (RV) (seasonality and uneven distribution of rain within seasons) and extreme heavy rainfall events. These parameters were selected from the literature for their projections to increase in frequency, magnitude and scale of exposure in East Africa (Boko et al. 2007). An assumption was made that all farmers' livelihoods were affected by these parameters. Subsequently, the timescale typology was then used to document adaptive capacity to all three climatic events, documenting reactive/*ex post* responses as coping responses and anticipatory/*ex ante* strategies as anticipatory strategies, collectively referred to as livelihood responses. Respondents were also asked questions concerning demographic and socio-economic characteristics. Proxies selected to represent intrinsic attributes of sensitivity were gender, age, education and household size, selected for their innate features which determine ability to cope and adapt to shock (Eakin and Luers 2006). Selected external attributes were represented by land ownership, employment in a non-farm livelihood (any income-generating activity which was not crop or livestock production), participation in agricultural extension (extension farmers) and livestock ownership, all hypothesised to influence adaptive capacity (Below et al. 2012). Importantly, many farmers perceived temporal changes in rainfall and temperature, and these perceptions framed their responses. All interviews were conducted in the local language, '*Runyankole*', with translation provided by a recent graduate from a local university. The data from this exercise were triangulated with qualitative data retrieved from four focus group discussions with between 4 and 14 participants, including an historical timeline, problem tree and wealth-ranking analyses. Data also derived from case study ($n = 62$) and key informant interviews ($n = 35$) conducted for related research. Data were analysed as follows: descriptive statistics were applied by generating frequencies for nominal and ordinal data and the mean ± standard deviation for continuous data. Associations between nominal variables were established using the Pearson's Chi-square test, significance indicated by a p value of 0.005 or less.

Qualitative data were analysed by selecting themes and then coded using the conceptual framing for this research.

Results

The broader drivers of vulnerability experienced by farmers over time are documented in Fig. 2. Seventy-two per cent of farmers in Nyanja and 47.5 % of farmers in Rukindo had experienced decreases in income over time. Reasons attributed were soil infertility, increased soil erosion, increased pests and diseases, drought, land shortages and falling market prices.

Perception of climate risk

Farmers ranked specific climatic parameters which they perceived most threatening to their livelihood to explore perception of climate risk. Extreme heavy rainfall was ranked most frequently (48.1 %; $n = 160$), followed by drought (26.9 %; $n = 160$). Uneven distribution of rainfall was the third most stated (16.3 %; $n = 160$), followed by intense heat (4.4 %; $n = 160$) and then variability in the start (2.5 %; $n = 160$) and the end (1.9 %; $n = 160$) of the rainfall seasons. Extreme heavy rainfall was ranked more frequently by non-extension farmers, those with land less than 1 acre, and those with primary or no education, whereas drought significantly associated with extension farmers, and those who had attained higher education, revealing a trend towards vulnerable farmers ranking heavy rain as most threat, and wealthier farmers ranking drought.

Analysis revealed few relationships between farmers' perception of threat from the climate risk and their livelihood response. For example, those who perceived drought coped by selling livestock and turning to the government for assistance, often wealthier farmers who owned livestock and had the capacity to access these networks. Those perceiving extreme heavy rain were more likely to cope

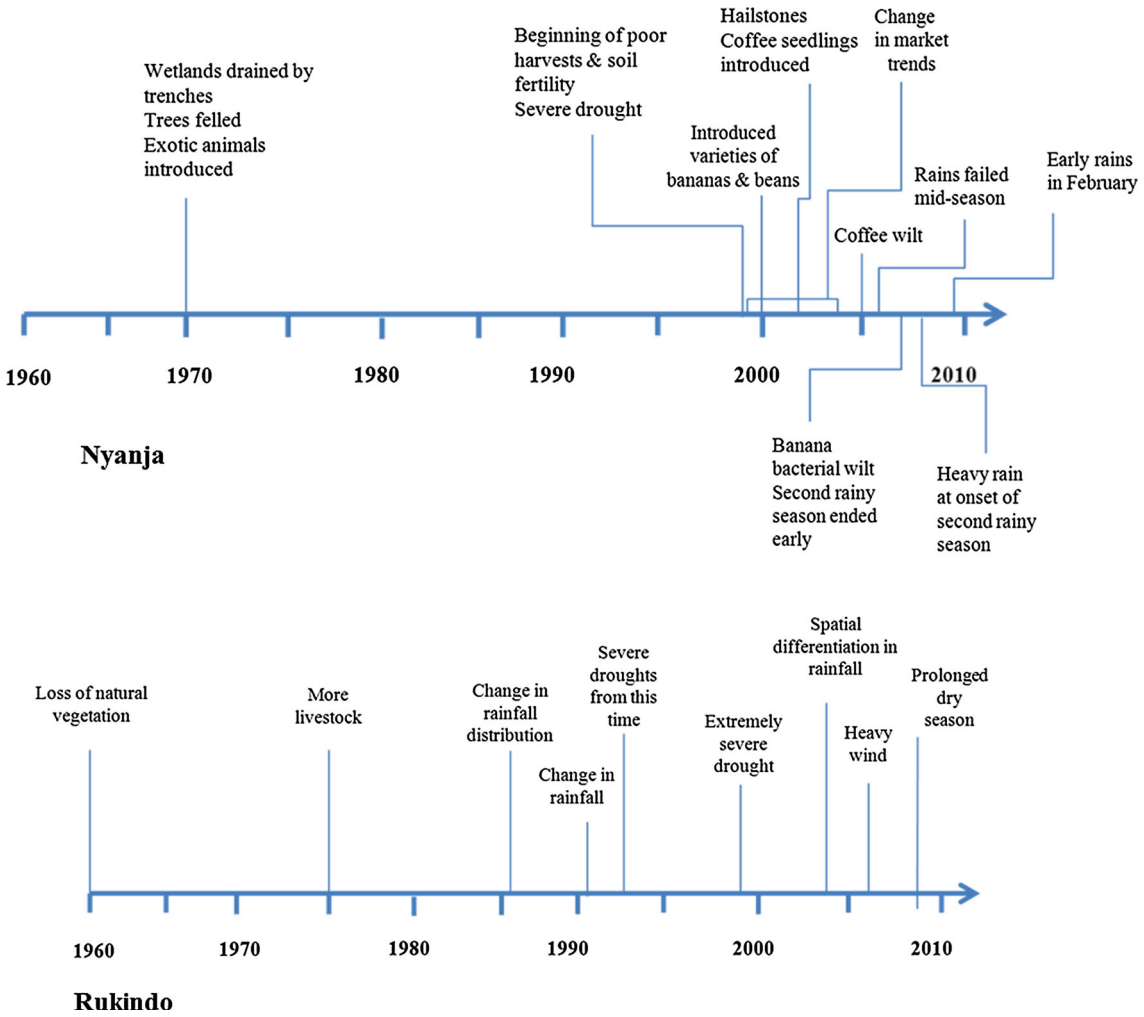

Fig. 2 Historical timeline of events chronicled by farmers ($n = 180$) in Nyanja and Rukindo

through replanting crops. These farmers had fewer assets and smaller cultivated areas to cope, thus necessitating the immediate replacement of destroyed crops for future food security. As would be expected, farmers perceiving an unpredictable start to the season anticipated through planting earlier, whilst those who felt most threatened by an unpredictable end anticipated by using tanks to water crops to assist maturation of crops. Those perceiving uneven distribution of rainfall anticipated through storing food or had no response on how to prepare for this variability. Other livelihood responses significantly associated with threats which did not correspond with their most ranked threat, potentially due to farmers perceiving another threat similarly, or because the response provided protection from more than one threat.

Adaptive capacity and exposure to climate risk

Exposure, coping responses and anticipatory strategies of livelihoods to drought, rainfall variability and extreme heavy rainfall are illustrated in Table 1. This section then continues to document farmers' perception of climate risk and cultural attributes.

Exposure to drought

Farmers' perceived impacts of exposure to drought and higher temperatures included the loss of livestock through death and disease and reduced income, stated by one-fifth of farmers. Impacts related to crop failure were prevalent, followed by famine,[2] accelerated banana ripening and the desiccation of trees. Three quarters of farmers referred to reduced water quality and availability and poor pasture. One-third of farmers mentioned soil infertility and compaction. Increases in malaria, less energy and flu-like symptoms were also reported.

The maintenance of livestock was frequently used to cope with drought in both parishes but by significantly more farmers in Rukindo, who had more options for selling livestock and more income to maintain livestock. Farmers in Nyanja travelled longer distances to water, as Rukindo was closer to a major river and wetlands. Farmers in Nyanja were twice as likely to source income from elsewhere, either from informal social networks or formal networks such as banks and microcredit groups. Nyanja's remote location may have facilitated a reliance on informal networks due to fewer non-farm livelihood options to obtain income.

Sourcing an alternative supply of water was common. Some farmers travelled to sources, whilst others owned storage tanks or wells. Accessibility to water was less challenging in Nyanja as they had a municipal system of pipes and taps, whereas Rukindo had a system of bore holes which became competitive to access during drought; therefore, buying water was frequent in Rukindo. Many responses directly or indirectly related to maintaining food security: either by directly buying in food and/or subsisting on stored food, or indirectly through obtaining money to purchase food. Farmers in Rukindo had increased reliance on non-farm occupations and subsistence on stored food. Close proximity to a major road and an urban centre presented other livelihood opportunities and income to store food, whereas farmers in Nyanja travelled for cheaper food and laboured, reflecting fewer livelihood options.

Storage of food in houses or granaries was a common anticipatory strategy, and the planting of drought-resistant crops was stored in the ground until needed. Securing water resources was important in Rukindo due to the insecurity of their bore hole system. Strategies included storage tanks, building dams, and the use of jerry cans and metal drums, additionally the conservation of wetlands and maintenance of water infrastructure. Financial difficulties were pre-empted by selling crops and labouring. Farmers' also stored forage, dug ditches and planted trees.

Exposure to rainfall variability

Crop failure was frequent with rainfall variability (RV). The uncertainty onset of rainfall resulted in confusion of when to plant leading to wasted seeds, reduced income, increased food prices and an inability to plan livelihoods. Ill health due to malaria and coughs was also documented.

In Nyanja, replanting crops after crop failure was used by third fewer farmers to cope with RV. Fifty per cent of farmers in Rukindo and one-third in Nyanja had no remaining seeds to replant or income to replenish seeds. However, some farmers overcame this by accessing social networks to swap seeds. Other farmers felt it was too risky to replant, whereas some waited for the next rainfall. Some farmers perceived that there was nothing they could do. Farmers in Rukindo responded using irrigation, from access to wetlands and the river.

Storing food was a frequent response to anticipate RV in Nyanja, whereas strategic planting was common in Rukindo due to increased information and more livelihood options. Strategic planting minimised crop failure through crop diversification, planting crops nearer wetlands and planting earlier. Planting drought-resistant crops was used by significantly more farmers in Nyanja. One-sixth of farmers did not know how to respond to RV in the future.

[2] Accelerated ripening of bananas occurs due to increases in the production of ethylene: a plant hormone produced excessively when plants are under stress (Liu et al, 1999). Further climate stress palpably has serious implications for this region's food staple.

Table 1 Exposure, coping responses and anticipatory strategies of farmers (%) to climate risk in Nyanja ($n = 80$) and Rukindo Parishes ($n = 80$)

Exposure	Drought: Livestock death/disease Reduced income Famine/Crop failure Accelerated banana ripening Desiccation of trees Availability of [clean] water Compacted soil/pasture Health problems		Rainfall Variability: Reduced income Wasted seeds Crop failure/rotten crops Planting confusion Famine/high food prices Compacted soil/poor pasture Increase in malaria		Extreme Heavy Rainfall: Livestock death/disease Reduced income Destroys houses Crop failure Famine/pests Soil erosion/reduced pasture Flooding Felling of trees Flu/disease/malaria Death	
	Nyanja	Rukindo	Nyanja	Rukindo	Nyanja	Rukindo
Coping responses						
Livestock maintenance	57.5	80.0	1.3	1.3	33.8	25.0
Travelled to water source	51.3	17.5	0.0	1.3		
Alternative water source	37.5	46.3	1.3	2.5		
Purchased food	33.8	46.3	20.0	17.5	8.8	1.3
Liquidised assets	27.5	18.8	10.0	2.0	6.3	5.0
Source income	27.5	10.0	16.3	2.5	11.3	1.3
Labouring	17.5	6.3	7.5	3.8	0.0	1.3
Medical assistance	12.5	10.0			25.0	7.5
Irrigation	12.5	22.5	6.3	18.8		
Subsist on food stores	11.3	32.5	2.5	10.0	10.0	2.5
External aid	7.5	0.0	7.5	1.3	21.3	6.3
Plants and waits	5.0	0.0				
No response	5.0	0.0	33.8	45.0	3.8	31.3
Alternative livelihood	2.5	15.0	0.0	3.8		
Crop technologies	2.5	3.8	6.3	5.0	3.8	0.0
Purchased water	1.3	36.3				
Water from borehole	0.0	28.8				
Replant crops			41.4	11.3	18.8	10.0
Travel to source food			10.0	3.8	6.3	5.0
Waits for next rainfall			2.5	1.3		
Accessed social networks			2.5	0.0		
Dig ditches					35.0	17.5
Support crops					32.6	31.3
Clear ground					20.0	16.3
Mulch/manure soil					10.0	2.5
Cut leaves					10.0	17.5
Rebuild houses					8.8	6.3
Anticipatory strategies						
Food storage	93.8	90.0	65.0	31.3	30.0	13.8
Water security	36.3	56.3				
Drought-resistant varieties	32.5	45.0	22.5	6.3	8.8	0.0
Livestock maintenance	21.3	37.5			37.5	12.5
Financial investment	11.3	11.3	3.8	2.5	3.8	1.3
Crop technologies	12.5	7.5	5.0	10.1	3.8	11.3
Change of strategy	12.5	2.3				
Plant trees	3.8	1.5			12.5	27.5
Digs ditches	1.5	3.8			77.5	75.0
No response	0.0	1.5	15.0	18.8	2.5	3.8

Table 1 continued

Exposure	Drought: Livestock death/disease Reduced income Famine/Crop failure Accelerated banana ripening Desiccation of trees Availability of [clean] water Compacted soil/pasture Health problems		Rainfall Variability: Reduced income Wasted seeds Crop failure/rotten crops Planting confusion Famine/high food prices Compacted soil/poor pasture Increase in malaria		Extreme Heavy Rainfall: Livestock death/disease Reduced income Destroys houses Crop failure Famine/pests Soil erosion/reduced pasture Flooding Felling of trees Flu/disease/malaria Death	
	Nyanja	Rukindo	Nyanja	Rukindo	Nyanja	Rukindo
Strategic planting			16.3	45.0	13.8	5.0
Seed storage			6.3	2.5		
Experiment with test area			3.8	3.8		
Short-maturing varieties			2.5	7.5		
Cut leaves			0.0	1.3	31.3	71.3
Buy in food			0.0	5.0		
Support crops					67.5	78.8
Mulches/manures					36.3	11.3
House protection					5.0	2.5
Protects firewood					2.5	2.5
Medical assistance					2.5	0.0

Exposure to extreme heavy rainfall

Crop failure was referred to by 96 % of farmers as an impact of extreme heavy rainfall, accompanied by strong winds and occasional hailstorms which destroyed fruit and young seedlings. Soil erosion was a major problem, reducing cultivable land area by washing away fertile soils and young seedlings. Livestock was occasionally lost from hailstones and disease. Destruction of houses was frequent due to wind removing roofs and landslides, occasionally resulting in death. Farmers complained of flooding limiting crop and livestock production, causing famine and increasing malaria and other diseases.

Significantly more farmers in Nyanja dug ditches to channel water and prevent soil erosion due to undulating topography increasing surface run-off. Crop supports (wooden poles or rope) were used to prop up banana plants heavy with fruit, along with clearing fallen fruit and debris. Fallen debris had multiple uses in the household, such as livestock fodder, cooking and transportation of crops. One quarter of farmers in Nyanja and fewer in Rukindo sought medical assistance for malaria, whilst farmers in Nyanja borrowed money and bought food due to fewer earning opportunities.

Anticipatory strategies were similar to coping responses through digging ditches and using crop supports. Farmers in Nyanja were more likely to maintain livestock, to protect their soil through mulching/manuring and to store food, indicative of the lengthier presence of government extension being and fewer livelihood options. Cutting leaves and planting trees as wind barriers in Rukindo were evidence of local tree-planting projects.

Sensitivity

Significant associations between the attributes of sensitivity and wealth indicated that wealthier farmers were more likely to own more land, participate in extension and have a formal education. Farmers in both parishes engaged in non-farm income, characterised in Rukindo by high- to middle-income farmers diversifying into skilled or entrepreneurial livelihoods, contrasting with low-income farmers in Nyanja who engaged in casual labouring. Overall, younger farmers were generally poorer than older farmers and marginal households had fewer members than wealthier households. No associations were detected for gender due to the wealth ranking representing the status of the household rather than the individual and the differentiation in type and number of livestock was not accounted for in the analysis.

Relationships between these attributes of sensitivity and farmers' perception of exposure to climate parameters, their coping responses and their anticipatory strategies were analysed. Data from both parishes were combined to assist analysis. No associations were detected between land

owned and exposure. Farmers with more land coped with drought by travelling further for water and by providing forage for livestock. These farmers tended to be wealthier, owning more livestock. Increased land facilitated the ability to buy in or grow forage for food storage. Farmers with less land had fewer assets or coped through labouring.

Diversifying into non-farm livelihood strategies increased income and provided a buffer against crop failure. Those engaged in non-farm livelihoods mentioned the exposure to lack of income for drought and famine more frequently, quoted by those who laboured casually, whilst those not engaging stated rotting crops and lack of clean water. Only those with a non-farm livelihood could dig ditches as a coping response having the potential to pay for the labour. Expensive technologies such as mulching/manuring and water storage were also only employed by those who diversified. Coping through replanting crops, anticipating by planting drought-resistant crops and having no response for RV were highlighted by farmers with no non-farm livelihoods reflecting their increased reliance on crop production.

Predictably, livestock ownership associated with those responses concerned with their maintenance. Livestock ownership an indicator of wealth correlated with the ability of farmers to store water in tanks, and use expensive and difficult to obtain short-maturing varieties of crops. Livestock ownership equated with participation in agricultural extension providing access to new technologies. A lack of response in anticipating RV could reflect their reduced reliance on crop production under times of stress.

Participation in extension revealed increased capacity among farmers. These farmers perceived exposure to less pasture and flooding of land. They were also more able to provide forage, support their crops and obtain water; 16.3 % of farmers in Nyanja and 50 % of farmers in Rukindo had experienced an increase in their income over previous years due to crop diversification initiated through training from extension services. Reduced capacity to cope with drought was indicated by non-extension farmers (farmers not participating in agricultural extension) engaging in opportunistic labour for food and/or money.

Women were more likely to labour for food and money and ask neighbours for food, and their close ties to crop production were indicated through a significant association with concerns of delayed planting. Men's responsibility for handling livestock and cash income was exhibited with obtaining water (for livestock) and saving money. Men were more able to irrigate and obtain water to cope with RV demonstrating increased awareness of technologies but also due to them being stronger and more capable of carrying a jerry can to water crops.

Education paralleled with wealth, with wealthier farmers having better education. Those with secondary or higher education could cope with RV by using crop management and through providing forage to livestock during drought. They also anticipated RV by planting earlier reflecting their ability to take risks. Those farmers lacking education were more vulnerable, coping with RV by buying food, asking neighbours for food and subsisting on stored food. They were also more likely forced to cope with heavy rainfall by selling livestock/crops leaving them more exposed to further shock, and to anticipate RV by storing food or have no response due to lack of options.

Older farmers tended to have more wealth than younger farmers. Those farmers over 60 years highlighted the accelerated ripening of bananas. Lack of pasture, cutting leaves, engaging in planting strategies, eating less, relying on drought-resistant varieties and the use of crop supports were documented with farmers aged between 31 and 60 years indicating increased access to resources and physical ability. Frequently, these age groups also had older children to contribute to livelihood activities and gained more experience of livelihood skills. In comparison, younger farmers struggle had less experience and access to less land which they may have to share with parents or siblings. This could explain the increased number of farmers aged <30 years accessing low-skilled employment or casual labour in Nyanja.

Few responses associated with household size. Smaller households coped with the immediate threat of heavy rain by digging ditches. This response may have been considered too laborious to implement as an anticipatory strategy due to the perceived higher effort, so only implemented under immediate threat.

Impact of culture on livelihood response were analysed through observations during fieldwork. These highlighted beliefs of a religious or superstitious nature. Religion was significant. When questioned on climate change, a church leader stated: 'Everything is written in the bible concerning the change in climate, everything we need to know is written there'. Farmers unsure how to respond to future climate change, stated their faith in God as their only future security to coping with inclement climate events. Beliefs also centred on witchcraft and superstition which produced similar fatalistic outlooks. Livelihood responses as superstitious beliefs included: 'When we get heavy rain with ice, I put this ice in a bottle and throw the bottle outside. This will calm the rain and winds down',[3] and "When there is heavy rain, I dig in the middle of the compound to stop the rain. I also get a bottle of soda and put this in the middle of the compound with a coin on top".[4] The following section discusses the findings of this research and draws out the important conclusions.

[3] Farmer interview: [SSI.23.MN.NY.Y, Nyanja, 16th February 2010].

[4] Farmer interview: [SSI.113.FN.R, Rukindo, 27th April 2010].

Discussion and conclusion

Climate risk was among various inter-related issues which contributed to livelihood vulnerability in Uganda. Factors such as population increase, bio-physical features (soil erosion, climate and changes in vegetation cover), intensification of production and the customary inheritance of land ownership have reduced land availability causing a decline in soil fertility (Vuylsteke et al. 1993; Bagamba 2007). Many farmers, particularly in Nyanja, had been forced to abandon their coffee plantations. The prolific increase in the disease coffee wilt, and a crash in international coffee prices in 1999 resulted in farmers losing 50 % loss of their coffee's value, making coffee an unviable option. Uganda has lost up to 45 % of their coffee trees severely affecting income for poorer households (You and Bolwig 2006).

The 'sharp' shock from extreme heavy rain, contrasted with the subtle pervasive nature of drought, which may explain why marginalised farmers perceived a higher threat from extreme heavy rain. Farmer perception has important implications for adaptation. Grothmann and Patt (2005), Patt and Schröter (2008) and Slegers (2008) all comment on cognitive biases which describe the propensity of farmers to underestimate large probabilities of risk and overestimate smaller probabilities of risk, or where they judge a risk according to the vividness and extent of their memory. This perception of risk has the potential to impact on an individual's perception of self-efficacy and perceived effectiveness of an adaptive action, so affecting their adaptive capacity (Grothmann and Patt 2005; Alpizar et al. 2011; Sarour and Routray 2012; Djoudi et al. 2013). For example, those who perceived RV as the most threat were more likely to have no response for future RV. Few associations were revealed between farmers' perception of threat from climate risk and their livelihood response. Essentially, climatic risk cannot be extracted from the complexity of the social, economic and political context; therefore, farmers do not extricate climatic risk from other stressors which influence the reasoning and decision-making behind a livelihood response (Mubaya et al. 2012).

Crop failure was the most frequent outcome from exposure to all three climatic parameters. Adverse weather conditions can affect water availability by altering surface hydrological dynamics, as in water logging and soil erosion from heavy rain, or reducing water availability through increased evapotranspiration during drought conditions, both reducing yields (Rosenzweig et al. 2002; Few 2003; Toulmin 2009; Thornton et al. 2010; McCord et al. 2015). Limited water availability also affected pasture, reduced access to clean drinking water and increased disease. Farmers coped by travelling and sourcing alternative water sources, buying in water or in the case of Rukindo, reliance on a limited number of bore holes. Shortages in water can have a deleterious effect on subsistence livelihoods, pervading every aspect of a household functioning, including food security, financial stability and health. Increased competition for water can ultimately result in conflict and the breakdown of social networks and institutional management of resource rights leading to insecurity and inequality to access rights (Tanner et al. 2014).

Many interventions for extreme heavy rainfall were laborious or expensive, which could explain its ranking by poorer farmers as the greatest threat to their livelihoods. Lack of income was a significant limiting factor for adaptive capacity. Income offers a buffer against risk and presents options to save, invest and implement a choice of responses, and to diversify away from agriculture (Kakota et al. 2015; Tanner et al. 2014). Fundamentals for income were self-organised microcredit schemes. Poorer farmers tend to be excluded from formal financial institutions through poor credit ratings and non-existent collateral, so microcredit helps bridge this gap. Hammill et al. (2008) stress the importance of these schemes for adaptation. For example, access to microcredit can enable the implementation of soil and water conservation techniques and regular meetings strengthen social capital.

There were no specific coping responses for RV, thus demonstrating the significant vulnerability of farmers to potential increases in RV events. RV made crop production a highly risky venture. Frequently, farmers only option is to replant in the event of crop failure, but this necessitates the reinvestment of already scarce resources (Cooper et al. 2008). Farmers attempted to offset this risk by planting earlier, planting short-maturing varieties and/or strategic planting. However, the unpredictability of the onset of rainfall may have brought mixed results. Farmers tend to wait for a significant rainfall event before sowing seed, but false starts can result in seed wastage and heightened perception of risk causing confusion on planting (Marteau et al. 2011).

Many responses were targeted towards food security and evident for all three climatic parameters. Farmers coped either directly through purchasing food, asking neighbours for food, subsisting on stored food, or indirectly by generating income and/or the liquidation of assets. According to Pereira (2013), this divide between production and consumption is becoming more common place in Africa, increasing reliance on the private sector for food. Aspects of livestock maintenance were a frequent indirect response. Livestock have a crucial role to play in adapting to climate risk as they are a source of wealth and provide a safety net at difficult times (Thornton et al. 2007; Freeman et al. 2008). However, the selling of assets can be a risky strategy for marginal households, as it can undermine their ability to cope in the future (Trærup and Mertz 2011).

Livestock maintenance was also important as a generic anticipatory strategy, along with the storage of food, mulching/manuring and the planting of drought-resistant crops. Food storage is considered one of the key strategies in buffering livelihoods from failed crop production (Codjoe and Owusu 2011). Unfortunately, climate change has negative implications for food storage. Unstable moist weather conditions and increased temperatures increase the moisture content in food, shortening preservation. An increase in extreme rainfall events will also damage granaries (FAO 2008). Drought-resistant crops were also important providing farmers with insurance against crop failure, and mulching/manuring improves soil fertility, aeration and moisture content (Lithourgidis et al. 2011; Otitoju and Enete 2014; McCord et al. 2015).

In Rukindo, farmers who participated in agricultural extension were more likely to own more land and generate non-farm income. This trend also equated with higher-educated farmers. In Nyanja, farmers active in extension were also more likely to own livestock. The research suggested selected attributes such as education, and participation in extension, operate in a self-perpetuating manner, where the possession of such attributes increase the likelihood of generating other attributes, such as assets and entitlements which influence wealth in the household and in turn adaptive capacity. For example, land ownership increased the capacity to store food, trade crops and livestock and produce forage for livestock. It also reduced the necessity to engage in casual labour. This is supported by Bryan et al. (2009) and Gebrehiwot and van der Veen (2013) who found larger land areas, improved access to land and property rights increased adaptive capacity, through enlarging the scope for experimentation and the implementation of risk-averse strategies such as strategic planting and increased crop production. Non-farm livelihoods provided additional income for farmers enabling them for increased capacity for water storage, digging ditches and applying manure/mulches. Non-livelihoods are increasingly important for coping with climate risk due to declining agricultural productivity (Paavola, 2008). Location was the fundamental driver for the increased likelihood of non-farm livelihoods in Rukindo, due to the proximity of a major town, road, river and extensive wetlands presenting more opportunities. Asset-rich households also have better connected social networks, including participation in extension, and are more capable of putting their social assets to use, particularly in time of shock. Poorer households have less social status and tend to be excluded from risk-bearing institutions such as financial services (Adato et al. 2006; Paavola 2008; Enete and Onyekuru 2011; Rodima-Taylor 2012; Gebrehiwot and van der Veen 2013).

Older age correlated with more land (Nyanja) and a wealthier status (Rukindo) which parallels with Deressa et al. (2009), Enete and Onyekuru (2011) and Gebrehiwot and van der Veen (2013) who all found older farmers had more experience and were better able to make decisions concerning risk and adaptation strategies. For example, Deressa et al. (2009) found per unit increase in age increased use of soil conservation techniques, changes in crop varieties and tree planting. Farmers tend to learn from trial and error by experimenting in their livelihoods resulting in an accumulation of knowledge over time (Berkes et al. 2000).

Large household sizes equated with wealth and with farmers having more land and livestock. The large household could be indicative of wealth due to the increased capacity of the household to support more family members and in turn increase the individuals available for labour and to earn income, as documented by Mortimore and Adams (2001) who found larger households had increased capacity to keep livestock.

Gender divisions were evident among some responses. For example, women were more likely to cope by labouring for food and income and asking their neighbours for food, whereas men were more likely to cope by obtaining water and irrigation. Also reflected in anticipatory strategies where men were more involved with livestock strategies and women in crop related. Generally in developing contexts, men and women have distinct roles within rural livelihoods and society in general. Women have different access to entitlements, assets and other opportunities, and often their decision-making has to be mediated through men (Ellis 1999; Nelson et al. 2002; Below et al. 2012). There is often a gender division of labour, where women are more responsible for caring roles and for crop production, whilst men take an active role with livestock and cash income. Women also face the choice of a narrower labour market and lower wages than men and are limited by other responsibilities, and lack of education, trapping them into customary roles (Ellis 1999; Otiso 2006). Molua (2011) and Rodima-Taylor (2012) found that women in Cameroon were just as risk averse as men, but their restricted access to resources and decision-making, constrained them to implementing low-cost adaptations for crop production.

The observations on cultural beliefs to climate change suggested that they could potentially impact on farmers' perception of risk and livelihood response, specifically those which lead to fatalistic outlooks and inaction. Ultimately, cultural beliefs can shape and influence people's behaviour, potentially leading to 'irrational livelihood responses', resulting from misinterpretation of institutional interventions for adaptation (Adger et al. 2013).

This analysis of vulnerability has highlighted some of the major issues challenging households in responding to climate risk and presents significant implications for adaptation. A fundamental driver of vulnerability was the inequality between households and their capacity to respond to climate risk. Wealthier households with increased assets, social status and education were better able to buffer climate risk than poorer households. Frequently, marginalised households are distanced from enabling institutional processes. It is essential that adaptation policy recognises this inequality by strengthening local institutions to include poorer households through local language, cultural recognition and social networks, also through the fairer distribution of resources by improving trust and accountability within the institutional framework (Cooper and Wheeler 2015).

Additionally, adaptation policy should recognise that climate risk is only one of a broad number of stressors to which household respond. This is clearly indicated with few household responses associating with farmers' perception of climate risk and farmers' temporal account of past shocks. This necessitates the mainstreaming of adaptation into other policy trajectories to underpin a systems perspective and account for livelihood responses to a multitude of stressors (Cooper and Wheeler 2015). Adaptation policy also needs to demonstrate flexibility in incorporating the context of any focus of implementation. For example, this research highlights the influence of contextual factors in livelihood response, for example the proximity of Rukindo to a major town and transport hub which improved livelihood opportunities through diversification and increased access to markets.

This research provides a 'snapshot' of vulnerability. Capturing the full complexity of what contributes to vulnerability was beyond the scope of this study. Future research needs to capture the dynamism of vulnerability by understanding how households respond over time and capturing the multitude of strategies and decisions which can be undertaken by households including trade-offs between assets (Below et al. 2012). The impact of intra-household dynamics of decision-making on household response is also fundamental, particularly concerning gender and issues of power and status within the household (Paavola 2008). Djoudi et al. (2013) state how power relations, different values and norms, and culture can influence one's own judgement on vulnerability and who is vulnerable. Further research is also essential to understand how perception impacts on cognition and risk behaviour to avoid cognitive dissonance and consequent maladaptive behaviour.

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