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Article

Farming System Evolution and Adaptive Capacity: Insights for Adaptation Support

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Abstract: Studies of climate impacts on agriculture and adaptation often provide current or future assessments, ignoring the historical contexts farming systems are situated within. We investigate how historical trends have influenced farming system adaptive capacity in Uganda using data from household surveys, semi-structured interviews, focus-group discussions and observations. By comparing two farming systems, we note three major findings: (1) similar trends in farming system evolution have had differential impacts on the diversity of farming systems; (2) trends have contributed to the erosion of informal social and cultural institutions and an increasing dependence on formal institutions; and (3) trade-offs between components of adaptive capacity are made at the farm-scale, thus influencing farming system adaptive capacity. To identify the actual impacts of future climate change and variability, it is important to recognize the dynamic nature of adaptation. In practice, areas identified for further adaptation support include: shift away from one-size-fits-all approach the identification and integration of appropriate modern farming method; a greater focus on building inclusive formal and informal institutions; and a more nuanced understanding regarding the roles and decision-making processes of influential, but external, actors. More research is needed to understand farm-scale trade-offs and the resulting impacts across spatial and temporal scales.

Keywords: farming systems; adaptive capacity; Uganda; adaptation; agriculture; resilience; vulnerability; institutions; climate impacts; climate change

1. Introduction

Human populations depend on farming as a source of food, livelihood, economic growth and development [1]. In Africa, the agricultural sector accounts for 32% of Gross Domestic Product (GDP) and employs more than 65% of the labor force [1]. Yet, the natures of the farming systems that support the agricultural sector vary between and within countries. Furthermore, farming systems are not only economically productive systems; they also have important political, social and cultural dimensions. Therefore, farming systems, also referred to as agro-ecosystems [2,3], and are an example of complex, social and ecological systems (SES).

Approaching farming systems as SES highlights that biophysical processes interact with human and management components to define the characteristics of the farming system [4]. Characteristics of the farming system are defined by: climate and environment; crop production and management practices; other agricultural activities; other natural resource based activities; and off- farm activities [5,6]. Various biophysical and human processes, including climate change, shape farming system structures and functioning. Such processes are dynamic and operate across multiple temporal and spatial scales, from the individual to the global level. Farming systems in sub-Saharan Africa, due to their dependence on rainfall and low adaptive capacity, are likely be impacted by future climate change and variability [7,8]. Work has been conducted into assessing these impacts on a range of crops [9–12] and livestock [8] at a range of spatial scales [13–15].

Mastrandrea *et al.* [16] note that research linking climate impacts studies with adaptation planning and management is important. "Impacts" studies have been used to identify "climate risk hot spots", vulnerable regions, sectors and peoples [17,18]. In recent years, maps depicting climate change "hotspots" have been increasingly used by researchers, advocacy groups and NGOs. Identifying likely climate change impacts and conveying them in a visual format can help to communicate issues in a manner that may be easier to interpret than text [17]. There have also been attempts to mainstream the use of impact studies to inform adaptation policy in developing countries, for example in the development of National Adaptation Programmes of Action (NAPAs). However, modelling studies simulating the impacts of climate change on agricultural productivity focus on biophysical processes. They often exclude considerations of adaptation or adaptive capacity, which will be important in determining the actual impacts of future climate change [19,20], and thus are criticized for leading to human-less projections of environmental change [3].

Adaptation is complex and often over-simplified in impacts studies, where it is most commonly defined as a change in planting date or switching to a different crop variety. However, adaptation is undertaken by multiple actors and is driven by both pressures and opportunities [21,22]. Individuals, including farmers, adapt through complex interactions between institutions and actors at multiple scales [22–24], making adaptation a complex messy problem. Thus, we define adaptation, in the broadest sense as "*a process of deliberate change, often in response to, or anticipation of, multiple* *pressures and changes that affect people's lives*" [21] (p. 146), to include all dimensions of adaptation; coping, adjustment and transformation [25].

Climate change adaptation is defined as "*an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects which moderates harm or exploits beneficial opportunities"* [26] (p. 7). Such a definition encompasses past, actual or anticipated responses to climate stimuli; also referred to shocks, stresses, hazards, perturbations, events and incremental changes in the wider literature [27]. Basset and Fogelman [28] question the novelty of current climate change adaptation studies, adding to the argument that adaptation to climate change is not necessarily special in relation to adaptation to other disturbances [29]. In addition to this, there is a growing body of evidence that individuals and communities across the developing world, including smallholder farmers, have historically responded to a range of climatic and non-climatic pressures and opportunities [2,29–31], where local knowledge and experience have played an important role in agricultural decision-making [31]. This suggests that climate change ought to be viewed as a signal nested amongst multiple drivers, rather than an independently occurring process [29] or encompassing envelope [32].

Climate change adaptation studies focus on the present, or future, often neglecting historical experiences of climate and other drivers of change. Approaches that try to link past experiences with future climate change projections can be problematic due to the uncertainty of future changes and the extent to which they exceed past experience [29]. However, recent studies are beginning to recognize the importance of current and historical factors in determining future climate change impacts [16], particularly given how vulnerability is determined by a function of exposure to perturbation or external stress, the level of sensitivity to the stress, and the capacity to adapt [33]. Past experience also has implications for resilience, defined as the ability of a system to recover, reorganize and develop following external stresses and disturbances [34–37], or the capacity to absorb, adapt and transform [25]. Such conceptualizations of resilience recognize the need for stability and change [38]. Holling [39,40] suggests that a history of past exposures may be important in building system resilience, "*every natural system is subject to regular disturbance; those that have survived, indeed must have built up some degree of resilience*" [41]. The assumption here is that all systems can learn from their past exposures.

Although rooted in different disciplines, numerous scholars recognize the potential linkages between vulnerability and resilience frameworks [42]. Both vulnerability and resilience can be viewed as being specific to a perturbation, highlighting that a system can be vulnerable to certain disturbances, but not others [25,35,43,44]. However, focusing on a particular disturbance can lead to "predict and prevent" approaches, which have been criticized for their limited ability to deal with the uncertainty and surprise associated with future climate change [45]. Vulnerability approaches have been further criticized for neglecting ecological factors and for creating a potentially disempowering discourse of vulnerability, which undermines the agency of human populations to take action [46]. Resilience on the other hand is not always desirable [47] and can also act as a barrier to change, development and progress. For example, areas depleted of natural resources are extremely resilient to change but may provide little in terms of food or money. Pelling [48] proposes that resilience cannot be conceptualized as buffering alone, as that would reinforce existing practices and lead to the maintenance of the status quo. Other conceptual similarities and differences between vulnerability and resilience can be found across the academic literature [19,44,49,50]. Overlaps between the concepts and some other key words from the literature which distinguish the two approaches are presented in (Figure 1).

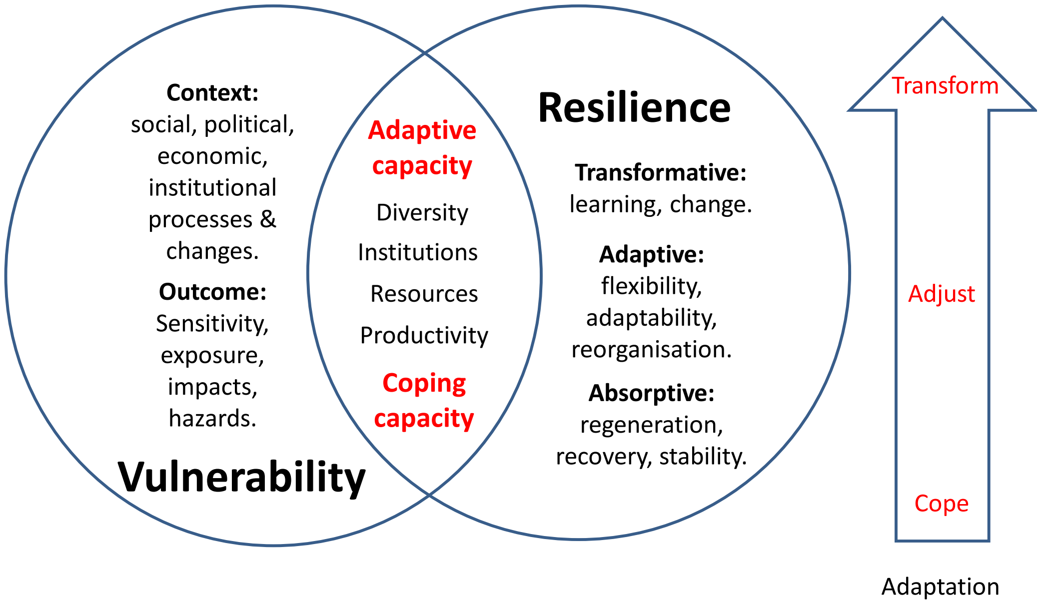
Adaptive capacity, defined as "*the ability to adapt*" [42] (p. 648) has been identified as a common thread linking vulnerability and resilience literature [42]. Adaptive capacity is generally accepted as a desirable property or positive attribute of a system for reducing vulnerability [42] and increasing resilience [49] (Figure 1), and as a prerequisite for adaptation to take place. In the language of vulnerability, adaptive capacity can offset sensitivity to a perturbation [19] and in resilience terms it can enhance the robustness of a system [49]. There is additional evidence from the practitioner community that adaptive capacity easily translates into practical actions and policy recommendations [42], "*at the heart of any local-level adaptation intervention is the need to increase the individual or community's adaptive capacity*" [51] (p. 2).

Adaptive capacity is multidimensional: it is determined by complex inter-relationships between a number of factors at different scales [52]. National indicators of adaptive capacity have been developed, but criticized for failing to capture many contextually relevant factors and processes; thus providing little insight at the level where most adaptations will take place [52]. In human societies adaptive capacity requires sufficient resources and appropriate institutional structures [53]. There has been a shift from asset-oriented approaches to adaptive capacity to include the processes which enable or constrain the ability to, for example, draw upon or switch between resources. This requires approaches that move away from simply looking at what a system has that enables it to adapt, to recognizing what a system does to enable it to adapt [54].

Adaptive capacity in the vulnerability literature focuses on the "what a system has" and the role of processes and functions that enable adaptive capacity. Jones *et al.* [51] suggest that the following processes are important: decision-making and governance; the fostering of innovation, experimentation and opportunity exploitation; and the structure of formal institutions and entitlements. Here, understanding adaptive capacity requires recognition of the importance of tangible resources and intangible processes, what we refer to as resources and institutions. Adaptive capacity in the resilience literature emphasises "what a system does", to enable it to adapt, for example what properties does it require, for farming systems we emphasise productivity and diversity.

Farming systems conceptualised as SES are dynamic and therefore constantly evolving, [2,22,55]. Building on and extending existing research into adaptive capacity, our aim is to explore how farming system evolution from 1960 to 2012 has influenced adaptive capacity using an integrated vulnerability and resilience conceptual framework. We focus on the evolution of farming systems, and therefore pay attention to incremental changes over time as opposed to those associated with particular shocks and stresses. To achieve this aim we investigate the following objectives: (1) what are the historical trends in farming system evolution from 1960 to 2012; and (2) how have such trends influenced farming system adaptive capacity. Firstly, we present the research approach and the integrated framework. Following this, the first part of the results section explores the evolution of farming systems from 1960 to 2012, whilst the second part examines how this has influenced their adaptive capacity. Through this we highlight elements of resilience and sources of vulnerability. The discussion section focuses on the enabling and constraining factors on adaptive capacity and presents the implications of the findings for adaptation planning.

Figure 1. Linking resilience and vulnerability concepts through adaptive capacity, adapted from Bene *et al.* [25]; Berman *et al.* [56]; Engle [42]. Concepts from adaptation literature are highlighted in red. Words in bold highlight distinctions in the literature between different types of vulnerability [57] and resilience [25], where related words are also listed.



2. Research Approach

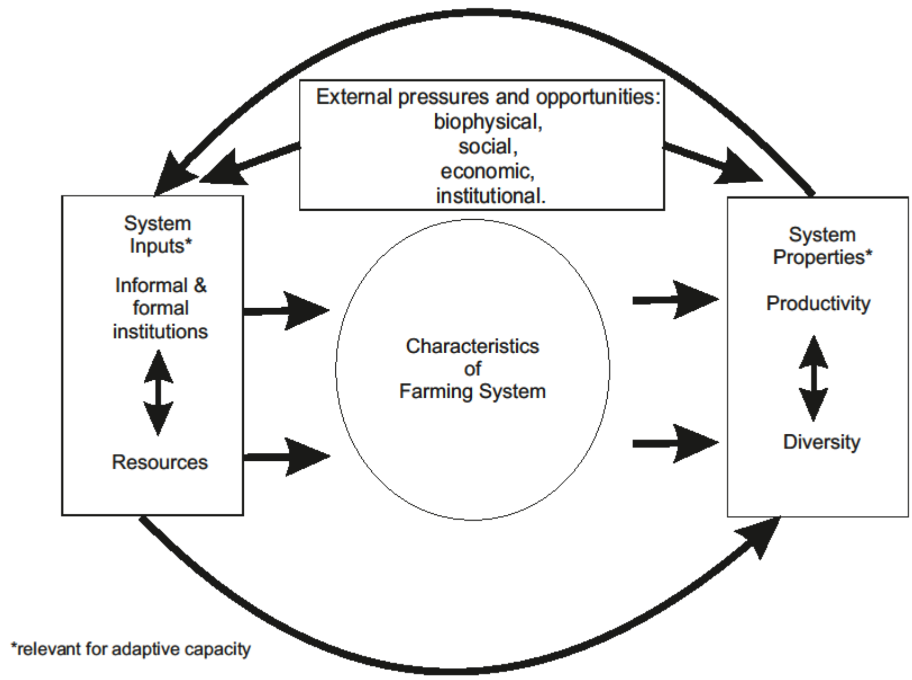
A farming systems framework was used to organise and analyse primary empirical data to track how farming systems in the study areas have evolved over time. Such an approach recognises the biophysical production system, made up of crops, climate, soils *etc.*, the management system, including people, values, goals, knowledge, resources and decision making [4] and the social, economic and institutional context in which they are situated. Using such a framework enabled the analysis of the interconnectedness and interdependence of components simultaneously influencing farming systems, yet operating across a range of spatial scales (e.g., climate, labour, markets, knowledge *etc.*). For more on how this approach was used to analyse primary data, see Dixon *et al.* [58]. For the purposes of this paper, the framework enables farm households with similar characteristics and constraints to be grouped together, allowing analysis of a "farming system". By focusing on the farming system and the wider context in which it is situated accounts for the fact that farming systems comprise multiple subsystems, as well as being embedded in multiple larger systems [49]. It thus recognises that within a farming system, "*a farm is likely to have links (flows, synergies, dependencies etc.) to farms with dissimilar structure, as well as to non-agricultural and non-rural parts of the economy*" [59].

Holling and Gunderson [60] suggest that diversity, connectivity and productivity influence the capacity of agro-ecosystems to respond to a range of pressures and opportunities. Quinn *et al* [2] use these concepts to analyse the vulnerability of agro-ecosystems to drought. Whereas, Fraser *et al.* [3] assess the vulnerability of agro-ecosystems to environmental changes based on the capacity of the system to remain productive, the capacity of individuals to adapt based on access to assets, and the collective capacity to respond based on institutions. What both Quinn *et al.* [2] and Fraser *et al.* [3] characterise is the capacity of the agro-ecosystem to adapt to environmental change, *i.e.*, adaptive capacity.

Advancing the frameworks developed by Quinn *et al.* [2] and Fraser *et al.* [3], this research integrates the resources and institutions that determine the capacity to respond to change, *i.e.*, system inputs, with properties that demonstrate a system is capable of responding. In the case of farming systems, these properties are productivity, diversity and connectivity. Combined, these components are fundamental to overall farming system adaptive capacity.

Resources, institutions, productivity and diversity provide a framework for analysing how trends in farming system evolution have influenced adaptive capacity. In the proposed adaptive capacity framework (Figure 2) connectivity, defined as the strength of internal connections, is considered as being part of institutions as it determines interconnectedness between parts of a system. Resources refer to the natural, human, financial resources or the assets used as system inputs, for example labour. Informal and formal institutions, *i.e.*, the norms, rules and procedures that define rights, responsibilities, entitlements and behaviours of various actors, operate across spatial scales to influence how resources are used to determine the characteristics of the farming systems [61]. The characteristics of the farming system result in certain system properties, productivity and diversity, which are also interrelated. Productivity is the accumulation of resources within a system that ensure it continues to function. Diversity, including crops, vegetation and livelihood strategies, captures the ability of the system to maintain functionality, whilst compensating for disturbances [2]. Both inputs and properties are connected and are also influenced by external biophysical, social, economic and institutional pressures and opportunities (Figure 2).

Figure 2. Integrated adaptive capacity framework drawing on concepts from resilience and vulnerability literature, where the components defining adaptive capacity are: informal and formal institutions; resources; productivity; and diversity. These components both shape the characteristics of the farming system and form part of the system properties. Arrows are used to highlight interactions between inputs, characteristics, external pressures and opportunities. Double arrows highlight the relationship between components of adaptive capacity.



Given a lack of information about appropriate weighting for these components, they are assumed to be equally important in shaping farming system adaptive capacity. Assessing these four concepts and how trends in the evolution of the farming system have impacted upon them provides insight into factors that enable or constrain adaptive capacity. This will be useful in understanding the how to minimise the potential impacts and maximise any potential benefits of future climatic and non-climatic changes, thus identifying priority areas for adaptation support.

3. Study Areas & Methods

Primary data were collected in the administrative districts of Soroti and Jinja, both located in the eastern region of Uganda. Soroti District lies in the Teso sub-region and Jinja District in the Busoga sub-region, resulting in socio-cultural, historical and language differences between the study districts [62]. These districts were selected to allow an in-depth exploration and comparison of two distinct farming systems [63]. Soroti District is located in the "Southern and Eastern Lake Kyoga basin" Agro-Ecological Zone (AEZ), has annual rainfall of between 1200 and 1450 mm per annum and experiences two rainy seasons and a distinct dry spell from November to February [63,64]. Jinja District is part of the "Lake Victoria Basin and Mbale Farmlands" AEZ. It has higher annual rainfall of between 1250 and 2000 mm [63] and experiences two rainy seasons, though the timings, duration and distribution are different to those of Soroti District. More geographical, environmental and climatic information about Jinja District and Soroti District can be found in Table 1.

Table 1. Environmental, climatic and geographical information for Jinja District and Soroti District.

Information	Jinja District	Soroti District	Source of Information
Sub-region	Busoga	Teso	[64,65]
Main ethnic groups	Basoga	Iteso, Kumam	[64,65]
Bordering districts	Kamuli (N), Luuka (E), Mayuge (SE), Buvuma (S), Buikwe (W) and Kayunga (NW)	Serere (E), Ngora (S), Katakwi (W), Amuria (N)	[64,65]
Agro-climatic zone	Sub-humid	Semi-arid	[66]
Agro-ecological zone	Lake Victoria Basin and Mbale Farmlands	Southern and Eastern Lake Kyoga Basin	[63]
Agricultural production zone	Lake Victoria Crescent	Kyoga Plains	[67]
Major crops	Maize, beans, sweet potatoes, coffee and bananas.	Banana, millet, cotton, cattle and a few annual crops	[63]
Vegetation	Some forest/savannah, but modified by urbanisation, industrial, commercial and residential activities.	Wooded and grass savannah	[64,65]
Annual rainfall range	1250–2000 mm	1200–1450 mm	[63]
Rainfall seasons	Bimodal: March–May, September–December. Low rainfall: December–March and June–July	Bimodal: March–June, August–November. Dry Spells: November to March	[63–65]
Strategic enterprises (2010–2015)	Dairy Cattle, Fish, Coffee, Poultry	Poultry, Cassava, Pineapples, Citrus	[67]

Methods

Data was collected in Uganda during January–September 2012, using a range of quantitative and qualitative methods including: observations, semi-structured interviews (SSIs), focus group discussions (FGDs) and household survey (HHS). The same methods were used in both districts to capture past and present issues as well as future concerns. 1960–2012 was selected as the time frame for enquiry in order to match people's ability to remember and to correlate with the baseline period used by climate models, thus allowing for comparability. Drawing on the livelihoods trajectory approach [68], participatory timeline building and discussions were used during both SSIs and FGDs to capture narratives around key events, changes in addition to the drivers, responses and impacts. Combining methods enabled triangulation of research findings.

Trained research assistants translated interactions between English and local languages throughout. Table 2 provides a summary of the methods used, the sampling strategies and the sample sizes for each of the study villages across the districts. Data were collected in four villages in each district. Villages were purposefully selected to represent a range of different sized villages and geographically, to capture the diversity within each district in terms of distance to an urban centre/main road. Different sampling strategies were used with different methods (Table 2). Snowball sampling was used to identify both village elders and key informants in the villages. Cluster sampling was used to ensure that the demographics were represented in the FGDs. Women only FGDs were held to overcome issues of participation (see [69,70]).

Table 2. Summary of the study villages, methods used and sample size for each of the study districts. Data compiled from semi-structured interviews (SSIs), focus group discussions (FGDs), household surveys (HHS) and observations.

District	Study Villages	Distance from urban centre/a main road (kms)	Number of households per village	No. of SSI respondents-farmers	No. of FGDs (No. of participants)	Number of HHS	Observations
Jinja	Bituli	11/11	~120	4	1	0	–
	Bukolokoti	3/3	~100	5	2 *	0	–
	Idoome	5/5	~320	4	2	0	–
	Kalugu	15/15	~120	5	2 *	0	–
	Total (n=)	–	660	18	7	0	–
	Additional Information	Source: FGDs	Source: Village Records	Sampling: Snowball	Sampling: Cluster	Invalid results	Recorded in field diary
Soroti	Adamasiko	12/7	113	8	2 *	98	–
	Agirigiroi	31/18	~600	8	2	99	–
	Kangeta	8/3	347	3	2	90	–
	Merok	25/3	106	7	2 *	100	–
	Total (n=)	–	1166	26	8	387	–
	Additional Information	Source: FGDs	Source: Village Records	Sampling: Snowball	Sampling: Cluster	Sampling: Random	Recorded in field diary

* Indicates female only FGD.

Following data collection, a follow-up trip was made to each village to further triangulate the HHS findings. During these visits a sample of community members were selected to take part with the assistance from key informants using cluster sampling. Sampling included representatives from the local leadership, women, youth and elders. In Jinja District, the HHS data was deemed to be invalid by participating community members and has therefore not been included in the analysis. Individuals who took part in the SSIs are referred to as respondents, whereas those who took part in FGDs are referred to as participants.

4. Results

4.1. Characterising Farming Systems

Characteristics of farming systems are defined by climate and environment; crop production and management practices; other agricultural activities; other natural resource based activities; and off-farm activities [5,6]. Table 3 presents the characteristics of the farming systems in the study areas to provide contextual background. It also provides a basis for distinguishing between the Jinja Farming System (JFS) and the Soroti Farming System (SFS), the key trends noted by farmers, and the drivers of change (Table 4). This is important in order to understand current farming systems, their evolution since from 1960 to 2012 and the extent to which farming system adaptive capacity has changed over time.

JFS and SFS are distinct in terms of the crop and livestock production, agronomic practices and the range of other livelihood opportunities being pursued to make up the farming system (Table 3). Both JFS and SFS are rain-fed farming systems with two growing seasons, though farmers in SFS tend to experience a distinct dry spell from November to February. In the JFS, farmers plant the same crops in the first and second seasons, whereas there is a distinction between first and second season crops in the SFS. Livestock also play an important role in the SFS, as productive assets used in cultivation, as well as providing a safety net, food, income and a means of resource accumulation. Visibly, the environments, topography, soils, tree species and coverage are different. Land tenure systems governing access, ownership and land use also vary and further distinction can be made in the way that agricultural products are sold or traded to generate food and income. Such findings highlight that the two farming systems differ in terms of the biophysical, social, economic and institutional context; such differences provide insight into our understanding of farming system adaptive capacity.

Table 3. Characteristics of Jinja Farming System (JFS) and Soroti Farming System (SFS) compiled from a range of primary data sources, including focus group discussions (FGDs), semi-structured interviews (SSIs), household surveys (HHS) and observations (O), see Dixon *et al*. [58] for methods and in-depth analysis of data.

Comparison between JFS and SFS	Jinja Farming System	Data Source	Soroti Farming System	Data Source
Climate and environment	Decline in natural forest cover	FGDs and SSIs	Grasslands with small shrubs and a few big trees	O
	Presence of a range of fruit trees, including mango, jack fruit, papaya	O & SSIs	Predominantly mango and orange trees	SSIs & FGDs
	Seasonal swamps in valleys	SSIs & FGDs	Seasonal swamps	SSIs & FGDs
	Two growing seasons (February/March–May & September–December)	SSIs & FGDs	Two growing seasons (March–June and July/August–November)	SSIs & FGDs
	Most land under cultivation—no communal grazing land	O & SSIs	Areas of uncultivated land and communal grazing land	O
	Combination of legal (freehold/leasehold) and customary land tenure system—women have no rights to customary land	SSIs & FGDs	Customary land tenure system—women have no rights to customary land	SSIs & FGDs
Crop production and agronomic practices	Rain-fed crop production	SSIs & FGDs	Rain-fed crop production	SSIs
	Main staple crops: maize, beans, sweet potatoes, groundnut, soya	SSIs & FGDs	Main staple crops: Cassava, sorghum, sweet potato, groundnut, peas	HHS
	Traditional seed varieties are diminishing	SSIs & FGDs	Integrated use of traditional and improved seeds	SSIs & FGDs
	Desire to use “improved seeds” increasing	SSIs & FGDs	Mixed perceptions on use of “improved seeds”	SSIs & FGDs
	Households sell crops from home, through middlemen	SSIs	Crops sold from local markets/trading centres	HHS, SSIs & FGDs
	Selling land/renting land out for sugarcane production	SSIs, FGDs & O	Oxen used for ploughing and tilling the land	SSIs & FGDs
	Use of hand hoes for tilling	SSIs & O	Low use of chemical fertilisers and pesticides	HHS, SSIs & FGDs
	Low use of chemical fertilisers and pesticides	SSIs and FGDs	–	–

Table 3. *Cont.*

Comparison between JFS and SFS	Jinja Farming System	Data Source	Soroti Farming System	Data Source
Livestock and other agricultural activities	Small-scale agro-forestry, mostly fruit trees	O & SSIs	Some evidence of agro-forestry (e.g., orange trees & tamarind trees)	HHS & SSIs
	Small-scale livestock production—mainly poultry, goats & cattle	O & SSIs	Integrated crop & livestock production—mainly poultry, goats & cattle	SSIs & FGDs
	Role of livestock as safety net, income, food—predominantly financial asset	SSIs & FGDs	Varying cattle herd sizes	HHS
	High prevalence of tsetse flies and cattle diseases	FGDs	Role of livestock as safety net, income, food, and productive asset	SSIs & FGDs
	No evidence of apiculture	O & SSIs	Majority of households own poultry, goats &/or sheep	FGDs
	–	–	Role of oxen as productive assets	HHS
	–	–	Cattle as indicators of wealth	FGDs
	–	–	No evidence of apiculture	O & SSIs
Other on-farm and off-farm livelihood activities	Evidence of other natural resource based activities on a small scale	O & FGDs	Evidence of a range of natural resource based activities	HHS & FGDs
	Emphasis on off-farm activities, for example small businesses and shops	O & FGDs	Some off-farm activities—e.g., casual work	HHS & FGDs
	Mostly men involved in off-farm activities (casual work)	FGDs	Men and women involved with off-farm activities	FGDs

4.2. How have Farming Systems Evolved (from 1960 to 2012)?

Farming system evolution from 1960 to 2012 was discussed during both SSIs and FGDs. During SSIs farmers recalled and discussed key changes in agriculture that have taken place in their lifetimes, the drivers of such changes, some of the impacts experienced and responses taken by farmers and other stakeholders. Although the length of memory and ability to recall events differed amongst individual interviewee respondents and FGD participants (confer Simelton *et al.* [71] and Marx *et al.* [72]), key trends that fall within the desired time scales were identified and subsequently discussed. Trends, the drivers of change and approximate timings of change identified by farmers in Soroti District and Jinja District are presented in a timeline format (Table 4). The timeline distinguishes between the farming systems during 1960s–1980s and then from 1990s to 2012. Many of the key changes happened during and since 1990s leading to farmers distinguishing between "then" and "now". This distinction also coincides with other political events, for example Uganda gaining independence in 1962, and then 1986 marked the beginning of President Museveni's term in office.

Similar trends are found when tracing the evolution of the SFS and JFS (Table 4). In both systems, the major trend farmers discussed was the shift from traditional to modern farming methods, including: changes in the crops cultivated; an increase in the cultivation of new varieties; increase cultivation in swamps; an increase in selling food crops; and an increase in off-farm activities. Despite these similarities, the details are specific to the farming system, in terms of which crops and which practices have changed (Table 4).

In both farming systems, other natural resources, for example trees, wetlands and indigenous forests, have been drawn upon as coping mechanisms in difficult periods by providing a source of food and medicine. Forest products, for example timber, have also been used to generate income to support the recovery of livelihoods following a range of shocks and to provide financial support for agricultural activities and rural livelihoods more broadly. Additionally, in the SFS, farmers identified a trend of cutting down trees after periods of political instability (1986–1992 and 2003–2004) and selling timber to generate income. This coping strategy, undertaken in both farming systems, has become a "normal" practice to cope with ongoing seasonality and stresses, resulting in localised natural resource degradation.

It is also important to note two key differences in the trends: fluctuations in livestock numbers (SFS) and decline in the interest in agriculture (JFS). Instability experienced in SFS resulted in declining livestock numbers, but as people rebuild their livelihoods, livestock numbers have been subsequently increasing. As a farmer in Soroti explained:

> "*first of all the cows have reduced the Karamajongs (ethnic group in Uganda) took away the cattle and people remained poor and they used to cultivate using hand hoes… then people started buying chicken, then they moved on buying goats, then they reach a level of being able to buy cows and bulls. That is now why you see that people are beginning to have a few livestock around*" [73].

In SFS, cattle have traditionally been a key feature of the farming system and used in production, despite the fluctuations in livestock numbers. This is not the case in the JFS, where the cultural and production practices differ, farmers have no access to communal grazing lands and currently most land is cultivated with crops.

Table 4. Key trends in the evolution of the Soroti Farming System (SFS) and Jinja Farming System (JFS) from 1960 to 2012. Data compiled from focus group discussions (FGDs) and semi-structured interviews (SSIs).

Soroti Farming System				
Trends	**Description of trend**	**Farming system from 1960s to 1980s**	**Drivers of Change**	**Farming systems from 1990s to 2012**
Shift in farming methods	A shift from traditional farming methods to modern farming methods. Increase in use of hand hoes for ploughing.	Traditional methods, including: Broadcasting seeds; oxen for ploughing; saving seeds; planting traditional crop varieties.	NGO programs Government policies Political Instability Increases in theft	Integration of modern farming, including: Planting in rows & spacing crops; using improved seeds; application of fertilizers/pesticides.
Shift in crops and varieties under cultivation	Decline in cotton and millet production. Increase in cassava and maize production. Cultivation of new crops not traditionally grown in the Teso sub-region. Introduction of new crop varieties, e.g. short maturing varieties.	Main food crops under cultivation: millet, peas, groundnuts, sorghum, sweet potatoes. Main cash crops under cultivation: cotton. Cultivation of mostly local varieties. Seeds for cash crops provided by government initiatives & cooperatives. Widespread practice of seed saving.	NGO programs Government policies Increase in weeds and crop diseases New market opportunities Changing farmer preferences Land fragmentation Changes in weather Market price fluctuations	Main crops under cultivation: cassava, sweet potatoes, groundnuts, sorghum, some millet & peas. New crops: maize, rice, sugarcane, beans, vegetables, tomatoes. Combination of both local and improved varieties. Some evidence of seed saving.
Increase in food crop production specifically for market	Increase in cultivation of food crops for market. Farmers selling traditional food crops to generate income, for example cassava, sorghum and millet.	Distinction between food and cash crops. Food crops saved and stored for eating & home use. Cash crops sold to market, some through cooperatives.	New market opportunities Increased demand for financial resources Market price fluctuations	Food crops are grown for home consumption and to generate income. All crops sold through markets.

Table 4. *Cont.*

Soroti Farming System				
Trends	**Description of trend**	**Farming system from 1960s to 1980s**	**Drivers of Change**	**Farming systems from 1990s to 2012**
Cultivation in wetlands	Farmers cultivating new crop varieties, e.g., rice, in swamp areas.	Wetlands and swamp areas uncultivated and generally used as communal grazing land.	NGO programs Government policies Changes in weather Increases in population Land fragmentation New market opportunities	Cultivation in swamps, especially new crop varieties (sugarcane, vegetables, rice).
Using natural resources to generate income & support farm activities	Evidence of clearing forests, cutting trees, charcoal burning, brick making, *etc.* Income used to meet household needs and invest in agriculture.	Natural resources used as a source of food and medicine and as coping strategy for various shocks and stresses.	Political instability New market opportunities Increased demand for financial resources	Natural resources as a source food, medicine. Natural resources used to generate income.
Increase in off-farm activities	Farmers are pursuing off-farm livelihood activities to generate income.	Dependence on livestock and crops. Off-farm activities used as a coping strategy to multiple shocks and stresses.	Political instability Decline in livestock numbers Increase in off-farm opportunities Increased demand for financial resources	Range of livelihood strategies being pursued. Livestock numbers are recovering. Off-farm activities used as a coping strategy to multiple shocks and stresses.
Fluctuations in livestock numbers	Livestock numbers declined following political instability 1986–1992. As livestock numbers were recovering another period of instability in 2003 affected numbers. Since then, livestock numbers are slowly increasing.	Farming systems based upon the integration of livestock and crops. Livestock used as a productive asset, as well as providing a means of providing a safety net, accumulating farm assets and generating income. Communal and marginal lands, especially bordering swamps, as designated grazing lands.	Political instability Increases in population Land fragmentation New market opportunities New crops and varieties	Livestock numbers increasing since 2005. Farmers prefer to own and use livestock, especially oxen, as a productive asset. Livestock also provide a safety net, allow resource accumulation and generate income. Less communal/marginal lands available for grazing.

Table 4. *Cont.*

Jinja Farming System				
Trends	**Description of trend**	**Farming system from 1960s to 1980s**	**Drivers of Change**	**Farming systems from 1990s to 2012**
Shift in farming methods	Shift from traditional farming methods to modern farming methods. Farmers no longer use traditional granaries to store large quantities of food; instead sacks inside homes are used. The need for money, market opportunities, and buying seeds each season has eroded traditional storing practices.	Traditional methods include: saving seeds; planting traditional varieties.	NGO programs Government policies Increases in theft New market opportunities Land fragmentation Changes in land use	Shift to modern farming methods, including: Planting in rows & spacing crops; using improved seeds; application of fertilizers/pesticides. Reduction in the amount of land cultivated for food crops.
Shifts in crops and varieties under cultivation	Cultivation of cotton has declined since 1960. Cassava and groundnut production are declining. Coffee was introduced in 1970s but is now in decline. Areas of banana plantations are also declining. Maize and sugarcane production has been increasing since 1990s. New crops and improved varieties are now under cultivation, for example rice and vegetables.	Main food crops: sweet potatoes, cassava, groundnut, beans and maize. Main cash crops: cotton then coffee and cocoa. Mostly local varieties under cultivation. Seeds for cash crops provided by government initiatives & cooperatives. Widespread practice of seed saving and storing food.	NGO programs Government policies Decline in cooperatives Increase in crop diseases New market opportunities Land fragmentation Changes in weather	Main crops: maize, beans. New crops: rice, sugarcane, and vegetables, e.g., tomatoes, cabbages. Combination of both local and improved varieties. Some local varieties have almost disappeared, e.g., maize and groundnut. Reduction in the amount of land cultivated for food crops. Increasing sugarcane cultivation, includes selling off land, renting land out and planting on own land.

Table 4. *Cont.*

Jinja Farming System				
Trends	**Description of trend**	**Farming system from 1960s to 1980s**	**Drivers of Change**	**Farming systems from 1990s to 2012**
Increase in food crop production specifically for market	Farmers are selling traditional food crops, for example maize. Farmers growing food crops, e.g., vegetables, specifically for generating income.	Distinction between food and cash crops. Food crops saved and stored for eating & home use. Cash crops sold to market, some through cooperatives.	New market opportunities Increased demand for financial resources	Food crops are grown for home consumption and to generate income.
Cultivating in swamps	Farmers cultivating new crops, for example rice, in swamp areas.	Swampy areas not used for cultivation.	Government policies Changes in weather Increase in pests, e.g., moles Increases in population Land fragmentation Changes in land use	Cultivation in swamps, especially new crop varieties (vegetables, rice) and sweet potatoes to avoid pests.
Increase in off-farm activities	Farmers are pursuing off-farm livelihood activities to generate income.	Dependence on crops as a source of livelihood. Off-farm activities used as a coping strategy to multiple shocks and stresses.	Increase in off-farm opportunities Increased levels of education Increased demand for financial resources	Range of livelihood strategies being pursued. Off-farm activities used as a main livelihood strategy, especially amongst men.

Table 4. *Cont.*

Jinja Farming System				
Trends	**Description of trend**	**Farming system from 1960s to 1980s**	**Drivers of Change**	**Farming systems from 1990s to 2012**
Using natural resources to generate income (including deforestation)	People involved in charcoal making, brick making, selling trees, timbers to generate income. Supplementary income used to support household needs, e.g. school fees, rather than invest in agriculture. Areas of indigenous forest have been cut and replanted with high value non-indigenous trees, for example pine. Trees and forests have been cleared for crop production, and to provide additional income generating activities.	Large areas of indigenous forests. Natural resources largely used for home consumption, e.g., firewood rather than to generate income. Large areas of indigenous forest. Trees and forests used as a source of food and medicine and as coping strategy for recovering from various shocks and stresses. Trees provide shade for coffee and banana plantations.	Increase in market opportunities Increased demand for financial resources Multiple pressures affecting yields Government forestry policy New market opportunities Increased sugarcane production Increased demand for financial resources.	Loss of indigenous forests since 1990s. Natural resources, especially trees have utilized to generate income. Such activities are now reducing due to natural resource degradation. Indigenous forest has disappeared and replaced with pine tree species. Fewer trees, though they are a source of food, medicine and income. Less diversity of tree species.
Decline in interest in agriculture	Men, especially educated youth, are increasingly seeking off-farm income generating opportunities, including casual work locally or migration to towns. Education levels, aspirations and preferences have changed; agriculture is perceived as "drudgery".	Mostly family labor used on farm. Some off-farm activities.	Increased levels of education Increases in off-farm opportunities Changing preferences and aspirations amongst the youth	Higher levels of off-farm migration—urban areas and sugarcane plantations. Decline in available farm labor and an increasing burden on women.

In both areas, men, especially educated youth, are increasingly seeking off-farm income generating opportunities. In JFS this includes: finding casual work locally on sugarcane plantations; gambling by playing cards or other games in local trading centres; and migration to nearby urban centres to seek employment opportunities. An emerging theme in JFS was the changing attitudes towards farming as a desirable livelihood option resulting in the decline in labour available. Although off-farm income generating opportunities are undertaken in SFS, they are not changing attitudes towards agriculture. Whereas, in JFS farmers noted that as more children are going to school and people become exposed to urban life their aspirations and preferences have changed; agriculture is now perceived as "drudgery".

> "*There is a shortage of labour in this area now, because of these children going to school… Everybody is at school and you find people of our ages, we don't have enough energy… Also young people today do not want to go to the garden. They want to go to school, then town, get good jobs, [which makes] coming back to the village a problem*" [74].

Although similar trends were identified by farmers in both areas, the drivers of change and the interactions between these drivers differed. To add further complexity, the data also show that some of the trends are also interconnected. Farmers in Soroti, for example, linked planting in wetlands to the cultivation of new varieties and new market opportunities, e.g., rice, which requires more water than traditional crops. Similarly, in the JFS, the decline in food storage is linked to an increase in selling of food crops, which farmers then linked to the type of crops and varieties grown at the farm scale and the market opportunities available. Farmers in one village explained:

> "*I remember the time when I came here, we would get food and we would not sell any food*" [75].

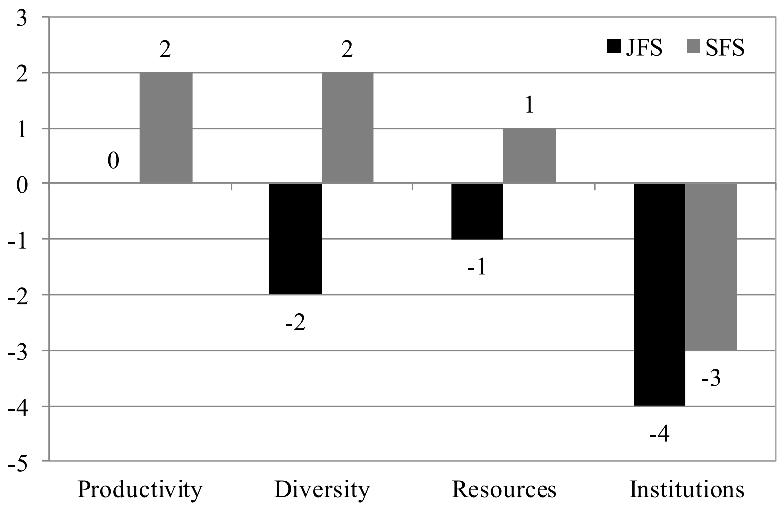
> "*Because of the higher price so maize, it has made people not keep maize, but in those days maize was at 100 shillings ($0.04) a kilo, now it is 1000 shillings ($0.4) a kilo and people really want to receive that money. So saving sometimes to keep maize is a problem*" [76].

Single drivers are also linked to multiple trends. In SFS, for example, when government policies and programmes are isolated as a single factor, they interact with other variables across time and space. In SFS they interact with NGO programmes, markets, and demographic shifts, to result in multiple outcomes: planting new varieties; cultivating in swamps; applying chemical inputs; and an increase in the selling of food crops. Despite the apparent similarities amongst the trends, the specific interactions, connections and context differ at the farming system scale, thus suggesting trends have had differential impacts on farming system adaptive capacity. For an in-depth analysis of these interactions see Dixon *et al*. [58].

4.3. What are the Impacts of Historical Trends on Farming System Adaptive Capacity?

A qualitative assessment of each trend and its impact on of adaptive capacity was carried out using primary data to assess whether it had a positive or negative impact on farming system productivity, diversity, resources and informal/formal institutions (Table 5). Qualitative analysis focuses on overall trends, *i.e.*, incremental changes, rather than specific shocks or stresses. Each impact that was deemed to have a positive impact was given a score of 1. Those that were deemed to be negative received a score of −1. The number of positive and negative impacts relating to each farming system was summed to provide a basis for a quantitative comparison (Figure 3). A score of zero, for example productivity in JFS (Figure 3), highlights that positive and negative impacts act to cancel each other out, rather than meaning that no impacts were recorded.

Figure 3. Historical trends and their impacts on the components of adaptive capacity, scores given for the Jinja Farming System (JFS) (black) and Soroti Farming System (SFS) (grey).



When the impacts of the trends are analysed collectively, there have been overall positive impacts on the SFS, and a range of negative impacts on the adaptive capacity of the JFS (Figure 3). Interrogating the data shows the biggest difference between the JFS and SFS is in how the shift from traditional to modern farming has impacted upon the adaptive capacity of the farming system, highlighting that the farming systems have had different experiences of shifting towards modern farming methods. In JFS, such methods have largely replaced traditional farming practices, crop varieties and methods, whereas in SFS they have been integrated into traditional practices.

Overall, trends, including the shift from traditional to modern farming, have had a positive influence on the productivity and diversity of the SFS. In the JFS they have had an overall neutral effect on productivity, but have negatively impacted upon diversity. Furthermore, the same trends have had an overall positive impact on resources in the SFS, whilst negatively impacting upon the JFS.

The biggest similarity between the trends is the collective impact they have had on informal or formal institutions, where there is a negative effect in both the JFS and SFS. Whereas, the biggest difference is how the trends have impacted upon on diversity, where there is currently less diversity in terms of crops, livestock, and income generating activities in the JFS. To further explore some of the reasons for these differences each of the indicators is considered separately.

4.3.1. Productivity

In both farming systems productivity has been maintained. Qualitative data presented does not allow any claims to be made about specific crop or livestock production (Table 5). Instead, it provides an idea of some of the factors influencing productivity, for example labour, income, weather and in the case of the SFS, political instability.

Table 5. The impact of the farming system trends on the adaptive capacity of the Soroti Farming System (SFS) and Jinja Farming System (JFS). Impacts with a "+" are deemed to be positive and those with a "−", negative. Impacts experienced in both farming systems are highlighted in bold, those related to SFS are in italics and JFS underlined.

Impact on: Trend:	Productivity	Diversity	Resources	Informal and formal institutions
Shift from traditional to modern farming—including: **(1) Shifts in farming methods** **(2) Shifts in crops and varieties** **(3) Increase in selling food crops** (4) **Planting in swamps/wetlands**	**+Maintaining productivity of farming system** **+Opening previously unproductive land** +Promoted as an intensive farming practice in response to multiple land and soil pressures to maintain productivity *+Facilitated the recovery of farming systems following instability and civil unrest* **−Mixed results on increasing productivity** **−Dependent on weather, access to knowledge & inputs**	*+Evidence that it is increasing the diversity of crops & varieties under cultivation* *+Maintaining diversity—evidence of farmers planting a combination of "improved" and traditional varieties* *−Some evidence of mono-cropping* −Widespread evidence of mono-cropping specific crops, e.g., sugarcane −Widespread evidence of mono-cropping of certain varieties, maize & groundnut −Loss of traditional varieties, e.g., maize and groundnut	**+Maintaining source of food and income **** **+Crops, e.g., sugarcane and cassava, require less inputs: time, labour & management** **+Providing income as a safety net, and resources to meet farm-scale demands and farm development** *+Reduces amount of seeds "wasted"* *+Provided income for recovery from instability and civil unrest fostering accumulation of productive assets e.g., livestock* *+Evidence of farmers gaining knowledge and experience, planting mix of traditional and improved varieties* **−Household resources, e.g., group membership or money are required to access training & inputs** **−Farmers have to buy seeds—decline in seed saving** **−Some crops, e.g., vegetables, require more inputs: time, labour & management** **−Evidence of natural resource degradation, e.g., swamps & soils** *−Increases in flooding/water logging of low-lying areas*	**+Strengthening village social networks through groups membership *** **+Farmers accessing new markets** **+Increases in income are allowing farmers to form saving schemes (e.g., Village Savings and Loan Associations—VSLAs)** **−Requirement of group membership excludes some farmers *** **−Farmers becoming dependent on external assistance—e.g., NGO assistance & markets** **−Reducing traditional seed saving practices** *−Eroding traditional practice of celebrating harvests by sharing with others in village, e.g., millet*

Table 5. *Cont.*

Impact on: Trend:	Productivity	Diversity	Resources	Informal and formal institutions
Increase in off-farm activities	**+Potential indirect impact on maintaining productivity through generating income **** **+Coping strategy used to respond to low yields, food shortages etc** **−Indirect impact on productivity by reducing labour available**	**+Diversifying livelihoods, less dependent on agriculture**	**+Income generating **** **−Increasing need for resources to hire labour to due reduced availability of farm labour**	**−Influence on family as a social institution** <u>−Indicator of changing aspirations of rural youth</u>
Changes in the utilisation of other natural resources	**+maintains productivity of farming system** *+enabled recovery of the farming system following instability and civil unrest* **−Indirect impact on productivity: reducing trees influencing weather patterns and growing seasons** <u>−Reduced shade, resulting in negative impact yields, e.g., coffee</u>	**−Reduction in biodiversity**	**+Income generating **** **−Leading to natural resource degradation**	**−Erosion of a traditional natural resource based coping mechanisms**
Fluctuations in livestock numbers	*−Indirect impact on productivity by affecting productive assets and the size of land under cultivation*	*+Preference for and integration of livestock adds to the diversity of the farming system*	*+Provides organic manure used as fertiliser* *-It is taking time for livestock numbers to recover, some farmers have no access* *+ & − Impacts upon the farm-level time, labour and resources needed for cultivation*	*+Farmers can hire, trade and share livestock, strengthening social networks* *-Currently creating a distinction between those that have and those that do not*
<u>Decline in interest in agriculture</u>	<u>−Indirect impact on productivity by reducing labour available</u>	<u>+Diversifying farm livelihoods, less dependent on agriculture</u>	<u>+Income generating **</u> <u>−Labour Shortage</u>	<u>−Migration influencing family as a social institution</u>

Notes: * Group membership is a requirement of both NGO programmes & Government agricultural research and extension services; ** Evidence that increased household income does not translate into food or livelihood security; it depends on farm-scale decisions making processes and the access to and control over resources.

Productivity in the SFS has been maintained through the use of natural resources and increases in off-farm income generating activities. These coping strategies enabled farming system recovery following periods of instability and civil unrest, thus confirming that natural resources are drawn upon to meet short term needs when socioeconomic resources and the institutional capacity to support farmers are limited (see Fraser and Stringer [77]). However, in the JFS the decline in interest in agriculture, especially amongst youth, has had negative impacts on productivity by reducing the availability of labour. Furthermore, in JFS natural resource utilisation has led to deforestation and degradation, and is negatively impacting upon production of specific crops, for example coffee. Positive impacts on JFS stem from the introduction of new crops and varieties that have maintained farming system productivity in the face of multiple pressures. However, overall, these trends combined have limited the productivity of the JFS.

4.3.2. Diversity

The biggest differences between individual trends analysed in Table 5 is how they have impacted on the diversity of the farming systems. In the case of the shift to modern farming, all of the impacts on diversity are underlined or in italics (Table 5), highlighting a difference between the impacts in the different systems. Overall, trends have had more positive impacts on the diversity of SFS, but negative impacts on the JFS. These differences can be explained through the adoption of modern farming practices; in the case of SFS there is evidence that such methods have been integrated into traditional system rather than replacing it, thus maintaining certain level of diversity. This can also be explained by the management practices employed at the farm-level, both in terms of specific crop varieties and livestock breeds, and the extent to which the introduction of modern farming has led to the loss of traditional varieties and breeds.

Evidence suggests that traditional varieties of some crops (specifically maize and groundnuts) are diminishing or have been lost altogether in JFS. A farmer in Jinja District explained:

> "*the traditional ones are diminishing, now we don't have traditional maize or groundnuts, they're not there*" [74].

> "*the other local variety no longer yields well, so we changed to this improved one which can yield at least*" [78].

Modern farming, particularly in the form of new seed varieties, was presented by farmers in Jinja District as the only solution to the multiple and pressing challenges they are facing. However, in Soroti District, opinions are mixed and there is more evidence of an integrated approach, whereby farmers are growing a combination of crops and varieties. Farmers in Soroti District described both positive and negative opinions about modern farming, and "improved" crop and livestock breeds in particular. How improved crop varieties were received by farmers depended firstly on the crop:

> "*take the example of groundnuts, the improved ones have proved to be good, but some have proved to be not good, We have serenut2 that one is doing well, but we have Serenut 3 and Serenut 4 (Serenut2, 3, 4* are improved varieties of groundnut), *but they have failed*" [73].

Secondly it depended on access to the other inputs necessary to obtain better yields:

"*it's not the same because the improved ones, if you don't spray you don't get anything, but these local ones can, you are sure you can still get something, even if the weather is bad and you don't spray you can get something*" [73].

Nonetheless, this range of opinions is distinct from the narrower range of perceptions of the farmers in Jinja District where improved varieties are seen as essential and desirable, and the use of traditional varieties has declined.

4.3.3. Resources

The main resources considered were: human (time, labour), natural and financial resources (Table 5). Although these resources cross spatial scales, the predominant focus was within the farming system. This means, for example, nearby forest reserves were excluded, but forests, swamps and wetlands that farmers utilise are included.

Data highlight differential impacts on resources, depending on the nature of the resource. However, collectively there was no overall positive impact on resources in the SFS, yet more negative impacts were noted in the case of the JFS, especially on the natural resource base. Data suggest that changes in land, forest and wetland management have resulted in environmental degradation, including loss of habitats and loss of non-crop diversity. Although the negative impacts upon the resource base may not be urgent problems at present, they could negatively influence future adaptive capacity. For example, although planting in low-lying wetlands helped to maintain productivity during dry spells, farmers in SFS suggest that heavier rainfall and processes of silting have increased water-logging and localised flooding in surrounding areas. Positive impacts on farm-scale financial resources were recorded in both farming systems, related to ability of the system to generate income. However, in some cases, more resources (human, financial) were needed to generate this income.

Comparing the results from both farming systems in this section is inconclusive as the actual impacts on the farming system depend on the crops grown and their management at the farm-level. For example, sugarcane cultivation in JFS consumes less time, labour and fewer on-going financial farm-scale resources; whereas vegetable crops in both farming systems require more time, labour and management. Although both of these trends potentially increase household incomes, they have also increased the need for other farm-scale resources (time, labour), or have had negative impacts on the natural resource base. Because they are mostly market-based crops, they have further contributed to eroding traditional coping mechanisms, such as drying and storing food. This complexity and interconnectedness highlights that trade-offs between resources, and therefore elements of adaptive capacity, occur at the farm-scale.

4.3.4. Informal and Formal Institutions

Out of all of the components of adaptive capacity, the most similarity between the SFS and JFS was in the impacts of trends on formal and informal institutions, where analysis shows few positive impacts (Table 5).

Formal institutions, such as government policies and programmes have eroded some informal institutions. For example, in SFS policies and programmes promoting the commercialisation of agriculture, increased market opportunities and the subsequent selling of food crops is eroding traditional cultural practices of celebrating harvests by sharing millet, drinking locally made brew and roasting meat with community members. In JFS, the increase in off-farm activities and migration, driven by labour market opportunities, is influencing the family as an informal institution.

Formal institutions have also had positive impacts on informal institutions, for example there are positive impacts associated with increased group membership, accessing new markets and the formation of saving schemes. However, the requirement to be part of a group to access extension services limits access to certain knowledge and technologies and is excluding some community members. Within a district or village, the way that the formal institutions play out results in winners and losers. A female farmer explained:

> "*Some have improved [seeds], some have local [seeds]. Those who are able to get the improved ones are those people who are in groups. NGOs when they come they don't give to individuals, they give to groups, so you find those groups at least have improved varieties and those who are not in groups grow local*" [79].

Simultaneously, trends are also increasing the dependence on external institutions such as markets, NGOs and government support. Farmers expect agricultural inputs, including seeds and new breeds from external organisations. These may have positive impacts for few farmers in the short term in terms of maintaining productivity. However, from the data it is unclear how they impact upon farmers who are excluded or what impacts they will have in the long term, and thus how they will shape future farming system adaptive capacity. Moreover, how governments and NGOs make decisions about what types of seeds, inputs, and advice to promote is unclear.

5. Discussion

Through the data presented in this paper, various factors that enable or constrain adaptive capacity can be identified. We reflect on some of the factors and the implications of the findings for future research. Reflecting on the similarities and differences between the farming systems provides insight into specific interventions needed to strengthen adaptive capacity both in the study districts and in farming systems more broadly. We identify areas for further research and where specific action is needed to build adaptive capacity as a means to maintain and strengthen farming system resilience and reduce vulnerability.

5.1. Enabling Factors

Higher levels of diversity have been maintained in the SFS compared with the JFS. Integrating modern farming methods rather than replacing traditional methods has contributed to higher levels of diversity. Although it is unclear whether this is an intentional approach adopted by farmers, government research and extensions or NGO programmes, it confirms that as "modern" varieties of crops and livestock are introduced, traditional production systems and associated local breeds are marginalised. Subsequently, this leads to a loss of genetic and cultural diversity in both crops and livestock [8]. Maintaining diversity will be important in fostering future farming system adaptive capacity.

Formal institutions, for example government policies, extension services and NGO programmes influence farming system adaptive capacity. This demonstrates that policy pathways are contingent on historical pathways and can be difficult to change [80]. Government research and extension services and NGO programmes should therefore think critically about the extent to which their approaches are enhancing or undermining adaptive capacity. There is potential to use the adaptive capacity framework presented here to assess the potential impacts of policies or programmes during the design process. Alternatively, there is potential to use the framework to explore the impacts of existing policies and programmes.

Data presented here reinforce the view that farmers have changed their agricultural practices and livelihood strategies in response to a range of pressures and opportunities [55]. Adaptation to climate change will, therefore, not take place in isolation [24]. Many management decisions and resource allocations, influenced by multiple factors operating across spatial scales, are made at the household level [58]. This confirms that farmers, who make these management decisions, influence the impacts of future changes [81]. However, farmers do not operate in a vacuum, and the decisions they make are based largely on outside influences [82]. Such decisions further influence farm-scale adaptive capacity, and therefore contribute to the overall resilience or vulnerability at a farming system scale. Future analysis of farming systems should recognise the agency of farmers and context of decision making processes as crucial to determining adaptive capacity [2]. There is a need to understand how farm management and resource allocation decisions are made, how such decisions shape adaptive capacity and ultimately, the vulnerability and resilience of farming system. Trade-offs made at the farm-scale and how they impact on adaptive capacity also need to be explored fully; presenting data collectively at the farming system scale can mask farm-scale variations.

5.2. Constraining Factors

A sole focus on productivity in the short term discounts the importance of fostering future adaptive capacity, which also includes maintaining long term productive capacity. Sound agricultural and adaptation policies must build upon rather than undermine farmers' traditional techniques as a means to fostering future adaptive capacity. Moreover, national and international agricultural research need shift focus from the short to longer term. We propose that there needs to be a balance between short term projects, which are often narrowly focused on productivity, and interdisciplinary long term research which seeks to strengthen all adaptive capacity components.

Despite the fact that overall the trends have had a positive impact on the adaptive capacity of the SFS compared with the JFS, other weaknesses in the farming system still exist. Whilst productivity, diversity and farm-scale resources have been maintained in the SFS, there is inconclusive evidence about the extent to which the SFS has been able to grow and develop, thus raising important questions about resilience, development and poverty reduction [25] and the synergies and trade-offs between them. For example, compared with Jinja District, Soroti District has much higher poverty levels and ranks lower in terms of socioeconomic development in multiple ratings [83–85]. The evidence on the extent to which farming systems with high levels of adaptive capacity are able to maximise productivity and increase incomes is inconclusive, highlighting additional areas for future research. This also raises important questions about trade-offs between short term socio-economic development and productivity with enhancing overall adaptive capacity, including productivity, in the long term [86]. These issues warrant further investigation.

Some issues, for example, the decline of informal insitutions, can be found in both farming systems, suggesting that some common actions are needed to enhance this component of farming system adaptive capacity. Currently, external actors and formal institutions are undermining informal cultural and social institutions. This highlights how the vertical interplay between formal and informal institutions across scale [87,88] can shape adaptive capacity [56]. Moreover, this interplay results in winners and losers within the farming system, which can exclude poor farmers and potentially reinforce existing power structures [89]. In recognition of this, future work should emphasise the social dimensions in SES systems and provide insight into complexity of institutional dimensions and how they shape adaptive capacity. Moreover, decision making and implementation processes of both governments and NGOs at the national and sub-national level are understudied, and more research is needed to understand the decision-making processes of such influential, but external, actors. Further empirical studies should examine the relationship between formal and informal institutions, whilst in practice, more emphasis is needed on fostering inclusive institutions.

5.3. Implications for Future Adaptation Support

Given that multiple drivers operating across spatial scales were identified as driving trends in farming system evolution (Table 4), this research supports the view that climate change "*is nested in among existing climatic conditions and numerous more proximal and pressing concerns*" [32] (p. 2). This perspective usefully highlights the contextual nature of farming systems, yet in line with Rickards *et al.* [32], we acknowledge that this runs the risk of overlooking the need for anticipatory or transformational change. Building on the approach used in this paper which analyses the evolution of farming systems, there is potential to integrate such understanding with future climate change scenarios to identify future impacts, and thus identify where adaptation support for anticipatory or transformational change is needed [90–92].

There is potential to learn from the experiences in Soroti District and Jinja District to promote strategies that enhance overall adaptive capacity, thus reducing vulnerability and strengthening resilience. There are some unique challenges specifc to the JFS and the SFS, for example the changing attitudes of youth in JFS and the role of livestock in the case of SFS, demonstrating that context specific actions will be needed. More broadly this highlights that the historical and contextual nature of farming systems is important, therefore policy and practice should move away from a one-size fits all approach. Taking actions, which maintain or enhance adaptive capacity (for example promoting diversity) may also provide "no-regrets" adaptation options to minimise the future impacts of climatic and non-climatic changes on farming systems.

Findings presented here suggest that NGOs and Government programmes focus on techno-fixes aimed at increasing crop and/or livestock productivity in the short term. Such programmes exclude consideration of the impacts this may have on diversity, resources and informal and formal institutions; though these are equally critical to maintaining and strengthening farming system adaptive capacity over time. These policies and programmes are in line with a global shift towards "modern agriculture", which is highly standardised, large-scale, mechanised and reliant on relatively few uniform cultivars.

In support of Stoop *et al.* [93], this paper also recommends a cautious approach to the promotion of modern agriculture because of the negative health, social and environmental impacts associated with high external-input use [93]. Instead, identification and integration of appropriate modern farming methods should be pursued, further highlighting the need for a shift away from a one-size fits all approach and a consideration of the implications of this in the long term.

The need for a long term view has significant policy relevance within and beyond Uganda. Firstly, it potentially challenges the underpinning principle outlined in the Plan for the Modernisation of Agriculture (PMA), the key agricultural policy in Uganda [94] and one of the pillars for achieving poverty eradication. Secondly, it highlights that there is a need to critically examine the goals of existing agricultural, development and adaptation policies and practices and identify the trade-offs and synergies. In order to enhance farming system adaptive capacity, targeted actions are needed for multiple actors across different sectors, including governmental and non-governmental actors and policies across levels. Future empirical work into vulnerability and resilience should not only consider the "of what to what" [35], but also consider "for who, where and when", *i.e.*, spatial and temporal scale dimensions of resilience and vulnerability.

6. Conclusions

Multiple pressures and opportunities have influenced the evolution of farming systems from the 1960 to 2012. These trends have not only influenced adaptive capacity, but also characterise current farming systems and will therefore, shape future adaptive capacity. In general, the shift to modern farming, including the range of interrelated sub-trends, such as shifts in farming methods, crop and varieties, represents a major change in both farming systems. Modernisation has had both positive and negative impacts on the components of adaptive capacity, where the most significant differences are related to diversity. Despite a range of changes, farming systems still remain important sources of food, income and livelihood. The major trends in the evolution of the JFS and SFS demonstrate that farming systems are dynamic and responsive to multiple pressures and opportunities operating at a range of spatial and temporal scales.

Using an integrated vulnerability and resilience framework provided a starting point for understanding past drivers of adaptations and how they influence farming system adaptive capacity. Such a framework lays a foundation for developing future approaches and intervention to strengthen resilience and reduce vulnerabilities in the face of growing uncertainties surrounding future climatic and non-climatic changes. The framework could be adapted for other adaptive capacity assessments and other social ecological systems, beyond the farming system. Further development of the framework could provide a practical framework for dynamic adaptive capacity assessments, for example through developing sub indicators. This could provide insight into how adaptive capacity can change over time and lead to the identification of contextually relevant enabling and constraining factors. As well as monitoring change over time, it could also be used to analyse how particular interventions may impact upon adaptive capacity before implementation, thus minimising negative impacts on adaptive capacity. Such a framework could be applied at other spatial scales in various geographical locations.

Through the enhanced understanding of farming system adaptive capacity, we propose the following points should be considered in future adaptation support: use of the vulnerability-resilience framework presented here to develop and implement interventions that enhance adaptive capacity; consideration of how to better integrate modern farming methods to maintain diversity, rather than a one size fits all approach; and a greater focus on building inclusive formal institutions. In addition, further research is required not only into how climate changes may impact on yields, but also how they will impact upon other components of adaptive capacity, specifically diversity and the natural resource base. Finally, we need to better understand trade-offs between short term productivity and longer term adaptive capacity, and within this, the role and decision making processes of influential actors, within a farming system and beyond.

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Conflicts of Interest

The authors declare no conflict of interest.

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