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Understanding adaptive capacity of smallholder African indigenous vegetable farmers to climate change in Kenya

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ABSTRACT

Understanding the adaptive capacity (AC) of farmers is crucial to planning effective adaptation. Action to promote farmers' AC is required because climate change (CC) is resulting in unpredictable alterations in weather patterns. Based on the sustainable livelihoods framework (SLF), this study explored how access to natural, physical, financial, social and human capitals enhances the AC. Quantitative data from 269 African indigenous vegetable (AIV) farmers in three selected agro-climatic zones in Kenya were analysed. Four indicators in each capital were selected based on previous studies and judgments collected from an expert online ranking survey (n = 35). The Kruskal-Wallis H test and an independent sample *t*-test were used to test the independence of AC scores and access to the different resources. The findings showed that the majority of farmers (53%) had a moderate AC, while fewer (32%) and (15%) had low or high AC levels respectively. Disparities in adaptive capacity scores were recorded between respondents in terms of their age, marital status and location. Farmers had high access to social capital but low access to financial, natural and human capitals. Female farmers showed lower capacities in the areas of financial, human and natural resources, while their male counterparts had low access to some human and social capitals. Resilient interventions that target individuals with low adaptive capacities are required.

1. Introduction

Studies indicate that smallholder farmers in sub-Saharan Africa (SSA) are particularly vulnerable to the effects of climate change (Phiiri et al., 2016; IPCC, 2014; Morton, 2007). Furthermore, the impacts of climate change are felt disproportionately among different socio-economic groups (Belloumi, 2014; Nelson et al., 2010). The impact may be greater for smallholder farmers in many developing countries because they are predominantly dependent on rain-fed agriculture for their farming activities and are increasingly being exposed to extreme events, in addition to their general widespread poverty and marginalisation (Harvey et al., 2014). In Kenya, the effects of climate change, such as recurrent droughts and floods, have serious environmental, economic and social impacts on smallholder farmers whose livelihood largely depends on reliable rainfall (Ochieng et al., 2016; GoK, 2013). In particular, smallholder farmers who produce vegetables, in this study African indigenous vegetables (AIV), seem to have different adaptive capacities due to differences in their access to resources and the occurrence of extreme climatic events (Stöber et al., 2017).

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Some AIVs such as Amaranth (*Amaranthus* sp.), cowpea (*Vigna unguiculata*), African vine spinach, jute mallow *(Corchorus olitorius)* and slenderleaf (*Crotalaria Brevidens*) tolerate a wide spectrum of abiotic changes. However, some species are more sensitive than others and also AIV farmers face pests and disease problems along with water shortages that hamper their productivity (Ibid). The production of nightshade, for instance, is constrained by sucking insects, particularly aphids and spider mites (Mureithi et al., 2017). Additionally cowpea aphid (*Aphis craccivora* Koch) can lead to 100% yield losses in leafy cowpea in the absence of any control (Mweke et al., 2016). Adaptation is therefore intrinsic to minimising the adverse effects of climate change Smit and Wandel (2006). Some of the most commonly used farm-level adaptation strategies adopted by AIV farmers in Kenya include ecologically sound strategies such as hand-watering of vegetables, mulching, agroforestry, crop diversification and a change of planting dates. Nevertheless, maladaptation strategies that could increase their vulnerability are common. For example, farmers adapt to the increased occurrence of pests and diseases by applying more synthetic pesticides (Chepkoech et al., 2018; Stöber et al., 2017). The increased risks associated with maladaptation are the acceleration of environmental degradation and human health issues (Aktar et al., 2009). Efforts are therefore needed to support socio-ecological systems that increase the AC and reduce long-term vulnerability (Magnan, 2014). The dissemination of adaptation strategies, however, depends on the adaptive capacities of farmers and their control over both tangible and intangible resources (Hogarth and Wójcik, 2016; Dixon et al., 2014). There is growing consensus that adaptation policies must take long-term sustainability into consideration, addressing inequalities that create and sustain poverty and transmit vulnerabilities. This is likely to require policies that address the challenge presented by the existing distribution of power and assets (Lemos and Boyd, 2009). However, in sub-Saharan Africa, adaptation policies to adapt agriculture or horticulture to climate change are not being specifically targeted at the different resource and power levels of smallholder households. This might be due to a lack of knowledge about the various adaptive capacity levels. There have only been a few studies examining an AC index in East Africa using a household asset indicator-based approach. Such studies have been conducted in Uganda, Ethiopia and Tanzania (Shirima et al., 2016; CARE and ALP, 2013; Dixon et al., 2014; Ibrahim, 2014 respectively). Attempts have been made to assess Kenyan farmers' AC in a range of studies. Some of these studies have examined what the communities or farmers do that enables them to adapt, while others have used the asset indicator approach. For instance Ndegwa et al. (2010) examined farmers' ability to use and interpret localised (simplified) climate information to adopt strategies such as the use of hybrid seeds and local crop varieties. The influence of the gender division of labour and access to resources on irrigated contract farming was analysed by Caretta and Börjeson (2015). A few studies have used the asset indicator approach to examine attributes that include access to credit, trust, social capital, human agency, community infrastructure (Cinner et al., 2015), financial, physical, social, human and natural capitals (Sorre et al., 2017), flexibility and access to resources (Recha et al., 2017), household assets and socio-economic resources (Simotwo et al., 2018), and assets, institutions and entitlements, knowledge and information, decision-making and governance (CARE and ALP, 2013).

While these studies all assessed the AC, it was determined using individual influencing factors. Few studies have developed an index for determining the adaptive capacity of smallholder farmers in Kenya using the SLF, but an index-based measurement would be beneficial for devising policies that target smallholder farmers' ability to adapt to climate change.

At present, agricultural policies in Kenya often ignore specific target groups because there is a lack of contextual information on farmers' specific socio-economic conditions. The aim of this study was to fill this knowledge gap by answering the following research questions: 1. What determines the adaptive capacity of AIV farmers in Kenya? 2. How does access to capital assets differ by farming household characteristics and between the selected areas? 3. What are the AC levels of AIV farmers in the selected zones of Kenya? 4. What policy structure would be needed to enhance the adaptive capacity of smallholder farmers?

2. Conceptualising adaptive capacity

The AC is framed as the system's ability to adjust to climate change (including climate variability and extremes), moderate potential damage, take advantage of opportunities and cope with the consequences (Adger et al., 2007; IPCC, 2007). Increasing the ability of systems to adapt or develop their AC is already becoming an important consideration in preparing for and responding to change (Brooks and Adger, 2005). Even small changes in climate can have significant negative effects on populations when the capacity to adapt is low (Byrne, 2014). Therefore, increasing the AC improves the opportunity of systems to manage varying ranges and magnitudes of climate impacts (Engle, 2011; Smit and Wandel, 2006; Brooks and Adger, 2005). According to Adger and Vincent (2005), the capacity to adapt is a critical element of the process of adaptation: it is the vector of resources that represent the asset base from which adaptation actions can be made. It is therefore fundamentally dependent on access to social, human, institutional, natural and economic entitlements that particular individuals or households can mobilise in order to cope with risk (Cassidy and Barnes, 2012; Wall and Marzall, 2006; Adger, 2003).

This research was based on the SLF developed by Ellis (2000) and DFID (1999), which takes the asset pentagon as the resource base of a household to develop its livelihood strategies in a given environment. According to Defiesta and Rapera (2014), indicators used recently are largely based on the SLF. The SLF shows how, in different contexts, sustainable livelihoods are achieved through access to a range of livelihood resources: natural, physical, financial, social and human capitals (Scoones, 1998). The strength of this approach is that it is people-centred and enables the development of nationally consistent and standardised measures of AC (Lockwood et al., 2015). According to Chambers and Conway (1991), a livelihood comprises the capabilities, assets (including both material and social resources) and activities that contribute to a means of living.

In order to operationalise the SLF concept, a wide range of indicators that serve as proxies for the five different capital assets have been used. For instance, Egyir et al. (2015) assumed that the AC would be boosted by increased natural capital (farm size), physical capital (good roads, potable water, market access), financial capital (access to formal/informal credit, savings, large capitals), social capital (association with educational institutions, research/training organisations, formal governmental organisations) and human capital (level of education, farming experience, business information). Defiesta and Rapera et al. (2014) quantified the AC of smallholder farmers in Philippines using measures of physical resources (farm size, source of irrigation, ownership of farm implements), financial resources (value of animal units, financial subsidy, credit access), human resources (farming experience, educational attainment of the household head, percentage of adults with primary education), information (type of training on farming, technical assistance, membership of organisations and source of climate information) and livelihood diversity (number of sources of income, number of crops, percentage of land not in crop). It was hypothesised that greater access to capital as represented by these proxy indicators increases the adaptive capacity.

Based on these experiences, the present study also applied an indicator-based assessment of AIV farmers' AC. It was based on an area-specific farmer assessment designed with common indicators adjusted for small-scale farming in SSA. This study calculated the AC using a composite index which, according to Abdul-Razak and Kruse (2017), is an approach that has been applied in several AC assessments at a local level in Ghana and by other studies in the Philippines, Canada, Australia, Uganda and Tanzania (Shirima et al., 2016; Ibrahim, 2014; Nelson et al., 2010; Cuesta and Rañola, 2009; Swanson et al., 2009).

3. Methodology

3.1. Study area

The study area was made up of three purposively selected ACZs in Kenya. Based on the vegetation characteristics, the amount and reliability of rainfall and land ecological potential, Kenya is divided into seven agro-climatic zones (Bryan et al., 2013). The high to medium potential areas comprise of agro-climatic zones I – humid, II – sub-humid and III – semi-humid. The humid and sub-humid zones are well watered, support arable agriculture and have a high population density with annual rainfall of more than 800 mm (MAFAP, 2013). The marginal or low potential areas comprise of agro-climatic zones IV – semi-humid to semi-arid, V – semi-arid and VI – arid and VII – very arid, and constitute the Arid and Semi-Arid Land (ASAL) or rangelands. These areas are generally hot and dry, with low and unpredictable rainfall of less than 600 mm per year (FAO, 2010).

Kakamega County (Humid Zone I) lies between longitudes 34° and 35° E and latitudes 0° and 1° N of the equator and within altitudes 1250–2000 m (Barasa et al., 2015a,b). The total area of Kakamega County is 3020 sq. km with a population of 1,660,651 (GoK, 2013). Kakamega County's climate is predominantly hot and wet most of the years with mean annual rainfall between 1800 and 2000 mm. The mean monthly trend of rainfall represents two maxima and minima over the year. The first and second maxima occur in April to June and August to November respectively (GoK, 2013). Generally, there are two main cropping seasons in most parts of the County that coincides with the 'long rains' and 'short rains'. The 'short rains' fall between March and May while the 'long rains' fall between October and December (Kabubo-Mariara and Karanja, 2007). The average temperature in the county is 22.5 °C. January and February are generally considered as dry months (Barasa et al., 2015a). It has high temperatures all the year with slight variations in mean maximum and minimum which ranges from 28 °C to 32 °C and 11 °C to 13 °C respectively. The mean annual evaporation is high and ranges from 1600 mm to 2100 mm with high humidity (Ngetich, 2013).

Nakuru County (semi-humid zone III) lies within the Great Rift Valley. The County covers an area of 7,235.3 sq. km and is located between longitudes 35° and 35° East and Latitude 0° and 1° South (GoK, 2013). The County lies between 1520 and 2400 m above sea level. The temperature varies between 24 °C and 29.6 °C. A bimodal rainfall pattern with a high of 1800 mm and a low of 500 mm characterizes the zone (Ogeto et al., 2013).

Kajiado County (Semi-Arid Zone V) has a population of 687,312 and occupies an area of 21,902 sq. km (GOK, 2009a). It is located between longitudes 360° 5′ and 370° 5′ east and between latitudes 10° 0′ and 30° 0′ south. The County has two distinct rainy seasons, long raining season from March to May and short rainy season from October to December (Babadoye et al., 2014; (GoK, 2014). The distribution of rainfall between the two seasons changes gradually from east to west across Kajiado County. In eastern Kajiado more rain falls during the long rains (March–May). The mean annual rainfall ranges from 300 to 800 mm (GoK, 2009).

3.2. Data sources and collection methods

A multi-stage sampling procedure was employed. The first stage involved the selection of three counties – Kakamega, Nakuru and Kajiado – which were chosen to represent the humid, semi-humid and semi-arid zones. In the second stage two sub-counties with high potential AIV production were purposefully selected from each of the selected counties. Butere and Lugari (Kakamega), Bahati and Rongai (Nakuru) and Kajiado North and Kajiado East (Kajiado) were selected. In the final stage, a snowball sampling procedure was used to select farmers in each sub-County. In survey research, 100 samples should be identified for each major sub-group in the population and between 20 and 50 samples for each minor sub-group Kathuri and Pals (1993); Borg and Gall (1989). A non-response of not more than 10% was expected in each county. Therefore, 110 farmers were sampled in each County (55 from each sub-county). However, a total of 100, 107 and 62 interviews were conducted in Kakamega, Nakuru and Kajiado counties respectively. In Kajiado County, only 62 interviews were conducted since there were difficulties in locating AIV farmers. Structured interview schedules were therefore administered to a total of 269 AIV farmers to collect information on socio-economic characteristics relevant for the AC assessment. The questions were developed based on the indicators selected from previous AC studies.

3.3. Data analysis

3.3.1. Selection and ranking of indicators of adaptive capacity

To understand how AC varies between AIV farming households, a list of indicators that capture the potential determinants of adaptive capacity was developed based on previous studies. The asset categories and the set of potential variables from the interview were based on previous empirical research (Williges et al., 2017; Egyir et al., 2015; Baca et al., 2014; Byrne, 2014; Defiesta and Rapera, 2014; Eakin et al., 2011; Eakin and Bojorquez-Tapia, 2008). In order to determine the indicators to be used for each capital index, an expert online survey was conducted. A total of 92 experts were contacted *via* e-mail and invited to participate in the online monkey survey. Follow-up reminders were sent, triggering a response rate of 38%. A total of 35 responses were collected from researchers (54%), PhD students (34%), extension agents (5%) and consultants (6%) in 8the field of climate change, agriculture and socio-economics. The majority (69%) were male, while 66% were aged between 29 and 39 years. Each respondent ranked the indicators in each capital asset category and decided which indicator contributed to the asset capital from most to least. The four highest ranked indicators were included in each capital to develop the index. The number of indicators to be included was based on previous studies and available data.

3.3.2. Indicator normalisation and index construction

Knowledge and information on scoring were generated from a review of previous AC assessments. According to Swanson et al. (2009), the literature does not provide a definitive direction on how the indicators are weighted. Following the methods used by other studies, a simple ranking system was established to score the results of the AC assessment (Abdul-Razak and Kruse, 2017; Gbetibouo et al., 2010; Eakin and Bojorquez-Tapia, 2008). This was done by considering the relative importance of one element over the other. A lack of access to a particular resource or element was scored zero. For example, access to a particular resource, Yes = 1 score and a lack of access No = 0 score. If elements contribute equally/are of equal importance they were assigned similar scores while those with strong importance were assigned higher scores. For instance, in land/ownership/tenure, households with private land with title deed were assigned the highest score as opposed to those who are in leasehold or ancestral land. This is because tenure security affects people's long-term investments in technologies. Insecure land rights constrain farmers from making the necessary investments in their land to increase its productivity and economic value. Moreover, limited land ownership restricts access to formal financing mechanisms since land is the most significant collateral for loans for smallholders. The scores for all indicators are contained in (Table 1). The overall values for each category were calculated by averaging all the scores from each of the indicating parameters/variables. The index was then formed from a sum of scores for each of the indicators. Comparison of adaptive capacity across the households required, first, that the individual indicators for each determinant be aggregated to a determinant value and, second, that these determinant values be aggregated into an overall index of adaptive capacity. The main conceptual challenge in such an exercise is the disparate units for each of the individual indicators that make up each determinant. Therefore, the values of disparate units were then normalized (Swanson et al., 2009).This was done to render the variables comparable. Normalisation is required prior to any data aggregation as the indicators in a data set often have different measurement units (OECD, 2008).

The min–max normalisation method was applied to the indicator scores. This method converts all values to scores ranging from 0 to 1 by subtracting the minimum score and dividing it by the range of indicator values. The following formula was used:

$$X_{i\,0\,\text{to}\,1} = \frac{X_i - X_{Min}}{X_{Max} - X_{Min}}$$

Where

X_i represents the individual data point to be transformed

X_{Min} the lowest value for that indicator

X_{Max} the highest value for that indicator and

$X_{i,\,0\,\text{to}1}$ the new value to be calculated, *i.e.* the normalised data point within the range of 0 to 1 (Fritzsche et al., 2014).

Since there is no general rule for classifying AC levels, the classification and cut points were based on previous studies and determined by the nature of the dispersion of data (Defiesta and Rapera, 2014). Three intervals that contain low, moderate and high AC were applied. The Kruskal-Wallis H test and independent sample t-tests were used to determine statistically significant differences in the adaptive capacity scores between household accesses to different resources. It was assumed that the AC scores varied with the extent of ownership of different livelihoods resources. The hypotheses were tested at the 5% level of significance. The two tests were chosen based on the distribution of data. For instance, Kruskal Wallis test was used when the assumptions of normality was not met and also because it allows the comparison of more than two independent groups while the opposite was true for the independent sample *t* test which is 'robust' to violations of normality and only allows for the comparison of only two independent groups.

Table 1
Index representation.

Adaptive capacity indices	Score range
Low	0.00–0.33
Moderate	0.34–0.66
High	0.67–1.00

3.3.3. Determining AIV farmers' levels of AC

The adaptive capacity index was constructed based on the higher ranked and selected indicators of five capital assets. The capitals (physical, natural, human, financial and social) each comprised four variables from the ranking survey. A few variables were included in the AC index that had been used in the studies of Abdul-Razak and Kruse (2017), Defiesta and Rapera (2014), Eakin and Bojorquez-Tapia (2008). Scoring criteria (Table 1) were taken from Abdul-Razak and Kruse (2017).

Since there are no absolute values in AC, the approach of creating an aggregate index from the composite sub-indices was chosen to maintain transparency, which is critical for end users (Vincent, 2007). The total score of every respondent was achieved by summing the scores from the indicators of the five capitals. The aggregate AC discussed resulted from a combination of scores from each of the indicators. The total scores ranged from 3.44 to 15.33. The overall scores were then normalised using the formula described above. For purposes of uniformity and consistency, a categorisation criterion was adapted from Asante et al. (2012). In this case households with the highest scores of the indicator variables had a total score of one (1), while those with the lowest level had total scores approaching zero (0). All farmers who scored less or equal to 0.33 were categorised as 'Low', those with scores ranging from 0.34 to 0.66 were characterised as 'Moderate', while those who scored more than 0.67 were characterised as 'High' (Table 1).

3.3.4. Description of the indicators from the ranking survey and assumptions

3.3.4.1. Natural capital. Natural capital is operationalized as access to resources such as land and water, on the basis of which households engage in agricultural pursuits and/or resource collection for both nutrition and income generation (Nawrotzki et al., 2012). According to an expert ranking, the type of land ownership is regarded as the most important asset in natural capital, followed by land size, decision-making about land management, and the source of irrigation water. More than half (56%) of the respondents were owners of farms with private title deeds, while the remainder were family/ancestral or leasehold lands.

Land tenure security – the extent of people's rights and how confident they are that their rights will be respected over time – affects people's long-term investments in technologies for managing their resources (Meinzen-Dick et al., 2002). Insecure land rights constrain farmers from making the necessary investments in their land to increase its productivity and economic value (Teklewold et al., 2013; Kassie et al., 2010). Moreover, limited land ownership restricts access to formal financing mechanisms since land is the most significant collateral for loans for smallholders. This is the case outside Kenya as well. Land size was nominated as another important indicator for assessing adaptive capacity. Farm size is associated with greater wealth, which increases the potential of households to adapt to climate change (Deressa et al., 2009). A study from Ghana also supports this connection by arguing that households with larger farms are more likely to adopt new technologies to adapt to climate change. Households with larger farms have a greater likelihood of engaging in mixed cropping and food crops. Moreover, they belong to the wealthier households that can afford to purchase the required inputs (Egyir et al., 2015).

In the expert ranking of AIV farmers' natural capital, the source of water for irrigation was another important asset. Distance and susceptibility to climate variables were the criteria used to assign scores to the indicators. For instance access to tap water was assumed to enhance adaptive capacity because tap water is more reliable and usually located next to the homestead. Wells and tanks, although also mostly located next to homesteads, may be more unreliable because they are at risk of drying up during the dry season (Ogendi and Ong'oa, 2009). In the study, majority of the farming households (78.4%), only the household head had decision-making responsibility over land management. Household decision-making concerning land management has been used in previous studies to assess AC (Defiesta and Rapera, 2014; Cassidy and Barnes). It was expected that households with more individuals involved in decision-making would have a higher AC compared to those where the household head/spouse was the sole decision maker. Research has shown that where men of certain groups have primary rights, women and tenants who have weaker, derived rights may not benefit as much because they may be less motivated (Meinzen-Dick et al., 2002).

3.3.4.2. Physical capital. Physical capital refers to the basic infrastructure, such as roads and electricity, and inputs such as tools and animals needed to support livelihoods (Sherbinin et al., 2008; DFID, 1999). The asset-based wealth approach takes into account the ownership of durable assets and is a reliable index for measuring household wealth compared with an index based on income or consumption expenditure (Howe et al., 2008). The Ghana study cited above revealed that a household with good access to basic infrastructure has a higher probability of engaging in productivity-enhancing techniques (Egyir et al., 2015). In the AIV farmers' expert ranking, a household's access to irrigation infrastructure was ranked as the most important indicator contributing to physical capital. Other resources included decision-making on asset use, the total number of assets owned by the household, and access to agricultural machinery such as tractors. Access to irrigation infrastructure is also a key asset in adapting to climate change in other studies as well (Egyir et al., 2015; Eakin et al., 2011). For instance, farmers who make use of improved irrigation are more likely to increase the size of plots under production because they save labour costs for irrigation and exploit the income opportunities in the dry season with dry-season vegetable farming. In the present study, sprinkler and drip irrigation were classified as 'improved' irrigation, while furrow and hand-watering were classified as 'simple' irrigation. Access to basic farm implements and machinery increases adaptive capacity. Ownership of farm machinery enables farmers to exploit better farming technology and hence enhances AC (Defiesta and Rapera, 2014). Decision-making on asset use is also important in building AC. Asset distribution within the household influences an individual's bargaining power in the household, which in turn affects household and individual wellbeing (Meinzen-Dick et al., 2013).

3.3.4.3. Financial capital. Financial capital is defined as the level, variability and diversity of income sources and access to other financial resources that contribute to wealth (Williges et al., 2017). The experts ranked access to off-farm income as the most important asset in the category of financial capital. Other indicators in descending order included access to formal/informal credit, the number of all sources of income, and a household's ability to employ a farm worker. Off-farm income was ranked high, because it can be attained in a short period of time and therefore increases the liquidity of the farm household, which allows the timely and sufficient purchase of the inputs that are often required for adapting to climate change. This assumption is supported by Egyir et al. (2015), who argue that access to off-farm income influences the adoption of modern coping strategies, with a lack of it increasing the likelihood of farmers adopting farming practices to sustainably intensify their production. However, the majority (68%) of surveyed AIV farmers did not access off-farm income.

The present findings revealed that more than half (56%) of the interviewed farmers accessed credit. Access to formal and informal credit increases cash flow and allows farmers to invest in capital-intensive technologies such as water harvesting and improved irrigation. According to Deressa et al. (2009), the availability of credit facilitates the purchase of farm inputs such as fertilisers and irrigation facilities. Greater financial resources allow the acquisition of physical and information resources that are vital in carrying out adaptations in the Philippines and Ghana (Defiesta and Rapera, 2014; Egyir et al., 2015). Additionally, access to credit also allows people to access funds in times of shocks and stress so that they are able to create a buffer against hardship and recover more quickly (CARE and ALP, 2013).

The survey results showed that income diversity was very low since the majority (67.3%) had only one income source. Income diversification is positively linked to adaptive capacity (Abdul-Razak and Kruse, 2017; Defiesta and Rapera, 2014). Greater financial access reflects a better ability to offset the possible negative impacts of climatic variability and to recover from material loss. Furthermore, diverse employment opportunities provide more options to minimise risk if climate affects a particular type of occupation (Wall and Marzall, 2006). A household's ability to employ a farm worker was seen as another indicator for measuring the adaptive capacity of farmers. Farmers with greater financial capability are usually also able to employ an adequate labour force on their farms. Sufficient endowment with labour helps farmers to perform their farm operations in due time and try out new technologies that also require an investment in labour (Kansiime et al., 2018). In poor areas of rural China, the number of workers in farming households has been used to represent human resources that are important in increasing income levels, and is therefore a key determinant of household income (Wei, 2001).

3.3.4.4. Social capital. Social capital captures the features of social life, with interpersonal networks, norms and trust enabling participants to act together more effectively to pursue shared objectives (Putnam, 1995). Access to agricultural extension services was ranked as the most important asset contributing to social capital. Other assets that were ranked by the experts as enhancing AC were access to weather forecasts and group membership. A number of studies point to the importance of agricultural extension services in enhancing the adaptive capacity of farmers (Deressa et al., 2009; Frank and Penrose Buckley, 2012). They boost farmers' knowledge and skills around climate change adaptation and related practices and technologies (Abdul-Razak and Kruse, 2017; Hassan and Nhemachena, 2008). Farmers who have access to reliable weather forecasts are able to plan their adaptation strategies against prevailing climatic changes (Abdul-Razak and Kruse, 2017; Lo and Emmanuel, 2013). Most of the Kenyan AIV farmers surveyed had access to agricultural extension services, with even more having access to weather forecasts. In this study slightly more than half (52%) of the farmers were members of an organisation/group, indicating a rather high social capital. Community-based organisations and revolving funds such as the Kenyan *chamas* (investment groups) provide an important opportunity for money lending and seed sharing, as well as accessing weather and market information. Reportedly, affiliations to social groups provide farmers with access to useful information for climate change adaptation that may be exclusively available to group members (Defiesta and Rapera, 2014). Membership of associations was a relevant indicator of social capital in studies carried out with smallholder farmers in Indonesia and Kenya, Burkina Faso and Ghana (Abdul-Razak and Kruse, 2017; Yameogo et al., 2018; Grootaert and Van Bastelaer, 2001).

3.3.4.5. Human capital. Human capital represents the skills, knowledge and ability to provide labour and pursue different livelihood strategies in order to achieve livelihood objectives (DFID, 1999). The expert ranking revealed that the level of education of Kenyan AIV farmers was the most important asset in building human capital. Other indicators ranked in descending order were farming experience, household size and the number of adults in the household. The survey findings in the present study showed that 46% of farmers had a rather low level of education, ending at primary school. Educated farmers have a greater ability to process forecasted information and use improved agricultural technologies/machinery required for adapting to climate change. As in many other studies in which education is considered a cornerstone for enhancing AC, it was expected that moving from a lower to higher education level results in increased AC. Studies carried out in Pakistan and the Philippines have shown that higher levels of education increase farming households' AC (Elahi et al., 2015; Defiesta and Rapera, 2014). Similarly, case studies conducted in El Salvador and Brazil has shown that education has a direct influence on the residents' risk level and associated risk reduction.

Farmers who have spent several years in farming have a high AC because they are better equipped with local knowledge on adaptation than less experienced farmers (Abdul-Razak and Kruse, 2017). More often, adapting to climate change has been positively correlated with the number of years' farming experience (Nhemachena and Hassan, 2007; Defiesta and Rapera, 2014). Experienced farmers are older farmers who may have accumulated resources over time and are able to invest in increasing the number of assets that contribute to the overall AC. Household size as well as the number of adults in a household was used to capture the availability of household labour. This study followed assumptions that have been used in previous studies in Nicaragua and Botswana, attributing higher adaptive capacities to larger household sizes. Larger households are linked to greater labour availability, a higher accumulation of capital and better information networks (Byrne, 2014; Cassidy and Barnes, 2012). Similarly the number of adults in a household was linked to more available labour and a lower dependency rate in the Philippines and Uganda (Defiesta and Rapera, 2014; Dixon et al., 2014) (Table 2).

Table 2
Indicator scoring criteria (n = 269).

Rank of indicators	Clusters/grouping	% distribution	Scores	Normalised scores
Natural capital				
1. Type of land ownership	Leasehold	6.7	1	0
	Family/ancestral land	37.5	2	0.5
	Private with title deed	55.8	3	1
2. Size of land in acres	< 0.6	85	1	0
	0.6–1	10	2	0.5
	> 1.0	5	3	1
3. Source of water	Well	22.7	1	0
	Rain/tank	38.7	1	0
	River	24.5	2	0.5
	Tap	14.1	3	1
4. Decision over land management	Household head alone	78.4	1	0
	Spouse alone	6.7	1	0
	Household head and spouse	13.8	2	0.5
	Everyone in the household	0.7	3	1
Physical capital				
1. Type of irrigation	No irrigation	19.0	0	0
	Watering can/bucket	52.0	1	0.33
	Furrow	5.2	2	0.66
	Sprinkler/drip	23.8	3	1
2. Total number of assets	0 asset	0	0	0.0
	2–5	18.2	1	0.33
	6–9	59.9	2	0.66
	> 9	21.9	3	1
3. Ownership of basic farm tools	Yes	100	1	1
	No	0	0	0
4. Ownership of farm machinery	Yes	3	1	1
	No	97	0	0
Financial capital				
1. Off-farm income	Yes	32.0	1	1
	No	68.0	0	0
2. Formal/informal credit	Yes	43.5	1	1
	No	56.5	0	0
3. Number of income sources	1 source	67.3	1	0
	2 sources	27.1	2	0.5
	> 2 sources	5.6	3	1
4. Number of farm workers	0	55.4	0	0
	1 worker	22.7	1	0.25
	2 workers	16.0	2	0.5
	3 workers	3.0	3	0.75
	> 3 workers	3.0	4	1
Human capital				
1. Education level	Informal/no education	4.5	0	0
	Primary	45.7	1	0.25
	Secondary	31.6	2	0.5
	College	14.5	3	0.75
	University	3.7	4	1
2. Number of years in farming	1–5	46.8	1	0
	6–10	22.3	2	0.33
	11–15	8.6	3	0.66
	> 15	22.4	4	1
3. Size of household	1–5	48.0	1	0
	6–10	48.7	2	0.5
	> 10	3.3	3	1
4. Number of adults	1–3	60.8	1	0
	4–6	29.4	2	0.5
	> 6	9.7	3	1
Social capital				
1. Frequency of extension	No extension	23.8	0	0
	once	22.7	1	0.25
	2–5 times	19.0	2	0.5
	6–10 times	10.8	3	0.75
	> 10 times	23.8	4	1
2. Weather forecast information	Yes	92.9	1	1
	No	7.1	0	0
3. Group membership	Yes	51.7	1	1

(*continued on next page*)

Table 2 (*continued*)

Rank of indicators	Clusters/grouping	% distribution	Scores	Normalised scores
	No	48.3	0	0
4. Number of sources of weather information	0	9.7	0	0
	1	40.9	1	0.33
	2	27.9	2	0.66
	> 2	21.6	3	1

4. Results and discussions

4.1. Household characteristics

Apart from household characteristics, AIV biodiversity and whether the farmers are producing for commercial or subsistence purposes were discussed. Table 4.3 provides a summary of the farmers' profiles, indicating that the majority of AIV farmers (65%) were female. This is consistent with other studies that show AIV production often being managed by female farmers (Kebede and Bokelmann, 2017). Other results from the present study showed that the mean age of the farmers was 44.5 years old. Most of the interviewed farmers (81%) were in dual-headed households, while the rest (19%) were in single-headed households. The majority of the farmers (76%) grew AIVs for both commercial and subsistence purposes. More than 75% sold their vegetables at the farm gate and in local markets. Similarly, in a study conducted in the western region of Kenya, Opiyo et al. (2015) found that the main outlets for traditional vegetables were local markets and neighbours. Amaranth, cowpea, African nightshade (*Solanum villosum*) and spider plant (*Cleome gynandra*) were produced by more than 50% of the farmers. The least-produced AIVs included African vine spinach (*Basella alba*), Ethiopian kale (*Brassica carinata*) and Russian comfrey (*Symphytum officinale*), which were cultivated by fewer than 10% of the farmers. The mean number of AIVs grown per farm was four. The highest had ten, while the lowest grew only one type of AIV. Kakamega County, a high-potential area with a humid climate, had on average five species per farm, while the semi-arid Kajiado County was less diverse with three species.

4.2. Assessment of smallholder farmers' adaptive capacity in the study area

4.2.1. Variations in the adaptive capacities of AIV farmers by age and marital status

The T-test results showed that older farmers had a significantly higher AC than younger farmers (Table 3). These findings may imply that older farmers have more experience in production and may have accumulated more assets than younger farmers. Similarly, AC has been positively correlated with age in studies carried out in Nicaragua and Botswana (Byrne, 2014; Cassidy and Barnes, 2012). Other findings from the present study revealed significantly higher adaptive capacity scores in dual-headed households. Divorced, widowed and single people in this study were categorised as single-headed households, while married people were categorised as dual-headed households. In agreement with this, Thathsarani and Gunaratne (2018) show that dual-headed households have a better living standard and mutual support from spouses as compared to single, divorced and widowed people, and thus have a higher adaptive capacity. Even though male farmers recorded a slightly higher AC index than female farmers, the difference was not significant (Table 3). However gender differences did exist in access to specific capital assets (Fig. 1). With regard to human capital, most (51%) female farmers had completed only primary education and another 6% had only informal or no education. Only 36% of

Table 3
Differences in adaptive capacity scores by farmer/household characteristics.

Characteristics		Mean AC score	t	χ^2
Gender of AIV farmer	Male	0.47	0.57	
	Female	0.46		
Farmer is above 44 years	Yes	0.50	3.397****	
	No	0.43		
Marital status	Single	0.44		5.49
	Married	0.47		
	Divorced/widowed	0.41		
Household has no children < 14 years	Yes	0.46	0.29	
	No	0.48		
Grows more than four species of AIVs (AIV biodiversity)	Yes	0.48	0.973	
	No	0.46		
Purpose for production	Commercial only	0.41		4.81
	Subsistence only	0.48		
	Commercial and subsistence	0.47		
Location of farmer	Kakamega	0.47		7.65**
	Nakuru	0.42		
	Kajiado	0.52		

Note. *, **, **** indicates significance at $P < 0.1$, 0.05 and 0.001 respectively.

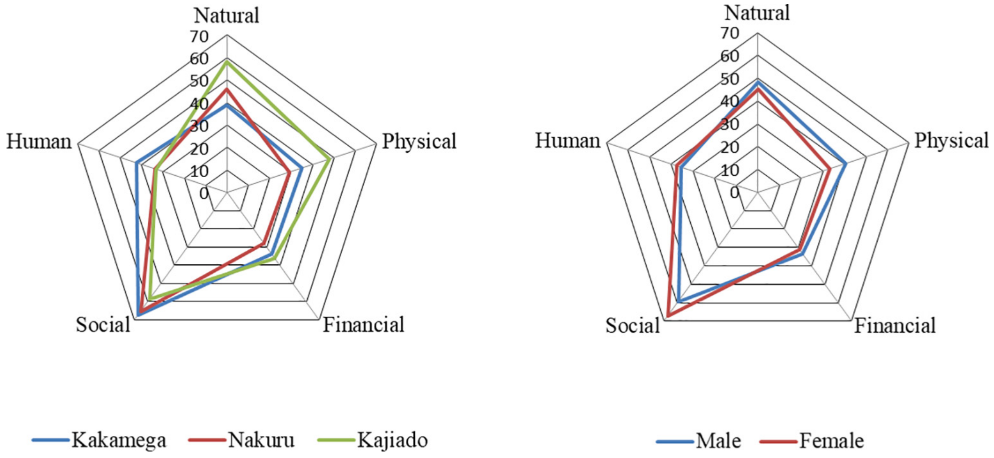


Fig. 1. The Average scores (expressed as %) in the five capitals by zone and by gender.

male farmers had completed primary education, while 2% had informal or no education. However, female farmers scored higher than their male counterparts in overall social capital. One major reason for this is the women's high participation in groups (59%) and good access to extension services (80%), while the participation of male farmers was much lower, with 37% of male farmers being a member of a group and 67% having access to agricultural extension services.

4.2.2. Variations in the adaptive capacity of AIV farmers by production purpose and AIV biodiversity

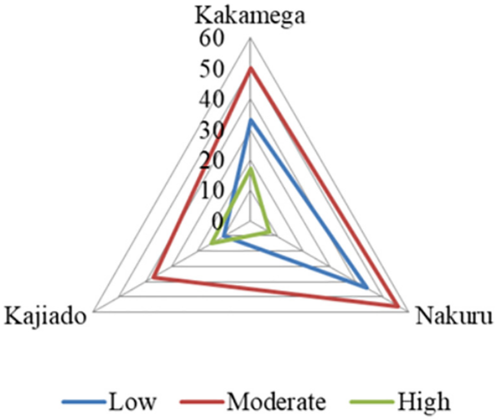
Results showed that the level of market integration for AIVs did not show a statistically significant difference in the AC scores. Unexpectedly, households producing AIVs for subsistence only had a slightly higher AC, while those involved in marketing AIVs had a lower AC. Commercial AIV farmer were more vulnerable because the majority (61%) were quite young, produced AIVs on land with ancestral rights (60%), did not access off-farm income and had only one income source with low group membership. Subsistence farmers were older with higher literacy rates, more secure land tenure and were only part-time farmers as they usually generated off-farm income. In terms of AIV diversity, households that grew more than four species of AIVs had a higher AC than those with fewer species. These results were expected because crop diversification has been recognised as an effective adaptation option for farmers in risk mitigation against uncertainty (Gebrehiwot and van der Veen, 2013) and has often been examined as a tool to stabilise crop revenue and farm income (Ogundari, 2013).

4.2.3. Gender differences in adaptive capacity and access to the five capitals

4.2.4. Variations in access to the five capitals of AIV farmers by zone

In terms of natural capital, farmers in rural Kakamega scored lower than those in the peri-urban Nakuru and Kajiado counties. In Kakamega county 84% owned less than 0.5 acres of land, with more than half of these being ancestral land. However, in Kajiado and Nakuru counties land tenure was more secure as more than half of the interviewed farmers owned private land with title deeds. The physical capital was low overall, with a small uptake of improved irrigation and low total physical asset ownership. Even though all the farmers had access to basic farm implements, very few had access to farm machinery. Nakuru and Kakamega counties scored fairly low in the ownership of physical capital, while most of the improved irrigation was adopted in Kajiado County. Although more than half accessed formal/informal credit, there was low access to financial capital overall due to low access to off-farm income and low diversity in income sources, with the majority of farming households having just one source of income. Access to financial capital was equally low in all three locations. The only striking difference was the access to non-agricultural income in Kajiado compared to Kakamega. Low access to financial capital has a particularly strong influence on the AC index, as financial capital is assigned a particularly important role in building adaptive capacity, according to various studies (Abdul-Razak and Kruse, 2017; Lemos et al., 2016; Defiesta and Rapera, 2014).

Similarly, human capital was one of the capitals with a lower score. While most of the farmers were experienced in farming, the literacy rate was very low as the majority (47%) had only completed primary education. Low literacy rates limit a person's ability to seek employment, which puts up entry barriers to better-paid employment opportunities. Kakamega County had a higher AC mainly due to the larger household size, since 45% of the households had more than six members. Social capital was the highest scored capital and this was uniformly reported in the three zones. This could be explained by the high involvement of AIV farmers in groups, the greater frequency of extension visits and better access to weather forecasts. In peri-urban Kajiado the level of social capital deviated at a lower level since the majority of the farmers did not receive extension visits. A lack of group membership was most pronounced in Kajiado and Nakuru counties where only 35% and 44% of farmers respectively were members of a farmers' group. While farmers had a relatively high level of social capital overall, unlike financial capital it was not quite as effective at building the level of adaptive capacity. In a study in Ghana, social capital was ranked relatively as the least important capital in enhancing



(b)

Fig. 2. percentage distribution of AC by zone.

adaptive capacity (Abdul-Razak and Kruse, 2017).

4.2.5. AIV farmers' AC levels

For more than half of the farmers, the index calculated a moderate AC level. Another third of the farmers seemed to belong to the group of farmers with a rather lower level, and only 14% to those with a rather high AC level. Table 3 shows that AC varied significantly depending on the farmers' geographical location ($p < 0.023$). In Kajiado County the overall AC level was highest, while it was lowest in Nakuru County. Farmers with a low AC index were mainly located in the semi-humid zone of Nakuru, while many with a high AC were from the semi-arid and peri-urban Kajiado County (Fig. 2).

5. Conclusions and recommendations

Based on the adaptive capacity index developed in this study, the majority of the AIV farmers showed a moderate AC. A third of all households had a low level and a smaller proportion had a high level. African indigenous vegetable farmers generally had low access to financial and natural capitals and greater access to social capital. From the study it was concluded that peri-urban AIV farmers in the vicinity of the capital city, Nairobi, had a higher AC than those in the remote rural areas of Kakamega and Nakuru.

Adaptive capacity develops over the course of a life time; with older farmers having a significantly higher level of AC. Subsistence farmers seemed to have a higher AC than commercial farmers. The low levels of education of smallholder farmers, their inability to access reliable water sources, the high adoption of inefficient strategies such as hand-watering of vegetables, and low access to off-farm income and credit seemed to hinder progress in adapting to climate change. Therefore the findings of this assessment suggest that there is a need for interventions that strengthen the asset base of smallholder farm households. This should prioritise programmes that include the provision of reliable water sources, the construction of water collection tanks or ponds, and the installation of an irrigation infrastructure. They should be supported financially and technically by institutions, especially non-governmental organisations (NGOs) and finance institutions working closely within the communities. Furthermore, investment in formal schooling is crucial in the three regions and should be targeted at both male and female younger populations to enable them to transition from full-time farming to more diversified livelihood strategies. Not least because of decreasing farm sizes, an important sustainable climate change adaptation strategy is income diversification through off-farm income. This is an important component in enhancing smallholder farmers' AC, especially in rural areas. Therefore, rural policies must be geared towards generating more productive and diversified rural employment opportunities through the decentralisation of industries and capacity-building for farmers, for instance by establishing rural small and medium enterprises. Finally there is an urgent need to invest in capacity-building programmes that empower younger and inexperienced farmers to access resources that are essential to enhancing their ability to adapt to climate change. For explaining the disparities in adaptive capacity and access to the various resources, further research is needed to collect qualitative data from key informants and smallholder farmers. This is especially useful in designing programs and interventions for building the adaptive capacities of smallholders.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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