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ORIGINAL ARTICLE

Farmers' knowledge and perception of climatic risks and options for climate change adaptation: a case study from two Tanzanian villages

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Abstract An in-depth understanding of the multiple layers of factors that shape farmers' knowledge and perception of climatic risks and their adaptive responses is a prerequisite for well-targeted agricultural adaptation planning. However, while farmers' perception is increasingly understood as being a key determinant, a conceptual framework that includes this focus of analyses is currently not available. Against this background, this study analyzes the agricultural adaptation context in two Tanzanian villages building on a newly developed agricultural adaptation and perception model (AAP). The AAP contains five dimensions as a frame of reference for empirical adaptation models: non-climatic determinants of vulnerability (1), general trends in livelihood strategies (2), perception of climatic trends (3), climate impacts in agriculture (4) and potentials and obstacles for adaptation (5). Empirical data were collected by applying various tools of rapid rural appraisal, a stakeholder workshop and supplementary interviews. The qualitative data were coded along the dimensions of the AAP and analyzed by means of qualitative content analysis. The results show that adaptation levels, sensitivities of the farming systems as well as perception and narratives about climatic and yield dynamics differ considerably among the two farming communities. Furthermore, farmers' adaptation responses are influenced by both their framing of climatic trends as well as the multiple benefits that the local agricultural systems provide. Thus, for improving food security in the face of climate change, farmers' perceptions and the multi-functionality of agricultural systems need to be explicitly recognized by agronomic adaptation research, and adaptation policy making should involve detailed vulnerability assessments.

Keywords Adaptation · Climate change · Perception · Sub-Saharan Africa · Tanzania · Vulnerability

Introduction

Farmers' climate change perceptions and responses happen in the context of a multiplicity of factors influencing agriculture and food security, namely current and past biophysical, socioeconomic and agronomic conditions (Battisti and Naylor 2009; Thornton et al. 2011). Because of preexisting differential vulnerabilities (Adger 2006), marginalized rural population groups are often disproportionately affected by climate change (Tanner and Mitchell 2008). Furthermore, climate change sensitivity depends strongly on the diversity of local landscapes and agricultural systems (Thomas et al. 2007). Hence, what climate change means to farmers appears to be a product of the context where the climate change and responses to it take place. Nevertheless, the exact relation between the adaptation context and perception is not sufficiently underpinned by empirical evidence (Safi et al. 2012).

An in-depth understanding of farmers' perception is a prerequisite for well-targeted agronomic adaptation

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research and practical agricultural adaptation planning. A discordance between farmers' and politicians' perceptions of the seriousness of climatic risks may easily result in failed policies (Patt and Schröter 2008). Moreover, under conditions of high uncertainty, rapid change and shifting baselines, agricultural innovation needs to be flexible, holistic and participatory, while taking into account a "wider context" than conventional linear diffusion models (Brooks and Loevinsohn 2011: 187).

In this regard, theoretical frameworks on smallholder farmers' adaptation to climate change exist (Morton 2007; Scoones 1998), but they do not explicitly consider the multiple layers of factors influencing farmers' climate change perceptions and responses. In contrast, a growing number of empirical contributions analyze the relationship between farmers' climate change perceptions and actual adaptation in industrialized contexts (Bryant et al. 2000; Wheeler et al. 2012) and in smallholder contexts of the global South (Esham and Garforth 2013; Anik and Khan 2012; Comoé et al. 2012; Dang et al. 2013; Nyanga et al. 2011; Kalungu et al. 2013). While such studies provide valuable insights about actual adaptation strategies and the factors influencing them, they are not predominantly based upon a conceptual framework that points out the factors relevant to study in order to ensure well-targeted future adaptation policies.

Against this background, the objectives of this paper are twofold: to enhance traditional adaptation frameworks by the newly developed agricultural adaptation and perception model (AAP) (objective one) and to empirically analyze how farmers in two Tanzanian rural communities perceive their agricultural adaptation context by applying the AAP (objective two). To achieve these objectives, an in-depth analysis of existing studies on the nexus between perception, context and adaptation is carried out. Furthermore, the empirical analysis rests upon qualitative data collected by applying various tools of rapid rural appraisal (RRA), focus group discussions, a stakeholder workshop at the village and regional level, and supplementary interviews. The case study region is Morogoro in central-eastern Tanzania. It is characterized by a high diversity of agroecological conditions and solid literature-based empiric documentation on the vulnerability to climate change (Paavola 2008). The data are analyzed using qualitative content analysis.

The agricultural adaptation and perception model

This section demonstrates the single components of the new AAP model for the study of farmers' climate change perception and responses (Fig. 1). The model contains five dimensions as a frame of reference for empirical adaptation models: non-climatic determinants of vulnerability (1), general trends in livelihood strategies (2), perception of climatic trends (3), climate impacts in agriculture (4) and potentials and obstacles for adaptation (5).

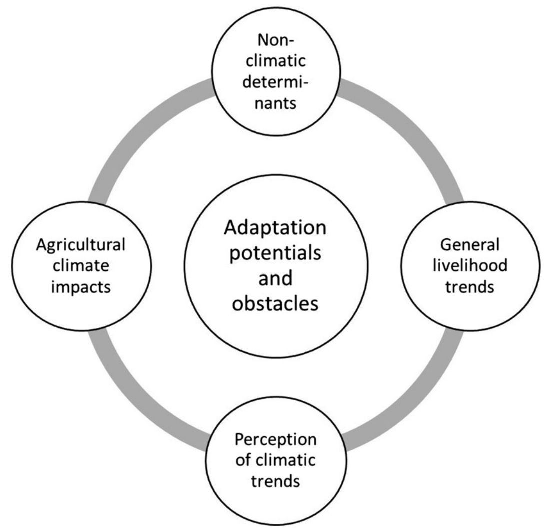

Fig. 1 The agricultural adaptation and perception model. *Source*: Own elaboration

Non-climatic determinants of vulnerability An important part of people's vulnerability stems from non-climatic factors (Füssel and Klein 2006), and for most farmers, problems related to climate variability and change are by far not the only source of stress affecting their productivity (Eriksen et al. 2011). Therefore, the analysis of farmers' adaptation behavior needs to gauge the relative importance of climatic sources of stress compared to other stressors (Reid and Vogel 2006). Otherwise, researchers run the risk of wrongly attributing farmers' adjustments to climatic stimuli when there are other more significant drivers.

Non-climatic factors can be broadly grouped into three subgroups: socioeconomic determinants at household level (e.g., size, age structure, gender, health status, wealth, possession of livestock, access to land), biophysical determinants (e.g., soil fertility, availability of water, fodder and wood, water requirement of farming system) and institutional determinants (e.g., existence of extension services, marketability, prices of farm inputs and products). In order to account for these factors and their interrelations with climatic stressors, it is necessary to assess them in socioeconomic climate change studies (Grothmann and Reusswig 2006).

Climate change vulnerability studies usually put less emphasis on non-climatic stressors, sometimes treating them as control variables. Research on resilience puts more emphasis on the non-climatic stressors and differentiates systematic stressors sometimes as climate change risk, disaster risk, conflict risk and economic and financial shocks (Mitchell and Harris 2012). Other authors find that non-climatic factors significantly influence agricultural decision-making in general and farmers' adaptation in particular (Smit and Skinner 2002; Bryant et al. 2000). Tschakert (2007) shows that farmers have a very good understanding of the multiple stressors they face. Quinn et al. (2003) found from a ranking exercise in twelve Tanzanian villages that livelihood risks are related predominantly to the problem of lack of water. This is followed by problems related to the lack of social assets. Ziervogel et al. (2006) found from a case study in Limpopo Region of South Africa that the type of agricultural actions pursued by farmers depends on a location-specific set of determinants, such as irrigation requirements, market requirement and the availability of forecast information.

General trends in livelihood strategies People's vulnerability and particularly their adaptive capacity is a product of a historically created yet permanently evolving human–environmental set of relations that needs to be taken into account when studying farmers' responses to climate change (Dietz 2011). The following research papers relate people's vulnerability and adaptive capacity to historic evolutions of human–environmental relations: Porter (2006) shows in a longitudinal study of 18 villages in Tanzania's Tanga region that the introduction of drought-resistant crops and varieties has been a constant endeavor since early times, and how historical events like the Rinderpest has shaped the landscape and the amount of vermin (ticks, malaria, tsetse). From fieldwork and an analysis of historical data related to natural resource use, Siedenburg (2005, 2008) has found that there exists a long history of changes in natural resource management regimes (e.g., induced by Rinderpest, German Colonization, etc.) in the Shinyanga district of Tanzania. He concludes that where very rapid changes occur within natural resource management regimes, farmers are unable to respond due to a lack of appropriate local knowledge. Bryceson (2002) found from a study of 6 countries in sub-Saharan Africa that since the mid-1980s, structural adjustment and market liberalization policies have led to accelerated deagrarianization. This has triggered deep-rooted social change, including changes in the use of natural resources (e.g., overharvesting of natural resources for crafts). Meertens et al. (1996) found that increasing population density impacts heavily on Tanzanian agricultural systems.

Perception of climatic trends Even though slow gradual changes in climatic parameters are difficult to observe, farmers often have an extensive knowledge about local climatic conditions and ecosystem variability (Tengo and Belfrage 2004; Comoé and Siegrist 2013). The perception of climatic risks may significantly influence farmers' adaptation decisions (Koerth et al. 2013; Patt and Schröter 2008). Adaptation particularly occurs when farmers link climate change to its negative impacts (Comoé and Siegrist 2013). Therefore, it is important to firstly assess whether long-term changes in climatic processes have been witnessed by farmers in order to inform and assist appropriate policy design in a given setting (Wheeler et al. 2012).

Climate impacts in agriculture Effects of climatic stimuli on agricultural systems are often complex because they involve a large number of components with nonlinear dynamic relationships (Lansing 2003). Activating stakeholders' analytical capacities through participatory qualitative research methods can provide fast and reliable information about these complexities, which is a prerequisite for successful adaptation action (Reid and Vogel 2006). In a study carried out in ten sub-Saharan African countries that combined a multiple linear regression analysis of household data with simulations of the process-based global vegetation model for managed land (LPJmL), Waha et al. (2013) found that crop yields are likely to decrease by up to 24 % depending on the global circulation model (GCM) and the crop management strategy used. Meta-analyses found overall changes in African agricultural production between −100 and +168 % relative to the current levels of production (Müller et al. 2011). Scenarios of the socioeconomic impacts of climate change on sub-Saharan Africa predict up to 175 million additional people at risk of hunger by 2080 compared to a reference scenario without climate change (Fischer et al. 2005). However, such aggregate figures may conceal important local and sub-sectoral differences which need to be taken into account for well-targeted practical adaptation planning.

Potentials and obstacles for adaptation relate closely to all previous dimensions and are thus at the center of the AAP. Farmers often have extensive experience in responding to adverse effects from climate variability and change (Halder et al. 2012; Tambo and Abdoulaye 2012). Therefore, local knowledge and perception may provide important insights into the potential for adaptation and the obstacles against it (Mbilinyi et al. 2005), and many studies seek to identify current adaptation practices at farm level in order to better understand local agricultural systems and their adaptive capacity (Esham and Garforth 2013; Comoé and Siegrist 2013; Comoé et al. 2012; Baudoin et al. 2013). In a second step, these studies seek to determine the particular obstacles for adaptation. Findings with respect to both existing adaptive responses and obstacles for adaptation are, as in all other dimensions outlined above, highly site-specific and therefore difficult to summarize. However, ethnicity and gender appear to influence how diversification (as one adaptation strategy) is pursued by different social actors (de Bruijn and van Dijk 1999), and Waha et al. (2013) find that farmer's choices of adequate crops, cropping systems and sowing dates can effectively reduce climate-induced yield declines.

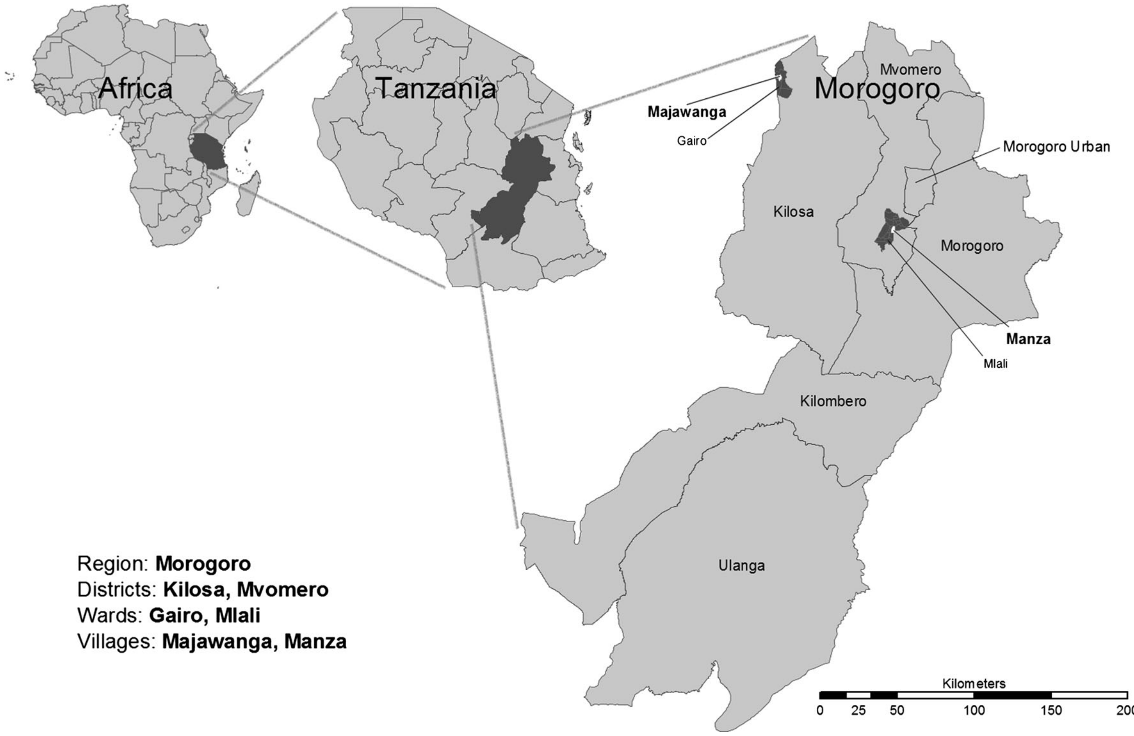

Fig. 2 Map of the research area. *Source*: Own elaboration

Methodology

Study sites

To explore how farmers perceive their agricultural adaptation context, two contrasting study sites in Tanzania's Morogoro region were selected. The comparative case study approach therefore reveals the influence of site-specific determinants on a given outcome as opposed to individual socioeconomic household characteristics (Dercon and Krishnan 1996).

Morogoro is characterized by a diverse topography, relatively poor soils and locally very distinct microclimatic conditions. The research sites were selected by assessing altitude, dominant livelihood situation and accessibility in order to identify the most typical villages for the overall socioeconomic and biophysical situation of the respective ward. The two selected villages of Majawanga and Manza are located at an aerial distance of about 125 km from one another and, respectively, represent a semiarid and a sub-humid agroecological setting (Fig. 2).

The distinct agroecological conditions of the sites determine their specific production potentials. Manza represents a system of relatively high agricultural potential and Majawanga a system of low potential. The potential of the two sites mainly differs due to climatic factors as opposed to soil types and other factors (Table 1).

Table 1 Biophysical and socioeconomic characteristics of the study area

	Manza	Majawanga
Altitude (meters above sea level)	620–760	1,240–1,290
Average annual evapotranspiration (mm)	1,427	1,683
Average annual precipitation (mm)	935	499
Climate	Sub-humid	Semiarid
Household numbers (in 2009)	512	600
Main agroecological zone	Lowland and river valleys	Plateau
Mean annual temperature (°C)	24	21
Number of rainy seasons	2	1
Productive potential of soils	Low	Low

Source: Chamshama et al. (2006), FAO (2006), Ikerra et al. (2006), Mitchell and Jones (2005), Ngegba (2006), URT (1997) and own elaboration

No downscaled projections of climatic trends and impacts on agriculture for Manza and Majawanga exist in the literature. However, assessments of the past climate of both sites for the period 1970–2005 indicate a change in temperature of about +1 °C and no change in precipitation (Mitchell and Jones 2005). According to unpublished process-based climate projections by Philip Thornton, Manza and Majawanga currently have probabilities of crop failure at about 10 %. By the 2050s, crop failure probabilities in Majawanga may double, but in Manza, failure rates may not change greatly and could even decrease somewhat (P. Thornton, pers. comm., 13 May 2010).

Data collection

The collection of empirical data comprised techniques of rapid rural appraisal (RRA) and a stakeholder workshop. Informal interviews with individual farmers and participants of the stakeholder workshop complemented the data gathered. The RRA tools used were inspired by Beck et al. (1997) and Bhatia and Ringia (1996). They were almost exclusively carried out in focus group discussions (FGD) (for the concept of FGD see Bortz and Döring 2006). In each village, seven FGD were conducted in Swahili between mid-June and mid-July 2009 with field assistants. The 12 to 14 participants of the FGD were selected to ensure that farmers from different political, socioeconomic, ethnic and religious backgrounds as well as male- and female-headed households could participate.

The participatory RRA tools that were applied to gain a deeper understanding of trends and problems of local livelihoods included: village walks (1), rankings of important food and cash crops, including the assessment of their production costs, yields and prices (2), participatory resource mappings (3), a matrix scoring of stressors for agriculture and responses (4) and the elaboration of a seasonal calendar (5). The outcome of the FGD comprised data on the perception of climatic and non-climatic risks, impacts, vulnerabilities and responses as well as seasonal calendars for temporal risk classification within the annual agricultural cycle. Table 2 clarifies the purpose, approach and results of the different RRA tools applied.

Finally, five senior participants of the previous discussions were invited to conduct a concluding trend analysis, focusing on long-term changes in precipitation, temperature, extreme weather events, yields, as well as demographic and other socioeconomic parameters within the last 25 years.

The stakeholder workshop was held in Morogoro, Tanzania, at the Sokoine University of Agriculture (SUA) on May 24, 2010. The 31 participants included farmers from Mlali and Gairo that had already participated in the village-level FGDs, representatives from ministries, members of the local and regional administration, scientists and stakeholders from non-governmental organizations. At this workshop, empirical results of the study were verified and validated using model-based climate projections for the study area (Mitchell and Jones 2005).

Data analysis

The information documented during the RRA sessions was summarized in reports containing observations, recorded statements, tables and calculations for each village. This analysis was discussed at the stakeholder workshop. A subsequent qualitative content analysis (Mayring 2000) classified the data from the reports and the results of the workshop using the five dimensions of the AAP model. Hence, instead of inductively developing categories from the reports and transcripts, text passages were coded with one of the five predefined dimensions of the AAP, allowing a structured comparison between the two villages under investigation.

The data quality was ensured by performing continuous and randomly applied cross-checks throughout the entire process of fieldwork. Feedback interviews with participants detected and aligned inconsistencies with regard to locally specific technical terms and units of measurement as well as strategic over/underestimations of sensitive topics such as income and livelihood measurements. Any observed inconsistency of the data was also investigated with (and aligned by) local experts such as field assistants or fellow researchers. In a few cases, secondary sources were used where a discrepancy was noted.

Results

Non-climatic determinants of vulnerability

At both research sites, non-climatic determinants of vulnerability were found to be closely related to people's livelihood assets and the local agricultural systems. Villagers in Manza without work possibilities or access to the fertile and humid land in the valley plain (*mabonde* land) used for horticulture were most affected by agricultural stressors and shocks. These were single elderly people, female-headed households, disabled people, as well as households affected by HIV-AIDS and other chronic diseases.

In Majawanga, livestock keeping and the temporal migration of young male inhabitants in search of casual labor, pasture or fertile cropland are important livelihood strategies. Most affected by stressors are thus female-headed households, orphans, family members of migrants that stay behind, households that do not possess livestock and other poor households that cannot afford to rent cropland outside the village.

The rankings of the RRA show that smallholders are concerned about a full range of problems when carrying out their farm decision-making. However, climatic stimuli

Table 2 Objectives, approach and outcome of the RRA tools applied

Activity	Objectives	Key questions/themes	Outcome
Village walk	To familiarize with the village, the population and the surroundings To get a first impression on agricultural problems and potentials of the village To identify participants for FGD	Historical development of the village? Size, distribution, population, land use, problems, etc.?	Participants for FGD Overall orientation of main trends in the village
Ranking of food and cash crops	To identify the most important food and cash crops To identify typical yields in below average/average/above average seasons	Most important food and cash crops? Below average/average/above average seasons?	Ranking of crops Documentation (written report) of discussions
Resource mapping	To gain an overview of the agricultural issues of the village as perceived by the villagers To find out and discuss different perceptions on problems related to resources within the village To learn about access to and control over resources To generate information about changes in livelihood strategies within the last 10 years	Existing and missing resources? Distribution of and access to resources? Main problems and potentials? Important changes in vegetation, agriculture, livelihood strategies and underlying reasons for such changes?	Map of the village showing all important items (e.g., natural resources, buildings, infrastructure) Documentation (written report) of discussions
Scoring of stressors for agriculture and responses	Prioritization of the main shocks affecting agriculture Overview of former efforts of responding to the shocks To find out the reasons for the failure of previous efforts To generate information about possible adaptation options To find out how households are characterized that are especially vulnerable to these shocks	Any shocks affected agricultural production and livestock keeping within the last 10 years? Which shock had the highest importance for the provision of livelihoods of the household? What did you do to respond to the shock? How can the households of the village be characterized that were most affected by the shock?	Ranking of stressors List of responses Documentation (written report) of discussions
Seasonal calendar	Generate information about seasonal trends Learn about inter-annual distribution of rains Identify times of labor bottlenecks for men, women, girls, boys in the village Identify periods of particular stress and vulnerability To learn about prices and costs of production	Climatic parameters over the months? Main work tasks over the months? Labor peaks and valleys? Other constraints?	Seasonal calendar showing climatic parameters, work tasks, labor peaks and valleys etc. Documentation (written report) of discussions

are perceived to be a major direct stressor for agricultural production in both villages (Table 3).

Key informants of Manza explain that, in their view, poor and poorly distributed rains rank first among the problems in agriculture, because "poor rains have the strongest impact on yields" (farmer in a FGD, 25.07.2009). Other important problems include crop damage from wild animals and insects, lack of inputs, plant diseases as well as poor access to markets. Farmers of Majawanga have a similar perception. Farmers rank poor and unreliable rainfall to be significant agricultural stressors, being surpassed only by the lack of extension services. This is followed by a lack of fertile land, lack of inputs, problems of pests and diseases, as well as poor access to markets. The ranking shows that Morogoro's smallholders are affected by a broad range of biophysical processes, with climatic parameters being a major reason for concern. The biophysical adversities are exacerbated by an imperfect and

Table 3 General problems of agricultural production in Manza and Majawanga village

Manza village, Mlali ward	Ranking score assigned by FGD	Majawanga village, Gairo ward	Ranking score assigned by FGD
Poor and unreliable rains	14	Lack of agricultural extension officer in the village	10
Crop damage from wild animals	8	Poor and unreliable rains	7
Insects and parasites	7	Lack of fertile land	6
Lack of inputs	5	Lack of inputs	4
Plant diseases	3	Pests and diseases	1
Poor market access	2	Poor market access	1

Source: Data from RRA 2009

incomplete institutional environment that does not provide, e.g., appropriate extension and advice on how to deal with the stressors. Nevertheless, climatic problems seem to be of paramount concern for farmers.

General trends in livelihood strategies

Farmers' adaptation to climate change does not happen in a historic vacuum. Man-made problems of environmental degradation already existed at both research sites long before the impacts of climate change in Tanzania had been identified. According to Bagshawe (1930) cited by Temple (1972), in the upper catchment of the Mlali River, farmland on the steep slopes of the Uluguru mountains had to be abandoned during precolonial times because of unsustainable land use. In Gairo ward, no such early documented evidence of land degradation problems exists. Apparently, the problems in Gairo only developed relatively recently but have worsened at a rapid pace. According to Gervin (2003), population pressure, intensive forest clearing and permanent cultivation of fields started as a late consequence of the Ujamaa villagization policy in the mid-1980s. While before Ujamaa only half a dozen families inhabited the area of Gairo, the number of inhabitants increased dramatically, with around 300 new families being relocated to the area despite the low-carrying capacity of the local soils.

Such findings were reconfirmed within the study. According to the results of the trend analysis, household numbers more than doubled over the last three decades in both villages. During the same period, new livelihood strategies emerged—horticulture in Manza and temporary migration in Majawanga—and competition for natural resources increased. While in both villages average maize yields dropped by roughly up to 50 %, productivity at Manza remains considerably higher compared to Majawanga. According to the farmers, maize yields in Majawanga averaged 0.35 metric tons/ha in the 1980s, while they have equated to around 0.12 metric tons/ha in recent years. In contrast, villagers of Manza estimate an average historic maize yield of around 0.88 metric tons/ha for the 1980s and current levels at around 0.33 metric tons/ha.

Farmers' perception of climatic trends

Farmers from both villages observed long-term changes in local climatic processes. The participants of focus group discussions in Manza perceived that the number of days with rainfall per year has decreased in the last decade, while the number and duration of dry spells and the number of hot days have increased. Furthermore, farmers said that during the same period, two small streams tended to carry no water during the dry season, which had not happened before. In the view of the villagers, deforestation, especially in upstream areas of the Mandehe River, has caused the changes in climatic and hydrological parameters.

Farmers of Majawanga also observed a decrease in rainfall days as well as a decrease in the reliability of rains—a phenomenon that started during the 1990s. They state that "many years ago, rain was good but now the movement goes down" (farmer in a FGD, 10.07.2009). Furthermore, the key informants mentioned a perceived temperature increase during the hot season of the year, but also extraordinary cold seasons that had happened lately. Decreases in the runoff of the seasonal river that lead to the disappearance of local bird populations and a sinking groundwater level were also mentioned.

Overall, the participants of the focus group discussions share the perception that climatic conditions have become more challenging over the last few years.

Climate impacts in agriculture

Adverse climatic stimuli translate into crop failure and livestock losses if certain tipping points of the local farming system are surpassed. One of these points is water availability for plants during crucial stages of their development. Under semiarid conditions, plants regularly suffer from water stress during some periods of the cropping period, while in the sub-humid zone, rain-fed farming is climatically more favored. Consequentially, the same trend in climatic stimuli is more likely to directly affect semiarid areas. The comparison of Manza's and Majawanga's experience with climatic impacts on agriculture only partly illustrates this functional relationship. Interestingly, farmers of the more humid study site expressed their worries about climatic causes of yield decrease, and farmers of the more arid site expressed worries about non-climatic factors. Local narratives help to explain this seemingly contradictory finding.

For the key informants of the sub-humid Manza, climatic impacts on agriculture are regarded as a severe problem. The villagers attribute the long-term losses in maize productivity predominantly to climatic trends. Other drivers such as soil fertility are not taken into consideration. In their view, the productivity of tomato cultivation increased because "we started to use fertilizer and pesticides for tomatoes" (farmer in a FGD, 26.07.2009). Nevertheless, poor rainfall is regarded as being responsible for the declining maize yields because "for maize, we still use the same cropping technique as we did 25 years ago when yields were high" (farmer in a FGD, 26.07.2009).

Contrarily, in the view of farmers of Majawanga, "yields have gone down because the soil is exhausted" (farmer in a FGD, 10.07.2009). According to them, the negative climatic trend adds additional uncertainty to an overall trend of weakening production performance. In four out of the last eleven years, most farmers of Majawanga village experienced high yield losses due to poor rainfall. During these years, food aid had to be delivered to households in the area.

The comparison of the two villages shows that different local narratives exist among farming communities about the causes of declining maize yields. Furthermore, the analysis shows that similar changes in external climatic stressors can lead to very different local impacts because the sensitivity of local environments and agricultural systems varies greatly, even over small spatial distances. If the *Masika* rains fail, farmers in Manza still have the chance to cultivate during *Vuli*, the short rainy season, and those farmers with access to *mabonde* land can irrigate their plots with water from the permanent *Mandehe* River. In contrast, the Majawanga farmer's room for maneuver is considerably smaller. In average seasons, yields and water availability for cropping have been lower. Besides that, there exists only one rainy season, and the Majawanga River does not provide enough water for irrigation. Consequentially, under current climatic conditions in Majawanga, food relief was necessary during some years, while this has not been the case for Manza.

Potentials and obstacles for adaptation

Many practices to reduce vulnerability to observed climate variability and change are already known and partly employed by smallholders from both villages (Table 3). On average, farmers of sub-humid Manza have a higher level of adaptation than farmers of semiarid Majawanga (Below et al. 2012). Farmers in Manza mention adaptation practices including irrigation with water from the local river, drought-resistant crops, early maturing varieties and forest protection. Farmers in Majawanga mention livestock, drought-resistant varieties, transport services with oxcarts, temporary migration and the permanent relocation to less drought-prone areas. However, farmers from both villages also point out that most of these practices involve trade-offs and barriers (Fig. 3).

Obstacles for adaptation relate to limitations in livelihood assets, adverse social impacts, as well as barriers created by the farming system. Some of the obstacles mentioned provide clear entry points for adaptation policy making, e.g., lack of resources, social cooperation and incentives for afforestation. Classic examples of targeted agricultural adaptation practices that deal with some of the aforementioned obstacles are cost-effective soil and water conservation measures that can be implemented with a participatory approach involving local user groups as well as governmental, non-governmental and private actors (Dorlöchter-Sulser and Nill 2012).

Yet a number of other obstacles appear to be less evident and difficult to address with adaptation programs. Farmers of Manza mention that drought-resistant crops such as Sorghum are perceived to be less tasteful when prepared for the main local dish, *Ugali*. Switching from conventional high yielding varieties to short maturing varieties may reduce losses during drought- or flood-prone years at the cost of lower yields during average years. In Majawanga, the drought-resistant crop cassava is not cultivated because most cassava varieties have a longer vegetation period than maize and "cattle would destroy all remaining crops after the maize harvest when fields are used for communal grazing" (farmer in a FGD, 09.07.2009). Temporary migration is only practiced by men. Families of migrants lack their labor. Furthermore, some respondents expressed worries that migrants could commit adultery and be infected with HIV-AIDS. No official plan exists to permanently resettle inhabitants of Majawanga to less drought-prone areas. Nevertheless, farmers expressed mixed feelings about this measure because some still remember the difficult times during the implementation of the Ujamaa resettlement policy in the 1970s.

Comparison of the findings at village level

Table 4 shows that smallholders in both villages are affected by similar livelihood trends and biophysical stressors. In the view of the farmers from both villages, problems of unreliable rainfall are of paramount concern for their farming. Most affected are households with a lower socioeconomic status. Furthermore, there is the unanimous perception that the climatic conditions have become more challenging over the last one or two decades.

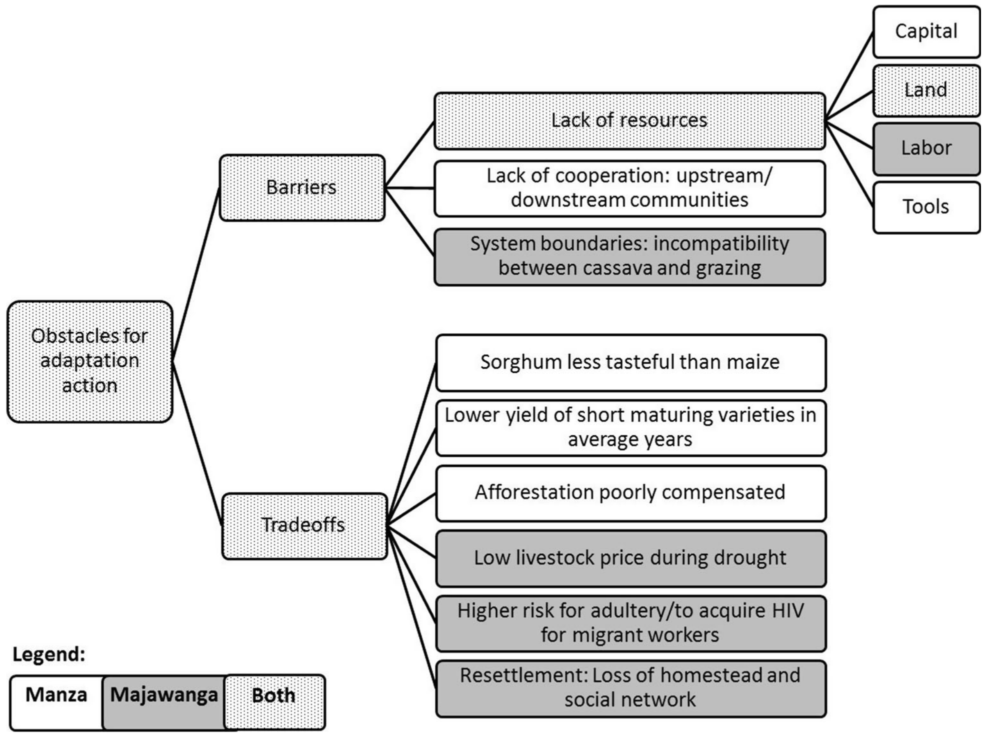

Fig. 3 Obstacles for adaptation action mentioned by farmers of Manza and Majawanga. *Source*: Data from RRA 2009, own analysis

Besides these similarities, the comparison also shows considerable differences. In the two villages, similar trends in external climatic stressors lead to different impacts because of the specific local environments and farming systems. Under current climatic conditions, farming in semiarid Majawanga already runs a high risk of failure, and there are few effective adaptation options. In contrast, farmers of sub-humid Manza are on average less affected by climatic stress, and they possess an overall higher adaptive capacity. However, the local narratives about climatic and yield dynamics vary among the two farming communities. In Majawanga, surprisingly, there is a relatively strong narrative about the danger of soil erosion, while in Manza, farmers' discussions focus more on water resources. This coincides with an overall higher level of adaptation to climate change in Manza.

Discussion of farmers' climate change perceptions

The results of this study correspond well to a number of previous studies from empirical adaptation research. That smallholders are aware and responsive to important non-climatic long-term trends undermining their livelihood system has been a recurrent topic in the literature focused on the study of livelihoods (Bryceson 2002; Siedenburg 2008). The literature is more heterogeneous in respect to farmers' perceptions of climate change. Some studies in other parts of Africa also found that farmers perceive a trend of worsening climatic problems (Silvestri et al. 2012; Tambo and Abdoulaye 2012), while others report that farmers witnessed no important long-term changes in climatic parameters (Reid and Vogel 2006). The finding that farmers of the two study sites judged the importance of climatic as compared to non-climatic stressors differently corresponds with Quinn et al. (2003) who found that risk perception among rural households in semiarid Tanzania is heterogeneous, and Patt and Schröter (2008: 265), who found that the perception of risks is "contingent on the social, cultural and economic conditions."

Notably, only the increase in temperature is confirmed by climatologists (Mitchell and Jones 2005). The discordance between scientists' and local stakeholders' perceptions of rainfall pattern in Morogoro is in line with many psychological studies on risk behavior (Slovic et al. 2004; Wynne 1992). A possible explanation for the discrepancy between local perception and the findings of Mitchell and Jones (2005) is different underlying systems of reference. Mitchell and Jones model mean annual parameters, while farmers depend strongly upon the distribution of water flows during important stages of the cropping period. This indicates that for farmers of Morogoro, trends of distributional parameters are not sufficiently captured by the existing climatological studies.

At the stakeholder workshop, a professor for agricultural engineering at Sokoine University of Agriculture (SUA) explained the discordance by arguing that "farmers have a different language and that makes it difficult to assess their

Table 4 Knowledge and perception of farmers from Manza and Majawanga village about climate change impacts and adaptation

Analytical category	Manza village, Mlali ward	Majawanga village, Gairo ward
Non-climatic determinants of vulnerability	Poverty, lack of access to productive assets, diseases, disabilities, gender of the household head, age	Poverty, lack of access to productive assets, gender of the household head, temporary migration, orphaning
General trends in livelihood strategies	Population growth, introduction of new cash crops, declining yields of food crops, arising conflicts over land, slow technological progress	Population growth, land cover degradation, agricultural encroachment, declining yields, start of temporary migration, beginning relocation of cattle in rainy season, arising conflicts over land, slow technological progress
General problems of agricultural production	Poor and unreliable rains, crop damage from wild animals, insects and parasites, lack of inputs, plant diseases, poor access to markets	Lack of agricultural extension, poor and unreliable rains, lack of fertile land, lack of inputs, pests and diseases, poor access to markets
Perception of climatic trends	Decrease in days with rainfall, increase in dry spells, increase in hot days, dry out of water bodies	Decrease in days with rainfall, less reliability of rains, temperature increase during hot season, temperature decrease during cold season, decreased runoff in seasonal water body, sinking of groundwater level
Climate impacts in agriculture	Decline in maize yields	Yield losses, additional uncertainty for cropping
Potentials for adaptation	Irrigation from river, drought-resistant crops, early maturing varieties, forest protection, petty trade, charcoaling, ridge cultivation, planting in deep holes, keep livestock, buy water pumps	Short maturing varieties, selling of livestock, drought-resistant varieties, wage work, temporary migration, permanent relocation, horticulture, sequential cropping, religious activities, community cereal bank, improved cropping techniques, rainwater harvesting, microfinance, improved climate knowledge, water pumps, marketing support from government
Obstacles for adaptation	Distance to water for irrigation, lack of motor pumps, sorghum less tasteful, high price of short maturing varieties, lower yields of short maturing varieties during average years, poor compensation and cooperation for forest protection	Low prices for livestock in years of drought, long growing period of cassava plants, families of migrant workers lack workforce, families of migrant workers fear adultery, higher risk of HIV-AIDS for migrant workers, negative memories about resettlement policies

Source: Data from RRA 2009

perceptions" (stakeholder workshop, 24.05.2010). According to the professor, in large parts of the Morogoro region, dry spells have become longer and more frequent, the variability of rains has increased, and the pressure on water resources has become stronger due to population growth. This view was supported by a farmer from Gairo ward during the same session. The farmer emphasized that in the "old times," there had been more certainty about the onset of rains. Currently, it is very difficult to plan because often the onset of rains is delayed, and the germination of seeds is not successful. "Our biggest problem is the unpredictability of rains," the farmer said at the stakeholder workshop. It can therefore be concluded that water availability in many parts of the Morogoro region is declining, and most farmers are aware of this problem.

Conclusion

This paper assesses farmers' perception of the agricultural adaptation context in two Tanzanian villages building on a newly developed AAP model. The AAP model was found more suited for studying the multiple layers of factors influencing climate change responses rather than traditional approaches that do not explicitly account for individual perception. The results show that adaptation levels, sensitivities of the farming system as well as perceptions and narratives about climatic and yield dynamics differ considerably among the two farming communities. In the village with higher climate change sensitivities, the historic influence of climatic trends on yield performance is perceived as less significant.

It is concluded that farmers' climate change perceptions and responses as well as local agricultural conditions are highly interrelated. The data indicate that farmers' adaptation responses are influenced by both their framing of climatic trends as well as the multiple functions driven by their local agricultural system. In addition, farmers' framing of climatic trends also depends on the local agricultural system. Thus, for improving food security in the face of climate change, farmers' perceptions and the multi-functionality of agricultural systems need to be explicitly recognized by agronomic adaptation research. This requires employing a more interdisciplinary scientific approach, as well as more in-depth assessments of farmers' knowledge and perceptions about climatic trends and agricultural practices. For improved agricultural adaptation policy making, interventions need to build on detailed vulnerability assessments in order to uncover perceptions as well as trade-offs and the complexities associated with local climate change response. An important contribution to sub-Saharan farmers' climate change adaptation can be cost-effective soil and water conservation measures implemented through participatory approaches involving local user groups. These measures require government support related to technical supervision, information brokerage and training, funding, as well as the improvement of legal frameworks such as land rights. Implementing these measures based on participatory assessments of farmers' perception and knowledge is key for achieving the intended development goals because it improves ownership, responsibility for the upkeep and the overall targeting of measures.

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