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Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania

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ABSTRACT

This article examines farmers' livelihood responses and vulnerability to climate variability and other stressors in Morogoro, Tanzania, to understand their implications for adaptation to climate change by agricultural households in developing world more generally. In Morogoro, agricultural households have extended cultivation, intensified agriculture, diversified livelihoods and migrated to gain access to land, markets and employment as a response to climatic and other stressors. Some of these responses have depleted and degraded natural resources such as forest, soil and water resources, which will complicate their living with climate change in the future. This will be particularly problematic to vulnerable groups such as women, children and pastoralists who have limited access to employment, markets and public services. In this light, fair adaptation to climate change by agricultural households in Morogoro and elsewhere in developing countries requires several complementary responses. Adaptation efforts should involve effective governance of natural resources because they function as safety nets to vulnerable groups. In addition, strengthening of national markets by infrastructure investments and institutional reforms is needed to give incentives to intensification and diversification in agriculture. Market participation also demands enhancement of human capital by public programs on health, education and wellbeing.

1. Introduction

This article examines farmers' livelihood responses and vulnerability to climate variability and other stressors in Morogoro, Tanzania, in order to understand their implications for adaptation to climate change by agricultural households in developing world more generally. The article seeks to move beyond two common views of adaptation to climate change. On one hand, a part of the climate change scholarship views adaptation as a matter of adequate management and "hardware" such as sea walls, flood protection, and reservoirs (e.g. IPCC, 1995). On the other hand, development community is increasingly associating adaptation to climate change with poverty alleviation (African Development Bank et al., 2003; Richards, 2003). This article seeks to demonstrate that while there are important synergies between adaptation and development efforts, fair adaptation requires multifaceted measures that address different aspects of human development and not only reduction of income poverty.

People in developing world face multiple stressors such as droughts, plant diseases, policy changes and market fluctuations (Misselhorn, 2005; O'Brien and Leichenko, 2000; O'Brien et al., 2004). In East Africa, droughts and climate variability in general are among the most important stressors (Misselhorn, 2005: 36). This raises the question to what extent past responses of agricultural households to climate variability and other stressors facilitate their adaptation to climate change in the future. There are limitations to drawing lessons

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in this way: past livelihood strategies and vulnerabilities emerged in a specific political–economic context which is different from the context within which people will adapt to climate change (Tierney, 1999). Then again, there is no self-evident way to examine adaptation to future climate change before it takes place. Contrasting past and present livelihood responses of agricultural households with those that are likely to be needed in the future can give us some indication about where the greatest pressure points and transformation needs will lie.

This article reviews literature and makes use of government statistics, a small number of expert interviews and other materials to draw lessons from past livelihood responses of agricultural households to climate variability and other stressors in Morogoro region in Tanzania. In interpreting these materials, the article draws from economic theories of agricultural change (Boserup, 1965; Platteau, 2000), research on income diversification (Barrett et al., 2001; Ellis, 2000; Reardon, 1997), and vulnerability scholarship (Watts and Bohle, 1993; Wisner et al., 2004; Adger, 2006; McLaughlin and Dietz, 2008). In the light of these literatures, obstacles to agricultural intensification and livelihood diversification create and structure vulnerability of households and communities to climate change. Therefore, adaptation strategies and policies only expand the opportunity sets of agricultural households if they address the amalgam of obstacles for intensification and diversification (Turner et al., 2003; Thomalla et al., 2006). That is, a set of complementary adaptation measures is needed to expand agricultural households' ''room for manoeuvre'' (Clay and Schaffer, 1984).

The article discusses how farmers in the Morogoro region have responded to droughts and other stressors by extending cultivation, intensifying agriculture, diversifying livelihoods, and migrating to gain access to access to land, markets, wage employment and self-employment. Some of these strategies have degraded and depleted natural resources such as soil, forest, and water resources. Because the natural resource base acts as a safety net for a variety of groups involved in agriculture during periods of stress, its depletion and degradation will complicate their ability to live with climate variability and change in the future. This is particularly problematic to vulnerable groups such as rural women, children and pastoralists whose access to land, employment, markets and public services is limited, and who thus cannot use diversification or intensification strategies to reduce their exposure to climatic risks.

The article suggests that reducing the vulnerability of the most vulnerable households involved in agriculture in Morogoro and elsewhere in developing countries requires complementary measures to safeguard key natural resources, to promote market access and to augment human capital. Effective governance of natural resources such as forests, land cover and water is needed because they provide a safety net for vulnerable groups (see Cleaver and Schreiber, 1994). The promotion of market participation through infrastructure investments and institutional reforms is important because it provides incentives and opportunities to diversification and intensification for agricultural households and communities, which in turn make it possible for them to reduce their dependence on activities that are subject to significant climatic risks, to manage such risks, as well as to increase incomes so as to live with the risks (Cleaver and Schreiber, 1994; Reardon et al., 1999). Finally, public spending and programs on health, education and wellbeing are needed in order to augment human capital, and to facilitate the diversification of livelihoods which is partly constrained by deficiencies in physical health, skills and knowledge (Fogel, 2004; Szreter, 1997).

In what follows, the second section discusses livelihood strategies and factors that make agricultural households vulnerable to climate variability. The third section examines climate variability and predicted climate change in Morogoro region. The fourth section examines livelihood strategies and vulnerabilities in the region. The fifth section discusses the implications of livelihoods and vulnerabilities for adapting to changing climate, and the conclusions review the implications for adaptation policy priorities.

2. Livelihood strategies and vulnerability

Two bodies of literature help to shed light on livelihood responses and vulnerability of agricultural households to climate variability and other stressors, and their implications for adapting to climate change (Adger, 2006: 271). First, the literature on agricultural development and sustainable livelihoods helps to understand responses of agricultural households to a variety of stressors. Second, vulnerability research offers several avenues for understanding the differential vulnerability of agricultural households to multiple stressors. This article combines insights from both bodies of literature to draw lessons from livelihood responses and vulnerability of agricultural households in Morogoro region, Tanzania, for adaptation to climate change in the future.

The rationale of this exercise is to contribute to a discussion on practical adaptation measures. For Smit and Wandel (2006: 284–285), this is still an uncommon approach to adaptation in comparison to more established adaptation research focusing on the potential scope of adaptation in the aggregate level to respond to climate change, merits of alternative adaptation measures, or relative adaptive capacity of countries, regions or communities. Research on practical adaptation measures typically focuses on specific communities and involves participatory vulnerability assessment (Smit and Wandel, 2006: 288). The goal of this article is slightly different, however. The article seeks to draw broader governance lessons about fair adaptation from local livelihood responses and vulnerability experiences, a task identified as important by Adger (2006: 276–277). The article draws from a variety of documentary and statistical sources to bridge the gap between the micro and macro levels.

The literature on agricultural development and sustainable livelihoods discusses how agricultural households adopt livelihood strategies such as agricultural extensification, agricultural intensification, livelihood diversification, and migration as a response to climatic and other stressors (Scoones, 1998: 9; Boserup, 1965). In what follows, I will discuss the rationale of these livelihood strategies to clarify later how they relate to vulnerability.

Agricultural extensification involves taking new units of land for low-input cultivation. A distinction should be made

between extensification and the standard economic theory according to which more marginal units of land will be brought under cultivation when the scarcity of land increases. If and when land is not scarce, new units of land brought under cultivation may have higher productivity than the units that are already in use (Boserup, 1965). Extensification can also create a portfolio of plots with different risk attributes to manage risks (McCloskey, 1976), and help to avoid financial risks of intensive agriculture. Opportunities for extensification diminish when the scarcity of land increases for example because of population growth or the gazetting of land for forest reserves or nature conservation. Intensification and diversification remain possible, however.

Agricultural intensification, as it was originally conceptualised by Boserup (1965), involves the application of more labour on a unit of land, because of population pressure and a surplus of labour, to achieve greater productivity. Boserup has been criticised for portraying agricultural intensification an automatic outcome of increased population density (Stone, 2001). However, she noted that population pressure and labour surplus may not be sufficient for agricultural intensification to take place in certain situations. For example, export-oriented or other activities could prevent the application of surplus labour on land. In the same vein, insecurity of land tenure can fail to create incentives to invest in productivity increases.

Failures to intensify agriculture have directed the attention of development scholarship and practice away from agricultural intensification. However, this judgement may be premature. Boserup (1965) drew her evidence from Asia and Latin America, where agricultural intensification has been relatively successful. Agricultural intensification has not worked equally well in Africa (Hyden et al., 1993) although there is some evidence of success (Mortimore and Adams, 2001). Reardon et al. (1999) distinguishes agricultural intensification based on increased use of labour and traditional cultivation methods from that of relying on increased use of other inputs, arguing that only the latter can work sustainably in Africa. But Platteau (2000) and Mortimore and Adams (2001) suggest that the conditions for Boserupian agricultural intensification have not been ripe in Africa and that it may succeed when the right conditions are in place. They and others also see that diversification to non-farming activities is important for improving consumption levels and wellbeing (Stone, 2001: 173–4).

Livelihood diversification involves the creation of a portfolio of farming and non-farming livelihoods. Households can diversify by complementing crop production with livestock rearing, employment in other farms or in the non-farming sector, self-employment, and gathering (Ellis, 2000: 15–17; Mortimore and Adams, 2001: 55). One rationale for diversification is to create a portfolio of livelihoods with different risk attributes, so that risks can be managed *ex ante* and that recovery is easier *ex post* (Reardon and Vosti, 1995: 1500–01). From this viewpoint, diversification entails the acceptance of lower economic returns for their greater security, and a potential poverty trap because productivity gains from specialisation are not realised (Barrett and Swallow, 2004; Barrett and McPeak, 2005; Dercon, 2004). But diversification can also respond to decreasing or seasonally varying returns to labour or land; imperfect markets for assets, finance and commodities; and economies of scope and scale (Barrett et al., 2001). In these instances, which are common in practice, factors of production may remain under-utilised and diversification can be the optimal strategy giving the highest return to factors of production. However, this does not mean all diversification is necessarily optimal—engagement in large number of activities may not be economically as rewarding as more intensive engagement in narrower set of livelihood activities (Eriksen et al., 2005).

Migration enables an agricultural household to transform its opportunity set and associated risks. Distinctions should be made between local and long distance migration, as well as between temporary and permanent migration. Local migration can open up access to land, other resources, markets, wage employment or self-employment (see Koczberski and Curry, 2005). Longer distance migration for wage employment can in turn generate remittances for those members of household who do not migrate. Voluntary migration can thus be an instrument for both agricultural intensification and livelihood diversification. But households may also be forced to migrate because of conflict, development projects, nature conservation, or environmental stress (Castles, 2003).

Early development scholarship and practice often considered agricultural extensification and livelihood diversification incompatible with agricultural intensification, because the latter was seen to require specialisation and dedicated investments. Recent scholarship on livelihood diversification in turn often considers agricultural intensification to entail high market risks that are more difficult to manage than climatic and other risks dealt with through livelihood diversification (Eakin, 2005). In both cases, the narrow construction of livelihood strategies is unfounded: there are several reasons for why multiple livelihood strategies can coexist.

Firstly, agricultural intensification should be considered a proposition about agricultural production, not about household income-generating strategies. The ''unit of intensification'' is not identical with the total landholdings of a household. Households may farm certain parcels intensively and others extensively (Boserup, 1965). Secondly, farming and livestock rearing seldom require full-time attention around the year: engagement in several activities may be necessary for the household to be able to make full use of its factors of production, particularly labour. Thirdly, economies of scale and scope may call for diversification alongside intensification. For example, farming and livestock rearing can exhibit economies of scope (Barrett et al., 2001) and economies of scale in selling produce or in buying inputs can be realised by trading on behalf of other households.

This reasoning suggests that all livelihood strategies are available to agricultural households. Different livelihood strategies may suit different households: some may intensify, others diversify, and there may also be some who are best served by migrating. But households may also combine strategies to a portfolio which best adapts them to the key stressors, given the constraints regarding information, assets and power. Their livelihood strategies are both constrained and facilitated by local and broader economy and society they are embedded in. For example, complex economies offer more opportunities for diversification than ones offering limited number of activities. In the same way, values, customs, level of

trust and other features of social life in the local community and the broader society influence livelihood strategies that are actually available to differently situated households.

From the viewpoint of the agricultural development and sustainable livelihoods literature, the ability of agricultural households to use livelihood strategies for adaptation to stressors such as climate variability influences the extent to which they are vulnerable or can be harmed. This literature traces the constraints in the use of livelihood strategies to institutions, power, inequality and other social factors (see Adger, 2006). But several other, complementary conceptions of vulnerability have been proposed in the literature on global environmental change, natural disasters and food security (see Liverman, 1990; Watts and Bohle, 1993; Turner et al., 2003; Wisner et al., 2004; Adger, 2006; McLaughlin and Dietz, 2008).

Climate change research defines vulnerability as a function of exposure, sensitivity and adaptive capacity (Adger, 2003; IPCC, 2001; Smit and Pilifosova, 2003; Yohe and Tol, 2002). The term ''exposure'' addresses the incidence of climate change impacts—the degree to which actors are in the ''firing line'' of climate change impacts. The term ''sensitivity'' in turn addresses the capacity of actors to be ''wounded'' by climate change impacts. Finally, the term ''adaptive capacity'', or ''resilience'' as suggested by Turner et al. (2003), addresses the ability of actors to shield themselves and to recover from adverse climate change impacts.

Climate change research has sought to recognise both physical and social sources of vulnerability. Physical conceptions of vulnerability focus on exposure and sensitivity to environmental stressors (see Liverman, 1990). Social conceptions of vulnerability draw attention to factors such as class, income distribution, and endowments which engender and characterise vulnerability (Watts and Bohle, 1993; Turner et al., 2003). For example, the natural disaster literature offers a definition of vulnerability as ''the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard'' (Wisner et al., 2004: 11; see also Turner et al., 2003). This definition regards vulnerability as the absence of adaptive capacity and draws attention to multiple factors such as assets, sources of livelihood, class, race, ethnicity, gender and poverty which demarcate vulnerable groups. These static descriptors of vulnerability help to identify and characterise vulnerable groups but they are not necessarily the root causes of vulnerability—factors that constitute and dispose certain individuals and groups as vulnerable (see Watts and Bohle, 1993; Adger and Kelly, 1999; McLaughlin and Dietz, 2008).

Turner et al. (2003) suggest that social and physical approaches to vulnerability are both essential parts of a comprehensive framework for understanding the vulnerability of coupled human–environment systems. They suggest that looking at coupled human–environment systems, instead of one or the other constituent system, highlights the role of the sequence and interactions of stressors, complexities and non-linearities, and issues of scale in vulnerability analysis. The greater resolution of this approach renders it ''place-based'' because the conditions of the coupled human–environment system are highly contextual (see also Adger et al., 2003; Smit and Wandel, 2006).

My analysis below acknowledges that environmental and social systems together construct the vulnerability of households in a context-dependent way. My aim of drawing more general adaptation lessons from local experience means that I am using the key insights of vulnerability scholarship as heuristics, rather than as tool of in-depth empirical investigation.

3. Climate variability and change in Morogoro

Morogoro is one of Tanzania's largest regions with 72,939 km^2 and a population of 1.75 million. Its population density of 24 people per square kilometre in 2002 was below the mean of 38 people per square kilometre in mainland Tanzania. Nevertheless, some areas in Morogoro such as Mgeta Division have high population densities up to 160 people per square kilometre (Jones, 2002: 1610). Two thirds of people live in the northern districts of Mvomero, Kilosa, and Morogoro while the southern districts of Kilombero and Ulanga host large protected areas and are less densely populated (Fig. 1 and Table 1).

Morogoro town is the region's administrative centre and largest city with its over 200,000 inhabitants. Morogoro town has enjoyed a strategic location along main transport routes since the pre-colonial era (see Young and Fosbrooke, 1960), which is why it has outgrown the region's other urban centres such as Ifakara, Kilosa, Kitadu, and Mahenge. Population of Morogoro town has grown by 6–7% a year for the past 60 years, over twice the 2.7% population growth for the region as a whole (see URT, 1997: 3; Young and Fosbrooke, 1960: 34). In total, a quarter of the region's population lives in urban areas.

Morogoro region lies between the seasonal rainfall patterns of northern and southern Tanzania. Northern Tanzania has bimodal rainfall. The short *Vuli* rains start between mid-September and mid-October and continue till December. The long *Masika* rains start in mid-March and last until late May. Southern Tanzania has unimodal *Msimu* rains, which start in November and end in April or May. Unlike Dar es Salaam, which is at the same latitude, Morogoro is considered to have unimodal rains (see Basalirwa et al., 1999 and Fig. 2).

Droughts are the most important aspect of climate variability in Morogoro region. Recent droughts happened in 2005, 2003, 1999–2000, 1996–1997, 1992, 1987, 1985, 1983, 1975–1976 and 1971 but they also occurred in 1969, 1966, 1958–1959, 1952–1953, 1949, 1946, 1943, 1933–1934,1928, 1925–1926 and

Table 1 – Population of the Morogoro region, 1967–2002

Administrative area	1967	1988	2002
Morogoro urban	24,999	117,601	227,921
Morogoro rural	291,373	430,202	263,012
Mvomero			259,347
Kilosa	193,810	346,526	488,191
Kilombero	74,222	187,593	321,611
Ulanga	100,700	138,642	193,280
Morogoro region	685,104	1,220,564	1,753,362

Source: United Republic of Tanzania (1997).

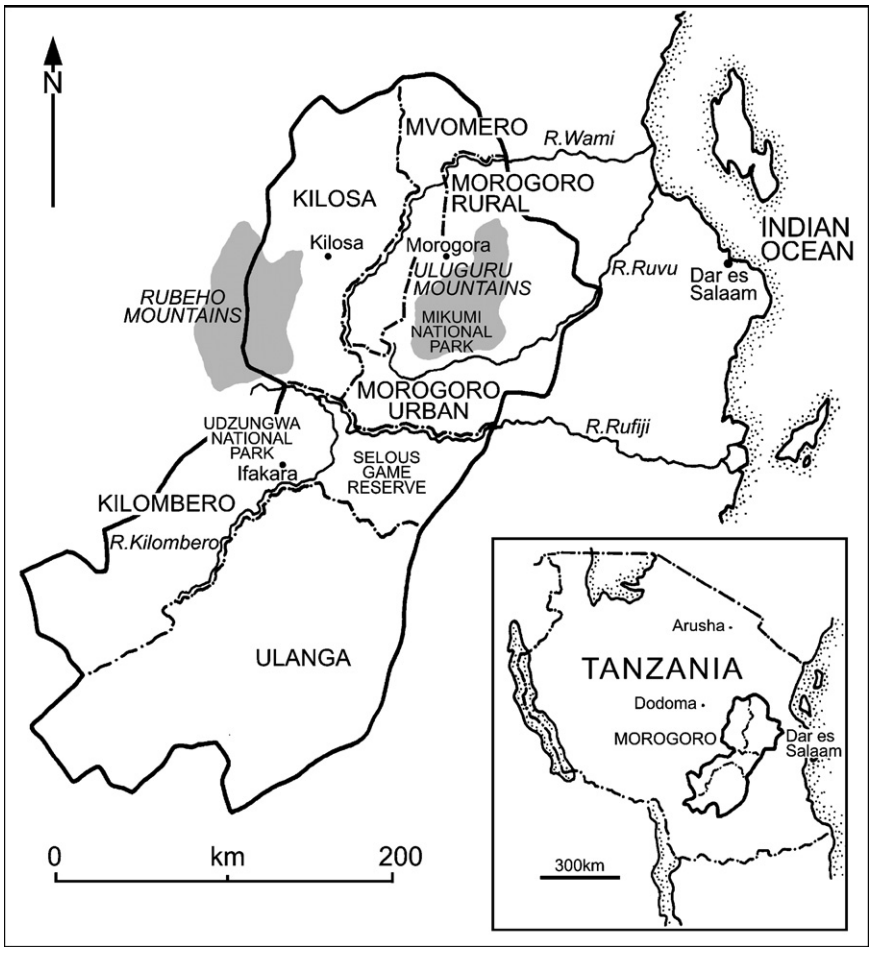

Fig. 1 – Map of Morogoro region.

1922 (Fig. 3; Brooke, 1967; Bryceson, 1990). Differences between the rainfall data from Mahenge reported by Bryceson (1990) and the rainfall data from Morogoro town (Fig. 3) indicate that drought experiences vary across the region. Droughts have often caused local food shortages. However, there have also been other reasons for food shortages, such as social unrest, locust swarms and floods (Brooke, 1967).

Annual rainfall in Morogoro region varies from 4000 mm in the high altitudes of the eastern slopes of the Uluguru Mountains to about 600 mm in the low altitude plains (URT, 1997). In Morogoro town, the long-term mean annual rainfall is about 890 mm. During the worst drought years, it has decreased to 500–600 mm. In the wettest years, annual rainfall has exceeded the mean by 50% (Fig. 3). In wet years, monthly

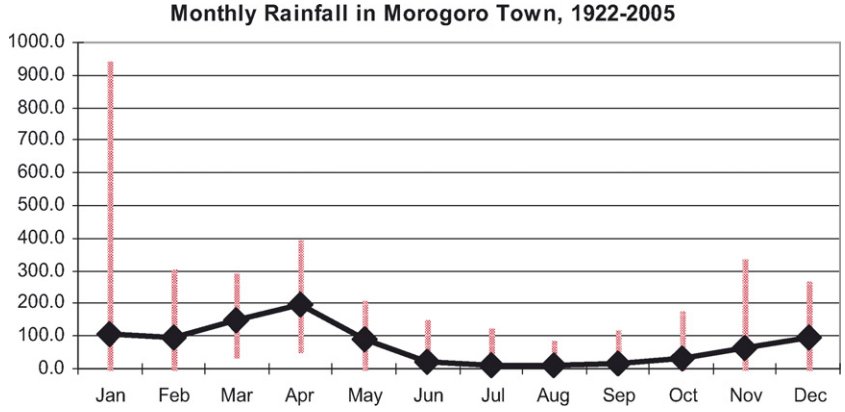

Fig. 2 – Mean monthly rainfall in Morogoro town, 1922–1988. Points indicate mean monthly rainfall and bars the range between minimum and maximum monthly rainfall. *Source*: Global Precipitation Dataset, Climatic Research Unit, School of Earth and Environment, University of East Anglia, UK, and Tanzania Meteorological Agency.

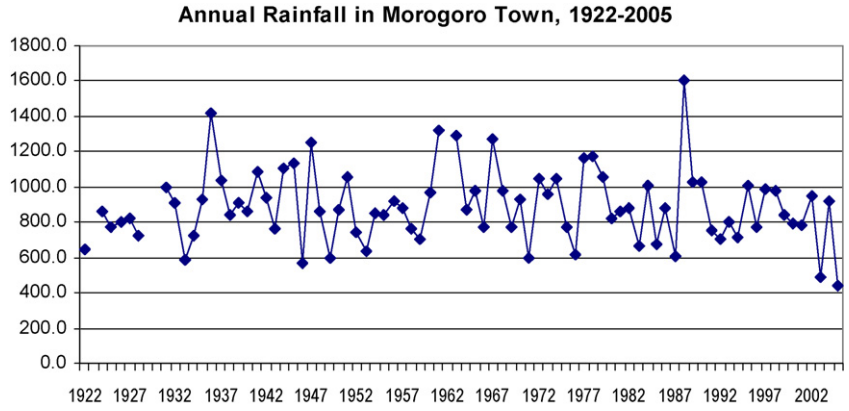

Fig. 3 – Annual rainfall in Morogoro town, 1922–1988. Gaps in graph indicate missing data. *Source*: Global Precipitation Dataset, Climatic Research Unit, School of Earth and Environment, University of East Anglia, UK, and Tanzania Meteorological Agency.

rainfall has been up to three times the long-term monthly mean. In dry years, monthly rainfall has been less than a third of the long-term mean, if there has been any rainfall at all (Fig. 3). Shorter dry spells of a week or two during critical periods of growing season – which do not necessarily register in the monthly rainfall data – can reduce crop yields significantly (Barron et al., 2003). Rainfall data suggest that climate variability may be increasing in Morogoro, as past 10 years have witnessed both the highest and two lowest rainfall years in historical record. Furthermore, the mean annual rainfall has declined after the 1950s (cf. Bryceson, 1990: 24).[1]

Wet years present a risk of flooding, particularly in the southern part of the Morogoro region which lies on the floodplains of the Great Ruaha and Kilombero rivers. Brooke (1967) notes that before 1935, floods destroyed lowland crops further down in the Rufiji District about once in 15 years but that after 1935 floods became increasingly common. He cites land use changes further upstream as the reason for the increased frequency of floods. Another explanation is that there simply was a wetter period after 1935 (Fig. 3). In 1963, flooding was particularly severe. Comparable amounts of annual rainfall were also received in 1947 and 1961–1962, 1967, 1973, 1979 and 1988 (Bryceson, 1990; Fig. 3). But floods do not have to be severe to cause locally significant damage. For example, in Spring 2004 a flood in the Magombera village in the Kilombero District made 2600 households homeless. Two years later, a flood in Kilosa district destroyed 130 homes and washed away a section of railway elsewhere in the region, stranding 1000 passengers for several days at Ngerengere.[2]

The Morogoro region will experience a mixture of climate changes and climate change impacts that are predicted for a Tanzania as a whole. Tanzania is predicted to warm 2–4 C° by 2100. Dry seasons will warm more than wet seasons and the country's interior is likely to experience higher temperature increases than coastal regions. Rainfall is predicted to decrease up to 20% in the interior and to increase 25–50% in the northeast, southeast and the Lake Victoria basin. Changes in temperature and rainfall are likely to prolong dry seasons and to worsen periodic droughts. This will be pronounced in the interior. The northeast, southeast and the Lake Victoria basin are likely to experience more frequent and severe flooding (Hulme et al., 2001; IPCC, 2001; Mwandosya et al., 1998: 1–24).

Warming and rainfall changes would diminish the availability of water for crops and shorten the growing season. Warming would also increase crop losses due to weeds, diseases and pests. Regional predictions suggest that Tanzania may loose 10% of its grain production by 2080 (Parry et al., 1999: S62–S64; Downing, 2002). Maize – a staple crop grown by a half of Tanzanians and providing a third of their daily calorie intake – is going to be hit hard. Average maize yield is predicted to decrease 33% by 2075 if CO_2 concentrations double and mean annual temperature increases by 2–4°. Maize yields may decrease 80% in the Tabora-Dodoma region (Mwandosya et al., 1998: 181).

Some rivers such as the Rufiji are predicted to have increased water flows while others such as the Ruvu and the Pangani are predicted to have reduced water flows. While the predicted annual flow changes are only about 5–10%, flows are likely to become more seasonal. Predicted minimum flows in the dry season are less than half of the present ones in Ruvu and Pangani (Mwandosya et al., 1998: 34–50). Lower minimum flows complicate water use for power generation, irrigation and water supply. This is of national significance as the plants on the Great Ruaha and Pangani rivers are central to national hydroelectric generating capacity. Drought in 2005–2006 lowered water level in the reservoirs on Great Ruaha to such an extent that it curtailed electricity generation and required a national load shedding program which gave most users electricity only 8–12 h in a day.[3] Ruvu also supplies water to Dar es Salaam. Predicted changes in rainfall and evaporation

[1] Declining annual rainfall in the latter half of the 20th century can be observed from 9-year sliding averages, but is difficult to discern from plain annual rainfall data.

[2] See Bilal Abdul-Aziz, 'Floods Wreak Havoc', *Guardian*, 19 April 2004; 'Floods render 130 Kilosa families homeless', *Guardian*, 17 February 2006; '1000 train passengers stranded after downpour', *Guardian* 15 February 2006.

[3] See 'Rationing to span 8 h, *Sunday News*, 5 February 2006; Power shedding to bite more, *Daily News*, 15 February 2006.

may also decrease ground water levels. Reduced water availability will require more time for water collection and reduce water use, which impairs hygiene and increases the incidence of contagious diseases (Cairncross, 2003; IPCC, 2001; Johnstone et al., 2002; McMichael et al., 1996).

Peak flows are predicted to double in Rufiji (Mwandosya et al., 1998: 34–50) and they are also likely to increase in many other rivers. Higher peak flows contribute to more frequent and severe floods which destroy infrastructure, buildings and belongings in the floodplains. In urban areas, floodplains are often populated by poor households. For example, two-thirds of Dar es Salaam's three million inhabitants live in flood-prone areas (UNEP, 2002: 241). Flooding contaminates surface waters and wells with human wastes and increases the incidence of water-borne diseases such as diarrhoea, typhoid and cholera. Warming, flooding and increased rainfall are also likely to increase the spread and incidence of insect-borne diseases such as malaria (Patz et al., 2002; cf. Rogers and Randolph, 2000).

In what follows, I will discuss how the region's agricultural households have used livelihood strategies to respond to climatic and other stressors in the past.

4. Livelihood strategies in Morogoro region

Morogoro region's agricultural and livelihood conditions are diverse. The highlands above the altitude of 600 m are suitable for perennial crops such as coffee, fruits, and cocoa, as well as maize and vegetables. The plateaus at the altitudes of 300–600 m are used for growing maize, sorghum, cotton and sunflower. Paddy rice, sugar cane, banana, cassava, and sweet potatoes are grown in the lowlands and river valleys (URT, 1997). Almost a half of agricultural land is used for growing maize and another quarter is used for cultivating other staple crops such as rice, beans, root crops such as cassava, and sorghum (Ellis and Mdoe, 2003: 1376). The cultivation of traditional cash crops such as cotton, coffee and sunflower has declined and today the most important cash crops include fruits, vegetables and sesame seeds. Cattle is kept by wealthier households and Maasai pastoralists.

Farmers traditionally extended their cultivation by clearing forest, which has been one reason for deforestation on the Uluguru Mountains. On the basis of aerial photographs, topographic information and forest remnants, Burgess et al. (2002) estimate that the Uluguru Mountains once had a forest cover of 500 km^2, of which nearly a half was lost by 1955—aerial photographs taken at that time suggest a forest cover of about 300 km^2. More recent aerial photographs indicate that another 40 km^2 was lost between 1955 and 1977 and that in 2001 forest cover was 230 km^2 (Burgess et al., 2002: 144). Today larger patches of forest do not remain outside the forest reserves (ibid.) and the possibilities of converting forests for agricultural land have been largely exhausted.[4]

Extensification can also be sought by taking land from fallow to cultivation. At the moment, fallow periods are short. Interviews conducted by the *Uluguru Mountains Biodiversity Conservation Project* indicate that in a third of the eighteen villages it surveyed land is not fallowed at all and in most others only a small proportion of land is fallowed for a year or two.[5] Farmers also reported that over the past three decades the yield of maize per hectare has decreased by 50–70% and the yield of rice even more. There is also other evidence that soil fertility and crop yields have declined (van Donge, 1992: 80).

Traditional agricultural intensification is under way in some places which have good access to markets. Ponte (2002: 113–132) observes that many farmers in Morogoro have switched to ''fast crops'' such as bananas, beans, cabbage, coconuts and tomatoes, which can produce 4–6 harvests in a year with low inputs. In Mgeta division, farmers have terraced their cultivation and use fertilisation and irrigation to produce fruits and vegetables for sale (van Donge, 1992; Jones, 1996). These efforts at agricultural intensification are based on additional use of labour as most farmers are hard pressed to increase their spending on other inputs—a situation which has become worse after the removal of regulations and subsidies on agricultural inputs as part of Tanzania's structural adjustment program (see Ponte, 2002). There is also evidence of faltering intensification at the Uluguru Mountains: land cover chances have reduced availability of water for irrigation in places.[6]

Livelihood diversification has been the main strategy for living with climate variability and other stressors in Morogoro. People cultivate staple crops predominantly for own consumption but they also sell a third of what they produce (Ellis and Mdoe, 2003: 1377; see also Foeken et al., 2004). Non-farm income from employment and self-employment has become consistently more important while the significance of agriculture has declined in livelihoods since the mid-1980s (Ponte, 1998: 336). Today agriculture and livestock husbandry still generate slightly over a half of cash income and non-farm sources such as wage income, self-employment and remittances generate the rest. But access to non-farm income is uneven, with better off households and urban households in general having easier access to income-generating opportunities (Reardon, 1997). As a result, the mean urban monthly income of 37,400 Tsh per month (or about $ 1 per day) was almost three times higher than the mean rural monthly income of 13,100 Tsh in 2000 (see NBST, 2002a).

Most households tap natural resources to cater for their subsistence needs and to earn cash income. Forests provide firewood, fruits, spices, fodder, traditional medicines and meat. Trees are also harvested for the production of timber, charcoal and bricks, which are sold particularly to Dar es Salaam (Luoga et al., 2000). Monela et al. (2000) report that households in Morogoro and Dodoma regions may obtain up to 68% of their total income from forests. The significance of forest resources is the greatest for peri-urban households

[4] Interviews conducted by the *Uluguru Mountains Biodiversity Conservation Project* indicate that in only two out of eighteen surveyed villages forest was cleared for agricultural use. Interview summaries are at the Uluguru Mountains Biodiversity Conservation Project's website at http://africanconservation.org/uluguru/downloads.html.

[5] Interview summaries are at the *Uluguru Mountains Biodiversity Conservation Project*'s website at http://africanconservation.org/uluguru/downloads.html.

[6] Deodatus Mfugale, 'No more timber? And the springs are dry', *Guardian*, 8 August 2005.

Table 2 – Average crop yields kg per hectare in Morogoro region

	1994–1995	1995–1996	1996–1997 (Drought)	1997–1998 (Flood)	1998–1999	1999–2000 (Drought)	2000–2001 (Flood)
Maize	1905	1590	439	1600	1300	1200	2000
Sorghum	1271	1400	1175	1600	1000	1000	1200
Millet	182	18	182	900	300	600	1000
Rice	1358	1566	1564	2600	2000	1500	2600
Sweet potatoes	1273	1318	2048	1300	2200	2300	1700
Pulses	698	870	550	800	500	800	2000
Bananas	1000	2250	2250	2500	1200	1800	2200
Cassava	2603	2605	2608	2600	2100	2100	3000

Source: Tanzania Ministry of Agriculture and Food Security (2002).

Table 3 – Change in the area of cultivation from the mean in Morogoro

Crops	1994–1995	1995–1996	1996–1997 (Drought)	1997–1998 (Flood)	1998–1999	1999–2000 (Drought)	2000–2001 (Flood)
Maize	+	–	–	+	0	0	+
Sorghum	0	+	+	–	0	+	–
Millet	+	+	+	–	+	+	–
Rice	+	+	+	–	–	–	–
Sweet potatoes	–	–	–	–	–	+	+
Pulses	+	+	0	–	+	+	0
Bananas	+	–	–	–	–	+	+
Cassava	0	0	0	+	0	+	–
Total	+	+	0	–	0	+	–

Source: Tanzania Ministry of Agriculture and Food Security (2002).

which have access to forests and to urban markets for forest products (Monela et al., 2000). Forest products contributed about 50% of total income also in more remote communities.[7] Freshwater fisheries are tapped in a similar fashion and artesanal gold and gemstone mining increasingly offers a source of non-farm income in the region.

Farmers also manage risks of agricultural production by switching between crops, by altering the crops they grow and by changing planting time in light of the evidence on growing season (O'Brien et al., 2000). Farmers can switch from maize to sorghum and/or cassava when there is a threat of drought or food insecurity, and to rice or banana when rainfall is abundant. The average yields of maize and rice have decreased in dry years such as 1996–1997 and 1999–2000 by up to 75% and 50%, respectively. In contrast, sorghum and cassava yields have varied less and the yield of sweet potato has increased in dry years. Rice and bananas have yielded 25% more in wet years such as 1997–1998 and 2000–2001 (see Table 2).

Regional agricultural statistics indicate that farmers adjust their practices to climate variability. The cultivated area of maize has decreased and that of sweet potatoes has increased in dry years (see Tables 2 and 3). Increases in the planting of cassava seem to follow years which had low maize yields and tell of its "insurance" function at times of food insecurity (Table 3). O'Brien et al. (2000) also found that the majority of their respondents in the Morogoro and Iringa regions used some of the above discussed strategies as a response to the seasonal weather forecasts of above average rains during the 1997–1998 season.

Migration is a frequently used strategy to live with climate variability and other stressors in Morogoro region. Interviews conducted by the *Uluguru Mountains Biodiversity Conservation Project* indicate that farmers move temporarily from remote upland villages to locations where farming conditions are favourable, or to locations which have good access to markets.[8] Gender and demographic imbalances in population statistics also indicate that young adults, especially males, move from rural villages to urban settlements both within and outside the region.[9] Parents also send children to cities to work for upkeep and cash income to reduce the number of people they have to support with uncertain agricultural income.

5. Livelihoods, vulnerability and climate change

Agricultural households have expanded cultivation, intensified agriculture, diversified livelihoods and migrated as a

[7] Meshack (2003: 9) reports that households obtain at least a third of their total income from forests in the West Usambaras in northern Tanzania.

[8] Interview summaries are at the *Uluguru Mountains Biodiversity Conservation Project*'s website at http://africanconservation.org/uluguru/downloads.html.

[9] There are fewer 15–25 year old males than females in Morogoro urban and rural and Kilosa districts. In Morogoro Rural, males make up only about 45% of 20–29 year olds while the shares of males and females are more balanced in the younger and older age groups (see NBST, 2002b). Gender balance of population is, however, a poor indicator (albeit one of the few available ones) of migration because both men and women do migrate.

response to climate variability and other stressors in the Morogoro region. These strategies have been instrumental in maintaining levels of consumption during periods of stress but they have also had adverse environmental consequences such as soil erosion, deforestation and changes in water flows which can undermine the use of past livelihood strategies for adapting to climate change in the future. At the same time, income and other constraints make it difficult for people to alter their livelihood strategies (Reardon and Vosti, 1995). Therefore, increasing environmental stress could accentuate vulnerability to climate change in the future.

Future vulnerability could be augmented by soil erosion. The most common tillage method in Tanzania is flat cultivation, which involves the preparation of a flat seedbed by turning the soil around with a hand hoe or a plough (Shetto, 1998) to bury vegetation residues or ashes. This method causes tillage erosion on steep slopes (Kimaro et al., 2005) and water erosion during heavy rains. It also exposes soil to crusting and compaction and increases runoff and reduces soil moisture. Loss of topsoil, which contains most of the nutrients (Kaihura et al., 1999), and reduced soil moisture can reduce soil fertility significantly. Increased run-off also increases peak flows and flooding and reduces minimum flows and causes water scarcity during dry seasons. Soil erosion and flow changes also cause sedimentation of watercourses.

Deforestation can constrain the use of livelihood strategies based on farm and non-farming activities and the use of forests as safety nets. In the past, the most important reason for deforestation was the extension of cultivation. Currently charcoal and brick production cause deforestation because they make non-selective use of tree species (Monela et al., 1993) and because their scale has increased as the markets of major cities such as Dar es Salaam have become accessible. The problem prompted the government to ban the harvesting and trade of all forest products, including charcoal, in January 2006.[10] Deforestation is a problem for adapting to climate change for several reasons. Reduced forest cover will provide reduced water retention which contributes to increased runoff, flooding and soil erosion as well as to greater scarcity of water during dry seasons. The scarcity of water will impact rainfed and irrigated cultivation, livestock rearing and public water supply.

The adverse effects of farming practices and deforestation are already felt in Morogoro and they are likely to become more pronounced in the future. Crop yields are reduced and watercourses are more seasonal. The flow of the Great Ruaha has ceased during the dry season in 10 consecutive years.[11] Official sources and the news media suggest that the reasons lie in land and water use outside the Morogoro region in the Usangu wetlands and plains.[12] However, mismanagement of the upstream reservoirs is also implicated.[13] At the Uluguru Mountains, deforestation has resulted in the drying up of springs and streams.[14] Yet flooding has become more frequent in Morogoro town and elsewhere.

Farming practices and deforestation also contribute to the sedimentation of watercourses. The Mindu reservoir which serves the Morogoro town is silting up because of soil erosion and artesanal gold mining in the watershed. This reduces the storage capacity of the city's water supply system and degrades its water quality. Gold mining also pollutes water with mercury and human wastes (Maganga et al., 2002: 923).[15] Farming and deforestation increase the turbidity of Ruvu river further downstream (see Ngoye and Machiwa, 2004), which reduces the quality of Dar es Salaam's water supply.

To summarise, current livelihood strategies can aggravate vulnerability to climate variability and change through their effects on environmental systems. Soil erosion and soil exhaustion will impact on farmers who are dependent on agriculture but whose low incomes prevent investments in intensification. The push for diversification has few outlets because of limited access to markets and limited capacity for investment (Reardon and Vosti, 1995). Tapping the natural resource base will continue to be important for maintaining consumption and income levels (Cleaver and Schreiber, 1994). However, the shrinking natural resource base will have reduced capacity to provide a safety net. In short, there is a danger of downward-spiralling cycle of increased environmental degradation and vulnerability.

I will now move on to the contribution of human systems to vulnerability. The livelihoods literature (e.g. Ellis, 2000; Ellis and Mdoe, 2003; Ellis and Allison, 2004; Scoones, 1998) suggests that low levels of income, high proportion of income used for food consumption, and dependence on rain-fed agriculture are factors that create vulnerability to environmental stressors. But, more broadly, sources of vulnerability include all obstacles for using livelihood strategies to respond to environmental and other stressors.

There is slightly less poverty in Morogoro than in Tanzania on average (URT, 2002: 66–74). Yet almost a third of the households suffer from basic needs poverty and 14% of them are below the food poverty line or unable to buy the essential amount of calories with the resources at their disposal (NBST, 2002a: 180). Poverty is a problem particularly for rural households that depend on rain-fed subsistence farming and lack access to other income generating opportunities, as well as to female and child-headed households that often have limited access to land, employment, and self-employment.

Also the region's human development outcomes are slightly better than national ones. Adult literacy rate is nearly 90% in cities and 66% in rural areas and the region's total enrolment rate in primary, secondary and tertiary education

[10] See Charles Kizigha, 'Government reviews ban on tree felling', *Daily News*, 9 February 2006; Pacifique Nkeshimana, 'Dealers in forest products to get temporary permits,' *The Guardian*, 10 February 2006.

[11] See the opening speech of Morogoro's Regional Commissioner, The Honourable Stephen J. Mashishanga (MNEC) at the ''Ruaha + 10'' event, ICE Conference Hall, Sokoine University of Agriculture, Morogoro, Tanzania, 11 December 2003. <http://eng.suanet.ac.tz/swmrg/outputsdownloable_files/wordpapers/speech_RegionalCommissioner.pdf>. Accessed 15 May 2004.

[12] See Zephania Ubwani, 'Government Bars Pastoralists from Grazing in Usangu Wetlands', *Guardian*, 18 March 2004.

[13] David Anderson, Personal communication, October 1, 2004.

[14] Deodatus Mfugale, 'No more timber? And the springs are dry', *Guardian*, 8 August 2005.

[15] See 'Mindu destruction setting stage for a catastrophe', *Guardian*, 14 July 2004.

was 87.2 (URT, 2002: 66–74). Adult life expectancy at birth varies between 44–56 years for males and 46–58 years for females in different parts of the region (Pison, 2005: 305). HIV/AIDS is the leading cause of death of adults (20% of deaths), followed by malaria (12% of deaths), diarrhoea (10% of deaths) and pulmonary TB (5% of deaths) (see Ministry of Health, 1997: 130–132). Infant and child mortality are 100 and 140 per thousand live births, respectively, but again with significant variation within the region. Almost half of child mortality is caused by malaria (Ministry of Health, 1997). There is thus a significant burden of disease and caring which taxes human capital and hinders the ability of households to generate subsistence and income (see Fogel, 2004; Szreter, 1997). Achievements in education are also in danger as school completion rates are sliding back in Tanzania (Paavola, 2006).

Access to resources and particularly land is mediated by institutions such as property rights and affects the vulnerability of households (on institutions and vulnerability, see Adger, 1999; Eakin, 2005: 1936). Among the waluguru, the largest tribe around Morogoro town, matrilinear clans allocate land use rights to households (Young and Fosbrooke, 1960). These rights can be transferred to the next generation of daughters within the clan but the rights of deceased sons revert back to their mothers' clan (Young and Fosbrooke, 1960). Households can also gain or loose rights to land on the basis of family size or need. Clan elders can give excess land to non-clan farmers upon the payment of a tribute or *ngoto* to the clan (ibid). While this land tenure system awards access to land to women, it is not unproblematic. In places up to 40% of households do not own land (Ellis and Mdoe, 2003: 1375), although the recent Household Budget Survey found that only 5% of the region's rural households are landless (NBST, 2002a: 178). Mean household land holdings of 4.5 acres are also smaller than the national average. Land disputes are common and land use is changing in ways which are undermining the traditional land tenure system (van Donge, 1993; Ponte, 2002). Increasing use of contracts to lease land and movement towards market exchange of land erodes women's access to land, because male members of households and clans make most decisions on market transactions. Moreover, women's access to other livelihoods than cultivation, such as employment and self-employment, is more limited than that of males (see Eriksen et al., 2005). This leaves women dependent on farming, which is subject to climatic and other risks. Another group whose access to land is not secure is the Maasai pastoralists.

Lack of access to income-generating opportunities is not only a matter of customary and legal rules, however. Poor transport infrastructure is an obstacle for rural development (Platteau, 2000). Main roads connect Morogoro to Dar es Salaam, Dodoma, Iringa and Mbeya and railroads connect Morogoro to Dar es Salaam, Dodoma, Tabora, Kigoma and Mbeya. This provides opportunities for intensification and diversification near the main transport corridors, particularly around the Morogoro Town. However, the region has only 0.05 km of road per square kilometre—just half of the national average. Many rural villages are not accessible by roads at all and for most villages access to markets and public services is limited. This is one reason why people migrate to gain access to income-generating opportunities.

Infrastructure also has implications for human capital and for the time which is available for income-generating opportunities. The same applies to public services such as schools, clinics and hospitals. Rural households are disadvantaged both in terms of their access to public utility infrastructure and to public services. In Morogoro, almost all urban dwellers but only a quarter of rural households are connected to a water supply system (NBST, 2002a: 172). About 40% of the urbanites have an electricity connection while rural communities remain unconnected (NBST, 2002a: 161–162). But even those households that have a connection use electricity mainly for illumination and cook with less expensive charcoal.

To summarise, rural households are more vulnerable to climate variability and climate change than the urbanites. Rural incomes and consumption levels are significantly lower than urban ones and rural households suffer from greater levels of poverty, lower human development outcomes and more limited access to markets and public services. Female-headed households, children, landless households and pastoralists are also more vulnerable than others because of their more limited and insecure access to resources and livelihood alternatives.

6. Conclusions

People in the Morogoro region have used extensification, intensification, diversification and migration to live with climate variability and other stressors. While these livelihood strategies have helped to maintain levels of consumption during periods of stress, they have also had adverse environmental consequences which increase vulnerability to climate variability and change. At the same time, income and other constraints prevent people from altering their livelihood strategies. There is no single solution which would enhance adaptive capacity in the region. Several complementary measures are needed, including effective governance of environmental resources such as soil, forests and water resources; promotion of increased market participation to stimulate both agricultural intensification and diversification of livelihoods, and; social programs and spending on health, education and wellbeing to augment both physical and intangible human capital so that rewarding market participation is possible.

Technical solutions for effective management of environmental resources such as soils, forests and water resources do exist. Soil erosion can be avoided by conservation tillage and erosion control measures which can be coupled with rain water harvesting and other solutions to deliver direct agricultural benefits. Pressure on the use of forest resources for charcoal production can be reduced by the promotion of efficient kilns and stoves and fuel switching and by reforms in forest tenure which give stronger incentives to forest management and tree farming. There is much scope for households to undertake these adaptive measures on their own. Management of water resources and water quality demands policies which are implemented and enforced effectively at both national and local levels. Yet the government has limited capacity to adopt and implement public policies, just like households have limited capacity to invest

in new practices and activities. This is why environmental measures need to be complemented by measures enhancing market participation.

Promotion of market participation is needed because increased market participation provides incentives for agricultural intensification and diversification of livelihoods. Successful intensification can create a buffer against and reduce climatic risks associated with agricultural production and augment income levels, which is needed to make investments that help to reduce dependence on the natural resource base and to conserve it. Diversification can also reduce dependence on risky agriculture and to help to employ factors of production more fully. Promotion of market participation will need both infrastructure investments and institutional reforms. Physical access to markets is the precondition to market participation but it also needs an institutional setting which guarantees the security of property rights and the enforcement of contracts, facilitates access to credit, and keeps corruption under check.

The cushion of improved income levels and diversified livelihoods cannot be achieved through increased market participation only, however. People's ability to participate in the market depends on their human capital. Health and nutrition are integral aspects of physical human capital which influence the capacity of individuals to earn an income. Income earning opportunities and productivity also depend on their education and skills. This is why the promotion of market participation has to be coupled with public programs and spending on health, education and social welfare which help to maintain and augment human capital in both its physical and intangible manifestations.

The three pillars of vulnerability reduction are complementary. Focusing exclusively on market participation would result in environmental destruction and increased vulnerability of most vulnerable groups which depend heavily on the natural resource base. Ignoring the role of market participation would potentially lead to a poverty trap and reduce the ability of environmental and human capital measures to reduce vulnerabilities. This three-partite strategy can also realise synergies between adaptation to climate change and development efforts. Broad-based development which recognises the integral role of the environment and human development alongside economic development can also assist in adapting to changing climate and other stressors in the future.

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