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By

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Abstract

This paper examines livelihood responses to climate variability and other stressors in the Morogoro region in south-eastern Tanzania, with an aim to understand the implications of these responses to adapting to changing climate in the region in the future. The paper indicates how farmers have responded to draughts by expanding cultivations, reducing fallows, switching crops and engaging in wage employment or in charcoal, timber and brick production. Farmers also frequently migrate on temporary basis to locations which have favourable farming conditions or better access to markets. More permanent migration to towns and cities has also increased. Farming practices and heavy reliance on forest resources have resulted in soil erosion and deforestation which have reduced water retention, increased flooding after rains and reduced water flow between the rains. These environmental changes complicate living with increased climate variability in the future because reduced natural resource base may not be able to provide the same safety net functions as it currently provides during periods of stress. This would be particularly problematic for those who live in more remote rural villages and who suffer from limited access to markets, public services and utilities. Efforts to reduce vulnerability to increased climate variability in the region would need to safeguard the natural resource base, promote market access and augment human capital. Natural resource base demands attention because its safety net functions are important to large proportions of rural and urban population and because the loss of ecosystem services would increase the exposure of large downstream populations to floods and scarcity of water. The promotion of market participation can provide incentives to diversification and intensification and help reduce dependence on risky agricultural production. Finally, diversification of livelihoods is constrained by deficiencies in physical health, skills and knowledge. Therefore, public spending and programs related to health, education and wellbeing can facilitate diversification in the future.

Keywords

Adaptation to climate change, vulnerability, livelihoods, social justice, Tanzania

1. INTRODUCTION

Climate change, water and poverty are intimately intertwined in the developing world where climate change is likely to be experienced primarily as increased variability in rainfall and availability of water. Availability of and access to water are strongly linked to human and economic development. Lack of clean, fresh water is one of the primary reasons for adverse health outcomes. Water-borne diseases such as diarrhoea, typhoid and cholera increase morbidity and mortality of infants and children but also of the adult population. Lack of water impairs hygiene and contributes to the spreading of other contagious diseases as well (see Cairncross, 2003; Johnstone et al., 2002). Another factor contributing to adverse health outcomes – malnutrition – is affected by the availability of water for cultivation and livestock rearing. Moreover, ill health and malnutrition cause poverty because good health and nutrition are important preconditions for the capacity to work and to generate income (see Fogel, 1994; Szreter, 1997). Climate change – especially changes in the availability of water – have the potential to aggravate adverse health outcomes, malnutrition and poverty as well as vulnerability to all forms of environmental stress. It goes without saying that any reasonable plans and policies calculated to assist in adapting to climate change must look closely at the water resources and how they interact with livelihood strategies and natural resources that are important to livelihoods.

This paper examines livelihood responses to climate variability in the Morogoro region in south-eastern Tanzania, with an aim to understand the implications of these responses for adapting to changing climate in the region in the future. The paper is based primarily on a review of published and grey literature. It also makes use of government statistics, summaries of interviews made in other projects, as well as a limited amount of expert interviews conducted on a preliminary fieldwork trip to Tanzania. This synthesis of existing knowledge aims to provide a basis for a targeted collection of primary material on living with current climate variability in the Morogoro Region.

The paper indicates how farmers have responded to draughts by expanding cultivations, reducing fallows, switching crops and engaging in wage employment or in charcoal, timber and brick production. Farmers also frequently migrate on temporary basis to locations which have favourable farming conditions or better access to markets. More permanent migration to towns and cities has also increased. Farming practices and heavy reliance on forest resources have resulted in soil erosion and deforestation which have reduced water retention, increased flooding after rains and reduced water flow between the rains. These environmental changes complicate living with increased climate variability in the future because reduced natural resource base may not be able to provide the same safety net functions as it currently provides during periods of stress. This would be particularly problematic for those who live in more remote rural villages and who suffer from limited access to markets, public services and utilities.

Efforts to reduce vulnerability to increased climate variability in the region would need to safeguard the natural resource base, promote market access and augment human capital. Natural resource base demands attention because its safety net functions are important for large proportions of rural and urban population and because loss of ecosystem services would increase the exposure of large downstream populations to floods and scarcity of water. Promotion of market participation can provide incentives to diversification and intensification and reduce dependence on risky agricultural production. Finally, diversification of livelihoods is constrained by deficiencies in physical health, skills and knowledge. Therefore, public spending and programs related to health, education and wellbeing can facilitate diversification.

In what follows, the second section discusses current climate variability and predicted climate changes and their impacts in Tanzania and Morogoro region. The third section

examines livelihoods, development outcomes and vulnerabilities in the region. The fourth section examines how people in the region have used a variety of livelihood strategies as a response to past and present climate variability. The fifth section discusses the implications of these responses to climate variability for adapting to changing climate in the future.

2. PREDICTED CHANGES AND CURRENT VARIABILITY OF CLIMATE

Climate change can be defined as a systematic change in the key dimensions of climate – including average temperature and wind and rainfall patterns –over a longer period of time. Climate variability in turn consists of a shorter term variation in the same dimensions of climate. In this section I will first discuss predicted climate changes and their likely impacts and conclude with a brief characterisation of current climate variability. This order of treatment is appropriate as I seek to use experiences from living with current climate variability to shed light on living with changing climate. Climate change and impact predictions should be considered as just what they are – predictions which are highly uncertain. Yet they will help to paint a scenario of what could happen in the future and to determine what those scenarios could entail to people living in the region.

Tanzania is predicted to warm by 2 - 4 Cº by 2100, somewhat less than north-western Africa and South Africa. Inner parts of the country are likely to experience higher temperature increases than coastal areas and cold and dry seasons will warm more than warm and wet seasons. Rainfall is predicted to decrease by 0 – 20 percent in the inner parts of the country. In contrast, rainfall is may increase by 25-50 percent in the northeast, southeast and the Lake Victoria basin. Changes in the mean temperature, rainfall patterns and rainfall variability are likely to prolong dry seasons and to increase the severity of periodic droughts. This will be pronounced in the interior part of the country which will experience higher temperature increases and reduced rainfall. The northeast, southeast and the Lake Victoria basin will be less exposed to droughts but they are likely to experience more frequent and severe flooding. The predicted sea level rise of 0.10-0.90 metres will aggravate flooding in the coastal areas (see Clark, Webster and Cole, 2003; Hulme et al., 2001; IPCC, 2001; Mwandosya, Nyenzi and Luhanga, 1998:1-24).

Predicted climate changes will significantly impact on food production. Warming and changes in rainfall will diminish water availability for crops and shorten the growing season. Warming will also increase crop losses due to weeds, diseases and pests. Regional predictions suggest that Tanzania may loose 10 percent of its grain production by 2080 (Parry et al., 1999: S62-S64; Downing, 2002). Maize – a staple crop grown by half of Tanzanians and providing a third of their daily calorie intake – is going to be particularly hardly hit. Average maize yield is predicted to decrease 33 percent by 2075 if CO2 concentrations will double and temperature increase by 2-4 degrees. Maize yields may decrease 80 percent in the Tabora-Dodoma region (Mwandosya, Nyenzi and Luhanga, 1998:181). There is considerable uncertainty regarding the impact of climate change on the yields of cash crops such as coffee, cotton and tea. Land cover is also predicted to change as a result of climate changes, wooded grassland and dry forests becoming more common.

Tanzania's water resources will experience varied climate change impacts. Some watercourses such as the Rufiji are predicted to have slightly increased water flows but the Ruvu supplying Dar es Salaam and the Pangani supplying Tanga are predicted to have reduced water flows. While the predicted annual flow changes are only about 5-10 percent, water flows are going to become more seasonal. Predicted minimum flows in the dry season are less than half of the present ones in Ruvu and Pangani and predicted peak flow in rainy season about twice the present one for the Rufiji (Mwandosya, Nyenzi and Luhanga, 1998:34-50). Higher peak flows contribute to floods which adversely affect human settlements and health. Lower minimum flows will in turn impact the use of water for power

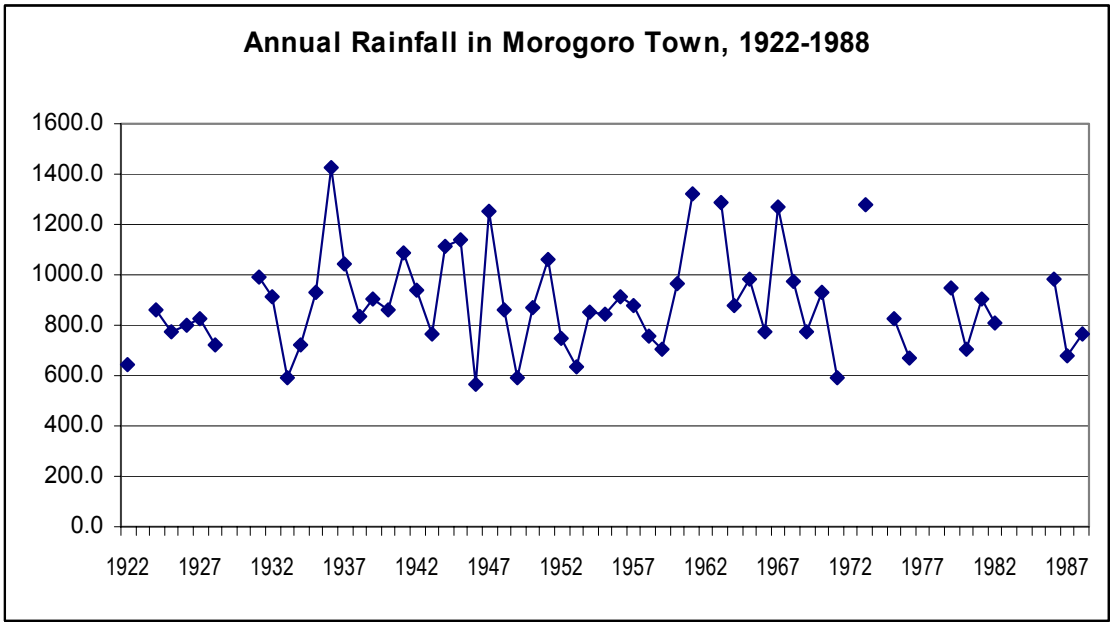
generation, irrigation and public water supply. This is of national concern as the Ruvu supplies an important proportion of water for Dar es Salaam and the power plants on the Great Ruaha, together with those on the Pangani river, provide the backbone of national hydroelectric generating capacity. Changes in rainfall and evaporation may also affect groundwater levels. Groundwater levels may increase in places where rainfall increases and soil is permeable but is likely to decrease elsewhere.

More frequent floods will destroy infrastructure, buildings and belongings in the floodplains, which in urbanised areas are often populated by poor households. For example two-thirds of Dar es Salaam's population (over two million people) are considered to live in flood-prone areas (UNEP, 2002: 241). Flooded pit latrines pollute surface waters and wells with human wastes and increase the incidence of water-borne diseases such as diarrhoea, typhoid and cholera. Moreover, warming, flooding and increased rainfall increase the spread and incidence of insect-borne diseases such as malaria. Draughts will impact all settlements, requiring more time for water collection and resulting in reduced water use. This impairs hygiene and contributes to the spreading and increased incidence of all contagious diseases. (Cairncross 2003; IPCC, 2001; Johnstone et al 2002; McMichael et al. 1996; Patz et al., 2002; cf. Rogers and Randolph, 2000)

Morogoro region lies between the central highlands and the coastal region and it will experience a mixture of above discussed climate changes and climate change impacts. The region also already experiences significant climate variability. The region has been affected by droughts about once in four years. Relatively recent droughts have occurred for example in 1999-2000, 1996-97, 1992, 1987, 1985, 1983, 1975-76 and 1971. During the worst drought years annual rainfall has been about 600 mm or 30 percent below the long term mean annual rainfall of about 890 mm (see Figure 1). Monthly rainfall has varied even more. During the twentieth century, monthly rainfall has been over three times the average one in rainy years and in dry years the monthly rainfall has been less than a third of average or there were no rainfall at all (see Figure 2).[1] It is also worth noting that shorter dry spells lasting from one to two weeks (which do not necessarily show clearly in the monthly rainfall data) during critical periods of growing season can reduce crop yields significantly (see Barron et al., 2003).

1. Northern Tanzania has bimodal rainfall and thus two growing seasons in a year. 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. Morogoro region lies between the bimodal and unimodal rainfall areas – its northern part has two rainy seasons.

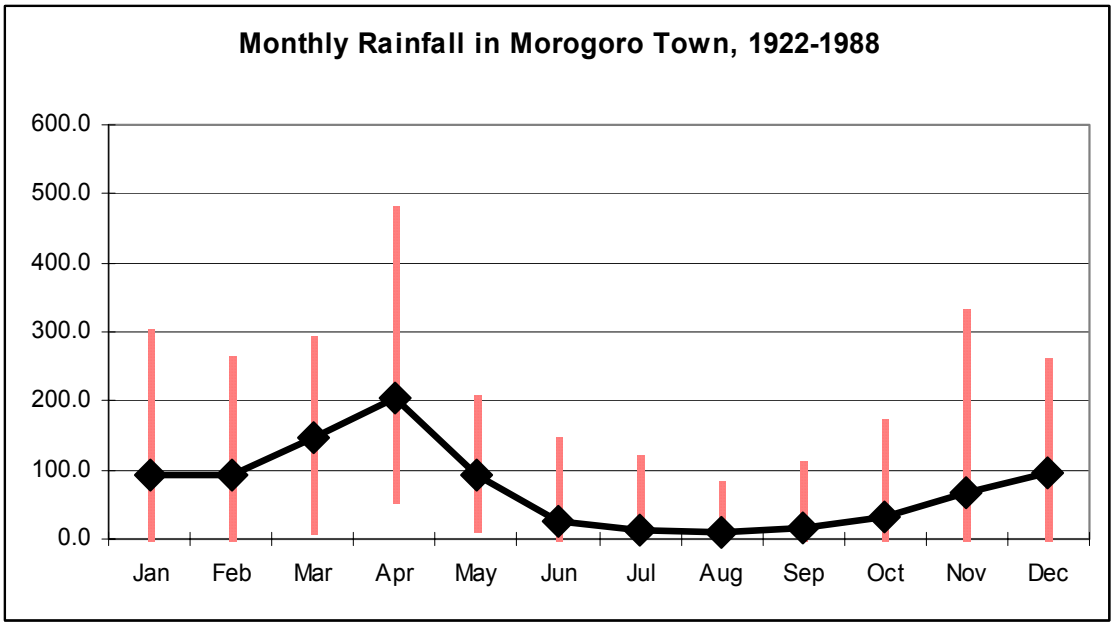
Figure 1: Annual Rainfall in Morogoro Town, 1922-1988



Wet years obviously bring the risk of flooding. Wide-spread floods occurred in Tanzania for example in 2000/01, 1997/98 and 1993. These years also brought floods to flood-prone southern parts of Morogoro region which form a part of the floodplains of the Great Ruaha and Kilombero rivers. Much of flooding is local, however. For example, the beginning of the main *Masika* rains in Spring 2004 resulted in local flooding in Magombera Village in Kilombero District, making 2600 households homeless.[2]

2. See Bilal Abdul-Aziz, 'Floods Wreak Havoc', *The Guardian*, 19 April 2004.

Figure 2: Monthly Rainfall in Morogoro 1922-1988. Points indicate average rainfall and bars minimum and maximum rainfall in each month.



The significance of present climate variability and predicted future climate changes can be judged better by contrasting them with the vulnerabilities that prevail in the region. The latter will be discussed in the next section.

3. VULNERABILITY, LIVELIHOODS AND POVERTY IN THE MOROGORO REGION

Research on adaptation to climate change frequently defines vulnerability as a function of exposure, sensitivity and adaptive capacity (Adger, 2003; Smit and Pilifosova, 2003; Yohe and Tol, 2002). The definition reminds us that people are not helpless and that they have capacity to cope with environmental stress, drawing attention to the determinants of adaptive capacity such as different types of social capital (Adger, 2003). Natural disaster literature also offers a useful definition of vulnerability. Wisner et al. (2004) define 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). This definition regards vulnerability as the absence of adaptive capacity. The natural disaster literature definition draws attention to multiple factors such as assets, sources of livelihood, class, race, ethnicity, gender and poverty which are likely to demarcate vulnerable groups. This view of vulnerability informs my analysis of responses to current climate variability in the Morogoro region.

Morogoro region lies in the south-eastern Tanzania between the central highlands and the coastal lowlands. The region's physical geography has several notable features. The Uluguru and Rubeho Mountains which lie in the region form the southern prong of the Eastern Arc Mountains – an internationally important biodiversity hotspot (see Burgess et al., 2002). Parts of the watersheds of the Great Ruaha and Rufiji rivers extend to the region's southern parts. Wami and Ruvu rivers – the latter of which is an important source of water for the three million inhabitants of Dar es Salaam – in turn have their origins in the foothills of the Uluguru Mountains. Morogoro region also hosts the Mikumi and Udzungwa National Parks and a proportion of the Selous Game Reserve. These protected areas comprise almost half of the region's land area and forest reserves make up a significant proportion of the rest (see URT 1997: 75).

Figure 3: Administrative divisions of Tanzania and Morogoro

Morogoro is one of Tanzania's largest regions with its 72 939 square kilometres. In 2002, the region had a population of 1.75 million people and a population density of 24 people per square kilometre – clearly below the average of 38 people per square kilometre for the mainland Tanzania as a whole. Two thirds of the population live in the northern districts of Mvomero, Kilosa, and Morogoro while the southern districts of Kilombero and Ulanga are less densely populated (see Table 1). Despite the relatively low population density, the large proportion of protected areas and the small proportion of arable land of the total result in significant pressure on land. Population densities can be high in settled areas. For example, the Mgeta division on the eastern side of the Uluguru mountain has a population density of 160 people per square kilometre (see Jones 2002: 1610).

Slightly over a quarter of the region's population lives in urban areas. Morogoro town is the region's administrative centre and largest city with its over 200 000 inhabitants. Its population has grown by an average of 6.5 percent in a year for the past 35 years while the average population growth for the whole region has been 2.7 percent, close to the national average. Other urban centres in the region include Kilosa, Ifakara and Kitadu. Main roads connect the region to other main urban centres such as Dar es Salaam, Dodoma, Iringa and Mbeya. However, the region's road density is only 0.05 km of road per square kilometre — half of the national average. As a result, many villages are not accessible by roads at all and for most villages access to markets is limited. Railroads provide connections from Morogoro to Dar es Salaam, Dodoma, Tabora, Kigoma and Mbeya.

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).

Agricultural and livelihood conditions are diverse. The average annual temperature in the region's highlands is 18 C but reaches 30 C in the lowland river valleys. Rainfall varies from 1200 mm in the highland plateaus to 600 mm in lowlands. The region has three agro-ecological zones. The highlands above the altitude of 600 metres are suitable for the cultivation of perennial crops such as coffee, fruits, and cocoa as well as maize and vegetables. The plateaus at the altitudes of 300-600 metres are used for growing maize, sorghum, cotton and sunflower. Finally, paddy rice, sugar cane, banana, cassava, and sweet potatoes are grown in lowlands and river valleys (see United Republic of Tanzania, 1997).

Small-scale subsistence farming forms the mainstay of agriculture. Mean household land holdings of 4.5 acres are small in the light of average household size of 4.8 persons and they are also 25 percent below the national average. While the recent Household Budget Survey found that only 5 percent of rural households are landless in Morogoro region (NBST, 2002a: 178), in places up to 40 percent of households do not own land (Ellis and Mdoe, 2003: 1375). Almost 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). About two thirds of these staples are consumed by the producing households and the rest is sold (ibid., 1377). 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 plays smaller role in the region than in the agro-pastoralist central highlands. In Morogoro cattle is kept mainly by wealthier households and by Maasai pastoralists.

Over a half of cash income in the Morogoro region is generated by agriculture and livestock husbandry. The reminder is obtained from non-farm sources such as wage income, self-employment and remittances. According to the Household Budget Survey of 2000/01, the mean monthly income in the region was 18400 Tsh. Mean urban monthly incomes of 37 400 Tsh per month (which equals to about $ 1 per day) are almost three times higher than the mean rural monthly incomes of just 13 100 Tsh. Mean urban incomes in the region are about 15 percent higher than the urban mean in the country while the mean rural incomes are slightly below national average of rural incomes (see NBST 2002a: 180).

Morogoro region has slightly less poverty than Tanzania on average (see URT 2002: 66-74). People spend about two thirds of their income on food. A fifth of households are female-headed. Almost a third of households suffer from basic needs poverty and 14 percent of households are below the food poverty line (NBST, 2002a: 180). Also the region's human development outcomes are slightly better than national ones. Adult literacy rate is nearly 90 percent in cities and 66 percent in rural areas and the total enrolment rate in primary, secondary and tertiary education was 87.2 for the whole region (see Table 2 and URT 2002:

66-74). Infant and child mortality were just below 100 and 140 per thousand live births, respectively. Almost half of child mortality is attributable to malaria. Other important causes of child mortality include acute diarrhoea (about 15 percent of deaths), injuries (about 10 percent of deaths) and malnutrition (about 5 percent of deaths) (AMMP 1997). Among adults AIDS is the leading cause of death (about 20 percent of deaths), followed by malaria (about 12 percent of deaths), diarrhoea (about 10 percent of deaths) and pulmonary TB (about 5 percent of deaths) (see AMMP 1997: 130-132). The region has the highest incidence (22.3 percent) of seroprevalence of HIV/AIDS for low-risk populations in the country (US Census Bureau, 2003).

Table 2: Social indicators for the Morogoro region and Tanzania

Indicator	Morogoro urban	Morogoro rural	Tanzania urban	Tanzania Rural
Female-headed hh.	20 %	20 %	26 %	22 %
Electricity	41 %	0 %	39 %	2 %
Adults without education	11 %	31 %	11 %	29 %
Adult literacy	88 %	66 %	88 %	67 %
Piped water supply	91 %	27 %	79 %	28 %
Expenditure on food	60 %	71 %	59 %	67 %

Source: National Bureau of Statistics Tanzania (2002a; 2002b); United Republic of Tanzania (2002, 2003).

About 40 percent of the region's urban dwellers are connected to electricity distribution network but the lack of connections in rural communities lowers the regional figure to 10 percent (NBST 2002a: 161-162). Even those households who have a connection typically use electricity only for illumination and cook with charcoal or fuel wood. Almost all urban dwellers but only a quarter of rural households are connected to a networked water supply system. The region's figures are representative of the national average, with urban dwellers enjoying somewhat higher connection rates than urbanites in other regions (NBST 2002a: 172).

Livelihoods literature (see 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 from risky agriculture are factors that create vulnerability. These factors characterise the situation of most people in the Morogoro region and demonstrate their vulnerability to current climate variability as well as to future climate change. Yet rural people are clearly more vulnerable than the urbanites. Rural incomes and consumption levels are clearly lower than urban ones and rural people also suffer from greater levels of poverty, lower human development outcomes and more limited access to markets, public utilities and public services. Female-headed households, landless households and pastoralists are more vulnerable than others because of their more limited and insecure access to resources and livelihood alternatives. The following section discusses in greater detail ways in which people have sought to deal with past and current climate variability.

4. RESPONSES TO CLIMATE VARIABILITY

People adopt and modify livelihood strategies as a response to environmental stress, of which climate variability and climate change are examples. People are often influenced by multiple stressors such as droughts and plant and livestock diseases simultaneously. This means that it is difficult to attribute specific responses to particular stressors. Yet droughts

are one of the most significant (and frequent) environmental stressors for agriculturalists and pastoralists alike in East Africa. Therefore, their livelihood strategies must be able to deal with them over longer periods of time.

Agricultural intensification (applying more inputs on units of land), agricultural extensification (bringing new units of land under cultivation), livelihood diversification (creating a portfolio of natural resource based and other livelihood activities) and migration are broad livelihood strategies (see Scoones 1998: 9) that are available for households as adaptive responses. Each of these livelihood strategies have their own logic. Intensification usually involves greater specialisation and investments which, if successful, will result in greater productivity and increased income levels. Improved income levels then provide the sought-after buffer against environmental stress. However, investments involved in intensification are themselves risky, especially in the context of pre-existing environmental risks. Extensification seeks to overcome environmental risks by low-input strategies that can increase outputs. Diversification in turn seeks to build up income streams that have different risk attributes, ensuring that some income streams remain if others diminish. Migration can in turn transform the opportunity set and its risks. Depending on the impact of livelihood activities on household assets, a distinction can also be made between accumulative, adaptive, coping and survival activities. Accumulative and adaptive activities augment or transform the asset base while coping and survival activities draw down the assets to maintain the level of consumption (Ellis, 2000).

Households in the Morogoro region have used many livelihood strategies to respond to past and current climate variability. Farmers have sought extensification by clearing forest and transforming it to agricultural land. For example, almost half of the original forest cover of 500 km^2 on the Uluguru Mountains was lost by 1955 when the forest cover was assessed to be 300 km^2. Another 40 km^2 or over 10 percent of the reminder was lost between 1955 and 1977. A recent estimate of the remaining forest cover is 230 km^2 (see Burgess et al., 2002: 144). Extension of farm land has been the primary reason for forest loss on the Uluguru Mountains. Larger patches of forest do not remain outside the forest reserves and there is thus little forest left for conversion to agricultural use (ibid.). For example, summaries of the interviews conducted by the *Uluguru Mountains Biodiversity Conservation Project* indicate that forest was cleared to obtain new agricultural land in only two villages out of eighteen surveyed ones.[3]

Extensification can also be achieved by taking fallowed land for cultivation. As land is scarce in many villages, it is either not fallowed at all or fallow periods are short. As a result, soils have become exhausted and yields have decreased (see van Donge, 1992: 80). For example, summaries of the interviews conducted by the *Uluguru Mountains Biodiversity Conservation Project* indicate that maize yields have decreased by 50-70 percent and rice yields even more in most of the surveyed villages in three decades. In a third of the eighteen covered villages land is not fallowed at all and in most others only a small proportion of land is fallowed for a year or two.[4]

Farmers also switch between crops, alter the mix of crops they grow and change the timing of planting in the light of evidence they obtain of the growing season (O'Brien et al., 2000). For example, farmers may switch from maize to sorghum and/or cassava when there is a threat of drought or food insecurity and switch to rice or banana when rainfall is abundant. Crop switching can make a difference. The average yields of maize and rice have decreased

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

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

in dry years such as 1996/97 and 1999/2000 by up to 75 percent and 50 percent, respectively. In contrast, sorghum and cassava yields have varied much less and the yield of sweet potato increased in these dry years. Rice and bananas have in turn given about 25 percent better than average yields in wet years such as 1997/98 and 2000/01 (see Table 3).

Table 3: Average crop yields per hectare in Morogoro region

	Crop yields kg per hectare in the Morogoro Region						
Crops	**94/95**	**95/96**	**96/97**	**97/98**	**98/99**	**99/00**	**00/01**
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).

O'Brien et al. (2000) found that the majority of their respondents from the Morogoro and Iringa regions used some of the strategies discussed above and below as a response to the seasonal weather forecasts of above average rains during the 1997/98 season. Also the regional agricultural statistics for Morogoro seem to substantiate that farmers do adjust their practices to cope with climate variability. The cultivated area of staple crops such as maize has decreased and that of sweet potatoes has increased in dry years (see Tables 3 and 4). Increases in the planting area of cassava in turn seem to follow years which had bad maize yields and tell of its "insurance" function at times of food insecurity (see Table 4). Farmers have also ceased to cultivate during short rains in some locations because of low and uncertain yields.

Table 4: Change in the area of cultivation from the mean in Morogoro

Crops	**94/95**	**95/96**	**96/97**	**97/98**	**98/99**	**99/00**	**00/01**
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).

Responses to climate variability also involve attempts to reduce dependence from agricultural production. In parts of Morogoro non-farm income has become consistently more important since the mid-1980s and it has compensated for the decline in farming (Ponte, 1998: 336). Many households tap natural resources in order to cater for their subsistence needs and to earn cash income. For example, forests provide timber, firewood, fruits, spices, fodder, traditional medicines and meat for subsistence needs. Moreover, trees are harvested for the production of timber and charcoal for local and more remote markets and the fuel wood obtained from the forests is used for energy-intensive production of bricks. Morogoro town's good road connections have made it one prime area for charcoal and brick production for the markets of Dar es Salaam (see Luoga et al. 2000). Monela et al. (2000) report that households in Morogoro and Dodoma regions may obtain up to 68 percent of their total income from forests. The role of natural resources was the greatest in peri-urban communities which have access to urban markets for forest products such as charcoal and firewood (cited in Morris et al., 2002: 64-65). Forest products contributed about 50 percent of total income also in the more remote communities. The results of these studies are in line with those obtained in other parts of Tanzania. For example, Meshack (2003: 9) reports that households obtain at least a third of their total income from forests in the West Usambaras in northern Tanzania. Fisheries are tapped in a similar fashion. Artesanal gold and gemstone mining have also increased in the region and offer a source of non-farm income.

People also frequently resort to migration in the Morogoro Region. Summaries of the interviews conducted by the *Uluguru Mountains Biodiversity Conservation Project* indicate that farmers frequently move temporarily from remote upland villages to locations where farming conditions are favourable or to locations which have good access to markets.[5] Moreover, young adults, especially males move from rural villages to urban settlements both within and outside the region.[6] Parents are also sending their children to cities to work for upkeep and cash income in order to reduce the number of persons they have to support with uncertain agricultural income. Finally, there are locations such as the TAZARA transport corridor which attract permanent migrants and stimulate the growth of new urban settlements.

Climate variability has also implications to pastoralists. For northern Tanzanian pastoralists such as the Maasai, Nyaturu and Barabaig, transhumance and the sale of cattle have been traditional responses to seasonal and other climatic variations. Transhumance involves regular population movements over relatively small distances which enables more extensive use of pastures and the maintenance of social links and organisation (Ndagala, 1998). The strategies of pastoralists have changed over the last few decades as a response to adverse climatic conditions, population pressure, cattle diseases, unfavourable price ratios between livestock and crops, restrictions of mobility imposed by the encroachment of sedentary agriculturalists and their relatively clearer property rights and deepening poverty in the pastoral communities. New strategies include the cultivation of staple and cash crops, long-distance relocation with cattle and migration to cities to wage employment (McCabe 2003; Ndagala, 1998).

Morogoro region has been a destination for pastoralists who have relocated as far to the south as the Lindi region and the neighbouring countries Zambia and Malawi (Mwampufe,

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

6. There are clearly fewer 15-25 year old males than females in Morogoro urban and rural and Kilosa districts. For example, in Morogoro Rural males make up only about 45 percent of 20-29 year olds while the proportions 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 ones that are available) of migration because both men and women do migrate.

1999: 7). The Maasai have been argued to have introduced up to 250 000 heads of cattle to Morogoro region by the early 1990s. Conflicts ensued in Fall 2000 when agriculturalists confiscated Maasai cattle that had strayed on and damaged their cultivations. Escalating exchange of retaliations first resulted in the killing of two Maasai tribesmen and three dozen heads of cattle. In December 2000, 35 people died in battles and 400 agriculturalists left their homes in fear of further retaliations.[7]

While the existing literature and other already available material indicate that households use a wide variety of strategies to deal with environmental stressors such as climate change, the account presented above does not provide sufficiently detailed household level information on extensification, crop switching, changes in the area of cultivations and migration. Collection of primary material would be warranted to clarify household strategies and spatial and socio-economic variations in them. Yet the foregoing observations enable the drawing of some preliminary conclusions regarding priorities in adaptation to climate change in the region. In what follows, I will discuss in greater detail the implications of the above discussed livelihood responses to adapting to climate change in the future.

5. IMPLICATIONS FOR ADAPTING TO CLIMATE CHANGE

People in the Morogoro region have lived with significant climate variability in the past and are likely to face increased climate variability and changing climate in the future. Households use a wide range of strategies as a response to current climate variability. Cultivations have been expanded, crops are chosen in the light of weather expectations, and people are increasingly growing crops for market exchange where access to markets is not a constraint. Non-farm activities are also becoming important and in places already form the main source of income for households. A wide range of natural resources are also tapped. Charcoal, timber and brick production are important sources of income and artesanal mining of gem stones and gold has increased lately. The region's farmers are also migrating temporarily to areas that provide more favourable conditions for cultivation and to locations that provide good access to markets. Pastoralists have in turn migrated to the area from the North in search of grazing land and water.

The extension of cultivations, charcoal production and timber harvesting play important roles in livelihood strategies. Extension of cultivations can augment or maintain income and consumption levels when the maintenance or improvement of soil productivity by using agricultural inputs is costly or impossible. Engagement in charcoal, timber and brick production can in turn maintain or increase levels of income and consumption and diversify the sources of income so as to reduce livelihood risks. While these strategies have been instrumental for survival they also increasingly have consequences such as soil erosion and deforestation which can undermine the possibility of using past livelihood strategies successfully in the future. At the same time people face severe income and other constraints to alter their livelihood strategies significantly. The threat of increasing vulnerability is serious when the prospect of increasing environmental stress is acknowledged.

Soil erosion has several causes which are related both to cultivation methods and the pressure for extensification. Flat cultivation is the most commonly used method of tillage in Tanzania. It involves preparing a flat seedbed by cutting and turning the soil around with a hand hoe or a plough (see Shetto 1998). It also involves burying crop and other vegetation

7. See 'Tanzania: Cattle Clash Sparks Bitter Feud', *IRIN News*, 14 December 14, 2000. In 2002 the National Defence and Security Committee identified the Morogoro region as one key destination area for illegal trade in small firearms. See 'Tanzania: Focus on Small Arms Impact and Control', *IRIN News*, 29 May, 2002.

residues or ashes when the residues are cleared by burning. This method of tillage can cause tillage erosion on steep slopes (see Kimaro et al, 2004). It also causes significant water erosion during heavy rains and exposes soil to crusting and compaction, which in turn increase runoff and reduce soil moisture. Loss of topsoil which contains most of the nutrients (see Kaihura et al, 1999) and reduced soil moisture can significantly reduce crop yields. Increased run-off also increases peak flows and flooding and reduces minimum flows and causes water scarcity during the dry seasons. Soil erosion and flow changes in turn cause siltation of watercourses.

Deforestation is a problem for several reasons. Reduced forest cover will provide reduced water retention services in the more variable climate of the future. This will contribute to increased runoff, flooding and soil erosion during rains as well as greater scarcity of water during dry seasons. The scarcity of water will be an impediment for rainfed and irrigated cultivation, livestock rearing and public water supply. Deforestation will also constrain the future use of forests as safety nets for supplementing subsistence and earning cash income. In essence, deforestation will limit livelihood strategies based on both farm and non-farming activities.

In the past several decades, the most important reason for deforestation has been the extension of cultivations, which has been driven by several factors such as the scarcity of water, loss of soil productivity and population growth. Currently charcoal production is an important contributor to deforestation because of its scale and relatively non-selective use of tree species (Monela et al., 1993). The scale of charcoal production has increased when the markets of major cities have become more easily accessible. Artesanal timber production contributes less to deforestation as it is not mechanised and uses selected tree species only.

The adverse effects of traditional farming practices and deforestation are already being felt in the region and they will become more pronounced in the future. Crop yields have already been reduced significantly. Watercourses are becoming increasingly seasonal with higher peak flows and lower mimimum flows. For example, the flow of the Great Ruaha river has ceased completely during the dry season in ten consecutive years.[8] The reasons are often argued to lie in the land cover and land and water use changes outside the Morogoro region in the Usangu wetlands and plains.[9] However, the mismanagement of reservoirs serving the hydro-electric generating plants in the upper reaches of the watershed is also implicated in the problem.[10] Flooding has also become more frequent after rains in the Morogoro town and elsewhere in the region, causing property damage and typhoid epidemics.

Farming practices and deforestation also contribute to the sedimentation of watercourses. For example, the Mindu reservoir which serves the Morogoro town is silting up because of artesanal gold mining in the vicinity of the reservoir and soil erosion further upstream in the watershed. This reduces the storage capacity of the city's public water supply system and degrades water quality. Gold mining also pollutes water with mercury and human wastes (Maganga et al, 2002: 923).[11] Farming and deforestation increase the turbidity of Ruvu river

8. 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.

9. ee Zephania Ubwani, 'Government Bars Pastoralists from Grazing in Usangu Wetlands', *The Guardian*, 18 March 2004.

10 David Anderson, Personal communication, October 1, 2004.

11. See also 'Mindu destruction setting stage for a catastrophe', *The Guardian*, 14 July 2004.

further downstream (see Ngoye and Machiwa, 2004), which reduces the quality of Dar es Salaam's water supply.

To summarise, current livelihood strategies have consequences which can aggravate vulnerability to climate variability in the future. Soil erosion and soil exhaustion will continue to burden farmers who are heavily dependent on agriculture but have too low incomes to invest in intensification. This push for diversification has few outlets because of limited access to markets and limited amount of savings available for investment. Tapping the natural resource base will continue to be an important way to augment subsistence and income levels. However, the shrinking natural resource base will have a decreasing capacity to provide safety net functions. Moreover, its reduced capacity to provide ecosystem services will increase environmental stresses such as flooding and scarcity of water with all of their direct and indirect consequences. In short, there is a danger of downward-spiralling cycle of increased environmental degradation and vulnerability which Charles Perrings (1989) has called in another context as the "optimal path to extinction".

6. CONCLUSIONS

People in the Morogoro region have lived with significant climate variability in the past and are likely to face increased climate variability and changing climate in the future. They have used a number of livelihood strategies spanning extensification, diversification and migration to deal with past climate variability. While these strategies have been instrumental for survival they also increasingly have consequences such as soil erosion and deforestation which can undermine the possibility of using past livelihood strategies successfully in the future. At the same time people face severe income and other constraints to alter their livelihood strategies significantly. The threat of increasing vulnerability is serious when the prospect of increasing environmental stress is acknowledged.

There is no single solution or measure which would resolve problems caused by responses to current climate variability and enhance adaptive capacity for the future. However, several necessary measures are evident. The package of measures has to include effective management of environmental resources such as soil, forests and water resources; promotion of increased market participation to stimulate both agricultural intensification and diversification of livelihoods away from risky agriculture, and; social programs and spending on health, education and welfare which can help to maintain and augment both physical and intangible human capital.

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 various 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 policies such as reforms in the tenure of forest resources which promote forest management and tree farming and by promotion of efficient kilns and stoves and fuel switching. Management of water resources and water quality in turn demands policies which are implemented and enforced effectively both at the national and local levels. Yet these policies will be difficult to implement because of limited government capacity to adopt and implement policies and limited capacity of households to invest in improved or new practices and activities. This is why environmental management measures need to be complemented by measures promoting market participation.

Promotion of market participation is needed because increased market participation provides incentives for agricultural intensification and diversification of livelihoods. Intensification, if successfully achieved (attempting intensification involves significant risks and failure to succeed may land farmers in a worse position than those who sought diversification), can

create buffer against and reduce risks associated with agricultural production while diversification can reduce dependence on risky agriculture. Both help to augment income levels which is in turn needed to make investments that help to reduce dependence on the natural resource base and to conserve it. 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 supportive institutional setting which guarantees the security of property rights, helps to enforce 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 physical capacity, education and skills. Health and nutrition are integral aspects of physical human capital which strongly influences 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 this kind of approach to vulnerability reduction are complementary. Focusing, say, on facilitating market participation only 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 in turn reduce the ability of environmental and human capital measures to reduce vulnerabilities. One argument in support for this sort of three-partite approach to vulnerability reduction is that it can realise synergies between adaptation to climate change and development efforts. Broad-based development which recognises the integral role of human development alongside economic development can also assist in adapting to changing climate in the future.

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