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RESEARCH FOR DEVELOPMENT (R4D) LEARNING SERIES

1



The Chinyanja Triangle in the Zambezi River Basin, Southern Africa: Status of, and Prospects for, Agriculture, Natural Resources Management and Rural Development

Tilahun Amede, Lulseged Tamene Desta, Dave Harris, Fred Kizito and Cai Xueliang

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Tilahun Amede, Lulseged Tamene Desta, Dave Harris, Fred Kizito and Cai Xueliang

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Front cover photograph: Close-up washing harvested groundnuts, Zimbabwe (credit: David Brazier/IWMI).

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SUMMARY

The Chinyanja Triangle (CT) is an area inside the Zambezi River Basin, inhabited by Chinyanja-speaking people sharing a similar history, language and culture across the dryland systems of the eastern province of Zambia, southern and central regions of Malawi and Tete Province of Mozambique. Chiefs and Chiefdoms play a critical role in decision making and influencing social relationships. The Zambezi River, which originates in the Kalene Hills in Zambia is joined by ten big tributaries from six countries, and is the major source of surface water in the triangle before emptying into the Indian Ocean. Dryland agriculture is the predominant source of livelihoods for over 90% of the rural population. This paper characterizes three distinct farming subsystems across rainfall gradients, namely maize-beans-fish, sorghum-millet-livestock and the livestock-dominated subsystem. It presents the socioeconomic characteristics, historical drivers of change, resources use and management (water, land, forestry) and the institutional disincentives affecting agricultural production and productivity in the region. The paper also attempts to identify major drivers of change, and inventorize key institutions in the region and suggests improved institutional arrangements for improving agricultural productivity, resilience and ecosystem health at farm, landscape and basin scales.



SOURCE: Cai Xueliang

1. HISTORICAL SETTING OF THE CHINYANJA TRIANGLE (CT)

Due to historical reasons, the African continent is divided into various countries without considering socioeconomic and agroecological realities. Three countries in southern Africa, namely Zambia, Malawi and Mozambique, share a common culture, heritage and language called 'Chinyanja', which is also called 'Chichewa' in Malawi. These communities are found in Makanga, Angonia, Tsangano, Zumbu, Maravia, Mautize and Chifunde districts of Tete Province, western Mozambique; in Lilongwe, Kasungu, Mchingi, Salima, Down, Chewu, Mwanza and Nkhototakota districts of Malawi and in Chipata, Katete, Petauke and Chandiza districts of eastern Zambia (Figure 1). The tribal groups of this CT are diverse and distributed across the three countries. Local chiefs in their respective countries predominantly administer them with one overall king, King Gelaundi of Zambia overseeing other chiefs in the region. The king also mediates in conflicts, facilitates social linkages, negotiates with high-level authorities and monitors yearly agricultural production of the various communities. He also organizes annual celebrations, events and rituals in June-July of each year. The government authorities of the respective countries assign the local chiefs, while the king usually endorses the choice of governments. Hence, local chiefs opt not to interfere with government policies, and sometimes align themselves with the politicians by mobilizing their communities during election times. As the president of the respective countries usually assigns them, the chiefs commonly avoid political interference. The concept of the 'Chinyanja Triangle' (CT) was created by ICRAF to serve this cohesive group with improved agricultural practices and exploit the linguistic-based collective spirit for agricultural development and economic growth given the ease of communication through traditional linkages (Sileshi Gebrehawariat, personal communication). The presence of the strong social linkages could be used as a stepping-stone to strengthen linkages among institutions at various scales and collectively address livelihood challenges.

The CT is mainly composed of the eastern Province of Zambia, southern and central regions of Malawi, and the Tete Province of Mozambique (Figure 1). The region is inhabited by the Chinyanja-speaking people, who share a similar history, language and culture. Within the CT, agriculture is the most predominant source of livelihood (Myburgh and Brown 2006). The farming system in the CT is predominantly crop production mainly comprising maize, groundnut, sorghum, and millet. Fisheries provide an important source of protein and cash income for parts of central CT, especially Malawi, which benefits from Lake Malawi, Lake Chilwa and many small dug-ponds. Crop-livestock farming is also an important production system in the region with the importance of the role of livestock for farmers' livelihoods increasing as we move southwards. In the southern parts of Tete Province, millet and sorghum production dominates though farmers

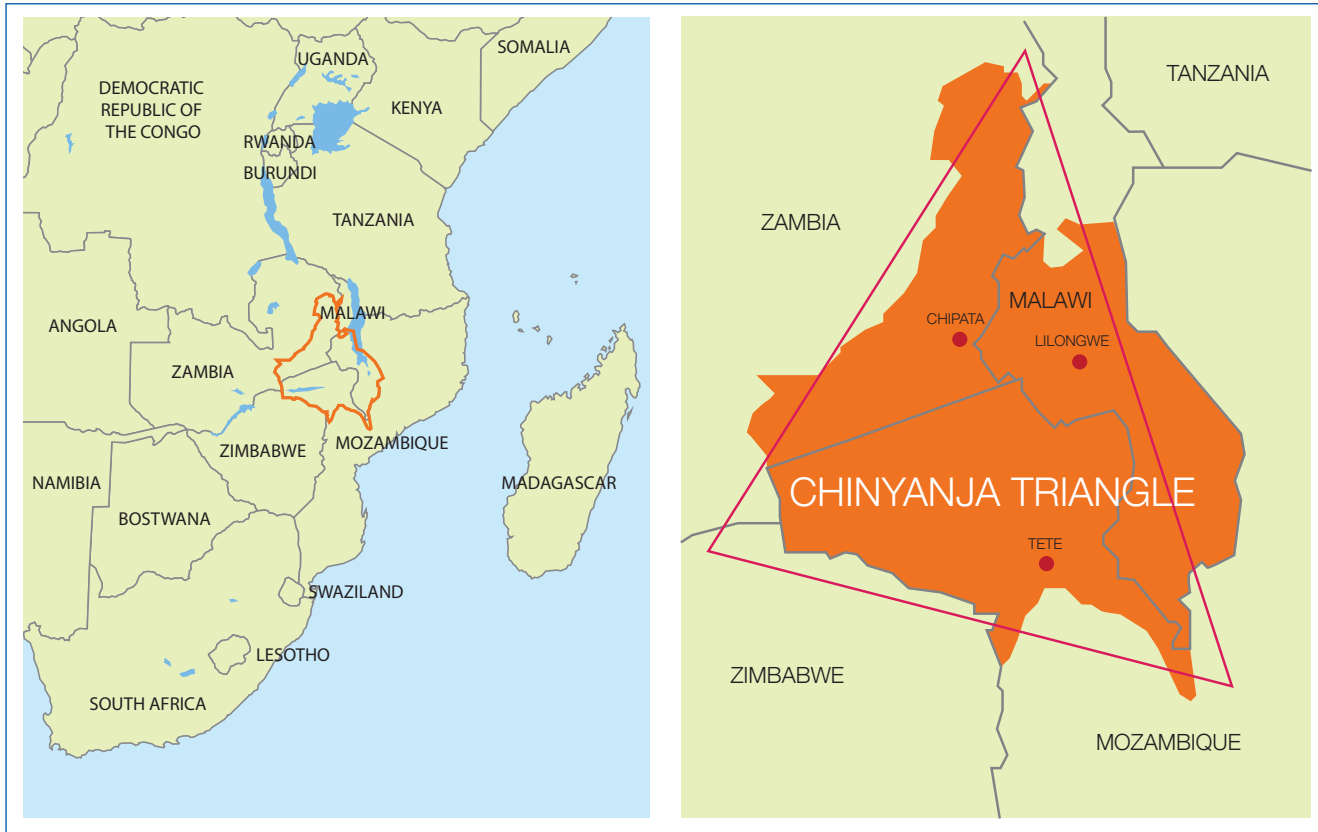
are introducing maize (despite climatic constraints) due to its higher profitability. In most of the CT, there is also an upsurge of cassava production for both food security and commercial purposes (Kambewa 2010).

Malawi is a low-income agrarian country where agriculture contributes to about 35% of the GDP, with about 53% of the population estimated to be below the poverty line. Among the rural population, about 10 to 30% of the households are food-insecure in most years with severe food deficits between October and January (NSO 2010). Female-headed households are more food-insecure than male-headed households (NSO 2010). Population is very dense, especially in central and southern Malawi, with a rapid growth rate (3.2% for 2011) and the landholding size for each of most households is less than 1 ha (Ajayi et al. 2003; Myburgh and Brown 2006). Zambia is also an agrarian country except that its economy used to be strongly supported by copper mining. Industry has still a higher share (31%) of GDP than agriculture (19%), although the poverty level is much worse in Zambia (87%) than in Malawi (<http://www.worldbank.org/en/country/zambia>), while population density is much lower than that of Malawi (16 km⁻² versus 137 km⁻²) (Krywkwow 2010). Similarly, in Mozambique about 55% of the population live below the poverty line, and about 63% live in rural areas (Krywkwow 2010). Except for recent developments in mining activities in Tete Province, agriculture is the mainstay for the majority of the population. Agriculture in Mozambique and Malawi is almost entirely dominated by smallholders while Zambia has a significant number of medium and large-scale agricultural producers.

About 91.5, 76.4 and 20% of the total land area of Malawi, Zambia and Mozambique, respectively, are within the Zambezi River Basin where the CT is located (FAO 1997). The river originates in the Kalene Hills in Zambia and is joined by ten big tributaries from Angola, Botswana, Malawi, Namibia, Democratic Republic of the Congo, and Tanzania, and flows through Mozambique before emptying into the Indian Ocean. The basin, with a catchment area of 1.39 million km² and a stream length of 2,574 km, is the fourth-largest river basin in Africa after the Congo, Nile and Niger basins. Within the basin, the river is used for irrigation but also feeds the Kariba Dam in Zimbabwe and the Cahora Bassa Dam in Mozambique, the two most important hydropower sources in southern Africa. The largest part of the Zambezi River Basin among the three countries lies within Zambia, with 574,872 km² (<http://www.fao.org/docrep/W4347E/w4347e0o.htm>). The Shire River, connecting Lake Malawi and the Zambezi River, is one of the largest tributaries and drains a large part of the triangle.

The geography of CT is heterogeneous in terms of topography, climate, policy, population density, farmholding size, and level of land degradation. Generally, the topography is characterized by a flat to a gently rolling landscape with altitudes ranging from about 137 meters above sea level

FIGURE 1. THE CT, WHICH INCLUDES CENTRAL MOZAMBIQUE, SOUTHERN AND CENTRAL PARTS OF MALAWI AND EASTERN PROVINCES OF ZAMBIA. (SOURCE: KRYWKOW 2010; ICARDA 2012).



(m asl) in valley bottoms of Tete Province to 1,300 m asl on the plateaus of Malawi (Olson 2007). Rainfall shows a high spatial gradient within the CT, where an annual precipitation of up to 1,750 mm can be recorded in central Malawi while it can reach as low as about 700 mm and below in southern parts of Tete Province.

The communities in the CT often share similar environmental challenges, such as persistent and recurrent droughts often alternating with excessive rain and floods (Kambewa 2010). Erratic rainfall and the predominantly rain-fed agriculture make the region extremely vulnerable in terms of food security. People of the triangle are among the poorest in the world with about 60–85% of rural households lacking access to food for 3 to 4 months per year (Akinnesi et al. 2006; Twomlow et al. 2008). Poor access to markets, limited institutional support, lack of investment, and overall deteriorating livelihood conditions also characterize the communities.

2. DRIVERS OF CHANGE AND DEVELOPMENT TRAJECTORIES

The southern African region has been attracting global attention in recent years due to the emerging economic opportunities, regional politics and natural disasters. Through literature reviews, a working tour and informal interactions with some of the major actors in the region, we have identified the following four drivers of change.

2.1 The mining sector

The southern African region has been recognized as one of the major global mining areas. The Zambian economy has been dependent on copper mining for the last century, with its contribution to the national economy increasing since the privatization of government-owned copper fields in the 1990s. Along with cobalt, it contributes about 64% to the national export revenue. Mining in Mozambique is relatively new due to the long civil war and the associated insecurity created in the last decade. However, an enormous reserve of coal and natural gas has recently been discovered and is beginning to be exploited. The contribution of mineral export to the total merchandise exports of Mozambique increased from 6.1 to 57% between the years 1999 and 2010 (ICMM 2012), with an expected value of USD 735 million in 2017. Most of the coal discovered was around Tete Province, within the CT, which has attracted multinational coal mining companies including Rio Tinto. Besides job opportunities, it has created market opportunities for medium and small-scale farmers. The mining sector is also boosting the economy through upgrading of the 600 km railway line (Figure 2) and improved port facilities will also bring broader economic benefits. While the small towns around the mining areas grow, the market demand for meat, vegetables, fruits and other items has increased accordingly. The increasingly expanding mining sector in the region could also create great incentives for policymakers to invest in roads and other market infrastructure. The contribution of mining to the total foreign direct investment of developing countries is usually more than 50% of the total Foreign Direct Investment

(FDI) (ICMM 2012) but we are presenting the agricultural FDI separately due to its importance as shown in Section 2.2. As the economic benefits are welcomed in the development of the mining sector, the associated environmental risks and the possible impacts on land and water remain unclear.

FIGURE 2. FACILITY FOR COAL LOADING IN TETE PROVINCE AND IMPROVED RAILWAY LINE TO FACILITATE IMPORT-EXPORT.



Source: CIAT

2.2 Foreign direct investment

Besides mining, there is an increasing impetus in foreign direct investment in agriculture, particularly in the Zambezi River Basin. Zambia and Malawi have paved the way for foreign investment by introducing the Lands Act and improving investment policies. Agricultural investment in Mozambique is on the rise, expecting to attract one billion US dollars, with Brazil being the biggest foreign investor. The availability of vast areas of land, water, power and cheap labor constitutes incentives attracting more investors to the country. Zambia has made available 1.5 million hectares (Mha) of land for FDI, while Mozambique granted concessions to investors for more than 2.5 Mha of land, only between 2004 and 2010 (The Oakland Institute 2011). The ProSavanna project in the Nicala Corridor has acquired 10 Mha of land, targeting Brazilian agribusiness companies for production and export of soybean, maize and other commodities (<http://www.grain.org/article/entries/4703-leaked-prosavanna-master-plan-confirms-worst-fears>). Moreover, Mozambique is one of the major tobacco-growing regions in the world with major players including the US-based company Mozambique Leaf Tobacco (MLT) engaging more than 200,000 farmers in outgrower schemes. Malawi earns about 70% of its foreign currency from tobacco exports. Despite the fact that these FDI are becoming controversial, it is the land governance system of the respective countries and the enforcement mechanisms that determine whether these large-scale land acquisitions turn out to be 'a land grab' or 'a development opportunity' (Cotula and Vermeulen 2009). Moreover, in various ways, these FDIs affect customary landholdings, water budgets, market linkages, ecosystem services, livelihoods, power balances between local communities and government institutions and overall socio-political relationships.

2.3 Climate and climate change

Africa in general, and the southern African Region in particular, are considered to be among the areas most vulnerable to climate variability and change, due in part to a lack of financial,

institutional and technological capacity (Eriksen et al. 2008). Long- and short-term climate data show that there was a general increase in temperature over the last 40 years (IPCC 2007), consistent with the global trend of rise in temperature. Between 1988 and 1992, over 15 drought events were reported in various areas of southern Africa, with an increase in the frequency and intensity of El Niño and La Niña episodes (IPCC 2007).

A wide variety of weather systems may bring extreme weather to the southern African region, including tropical cyclones and cut-off lows that bring widespread flooding to southern African countries, including Mozambique, Malawi and Zambia (Davis 2011) and destruction of agricultural enterprises and livelihoods. On the other hand, periods of sustained anti-cyclonic circulation and subsidence can cause the occurrence of heat waves and prolonged dry spells over the southern African region and this is expected to worsen in the future (Davis 2011).

The CT climate follows a clear rainfall gradient, with semiarid conditions in the west and humid conditions in the east (Figure 3). The rainfall gradient is also related to the topographic variation of the CT landscape. The western side has a higher elevation up to almost 3,000 m asl. This forms a leeward side for the rainfall to the west (predominantly Zambia) with accumulation of rainfall to the east side where the valley bottoms are (Malawi and Mozambique).

There are three distinct seasons in the CT; the main crop-growing season is between November and April, which is commonly warm and wet, followed by a cool dry season between May and August. September and October are considered as very hot and dry months. The amount of rainfall also varies depending on the altitude and landscape position (Figures 3 and 4). About 94% of the area receives more than 800 mm while 6% receives less than 600 mm (ICARDA 2012). There is only one cropping season per year except in areas with access to irrigation. The central, western and eastern parts of Tete Province are commonly dry, receiving rainfall ranging between 400 and 650 millimeters per year (mm.yr^{-1}). The mean temperature ranges from 15 to 48 °C depending on the season and locality, with the warmest location being Tete in Mozambique. Evapotranspiration in most of the CT commonly exceeds precipitation. In eastern Zambia, average rainfall is about 1,000 mm.yr^{-1} with about 85% of it falling in 4 months, December through March (Olson 2007). The central parts of Malawi generally receive up to 1,750 mm.yr^{-1} , one of the highest within the CT. The aridity index in the CT ranges between 0.2 and 0.65, with a higher value along the northern part of the transect (ICARDA 2012).

The drainage stream network also reveals the flow gradients from a higher elevation to the valley bottoms of the Mozambican part of the CT (Figure 4). Climate, especially rainfall, shows pronounced variability at various time scales from intra-seasonal, through interannual to decadal and multidecadal

FIGURE 3. RAINFALL MAP OF THE CT.

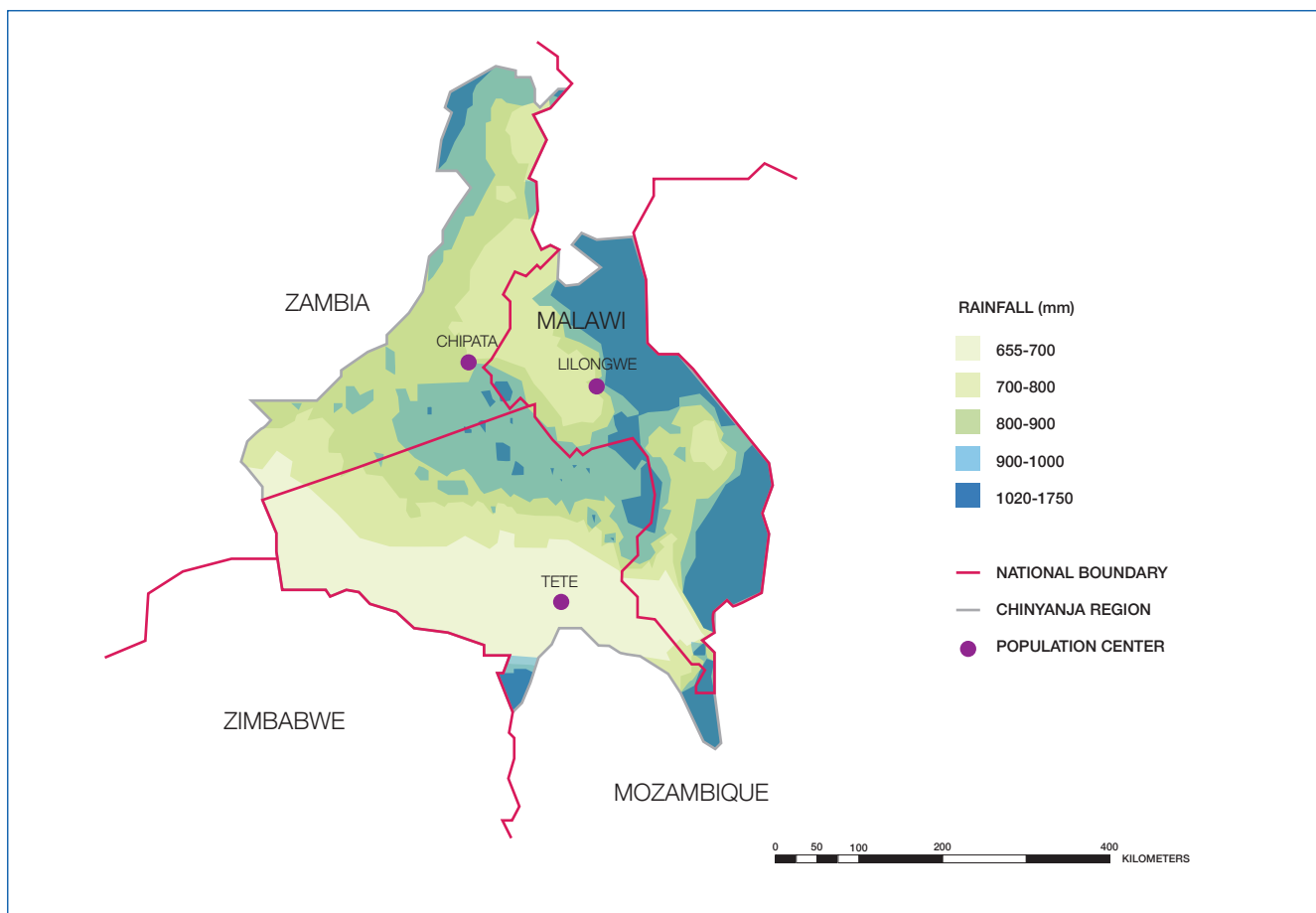
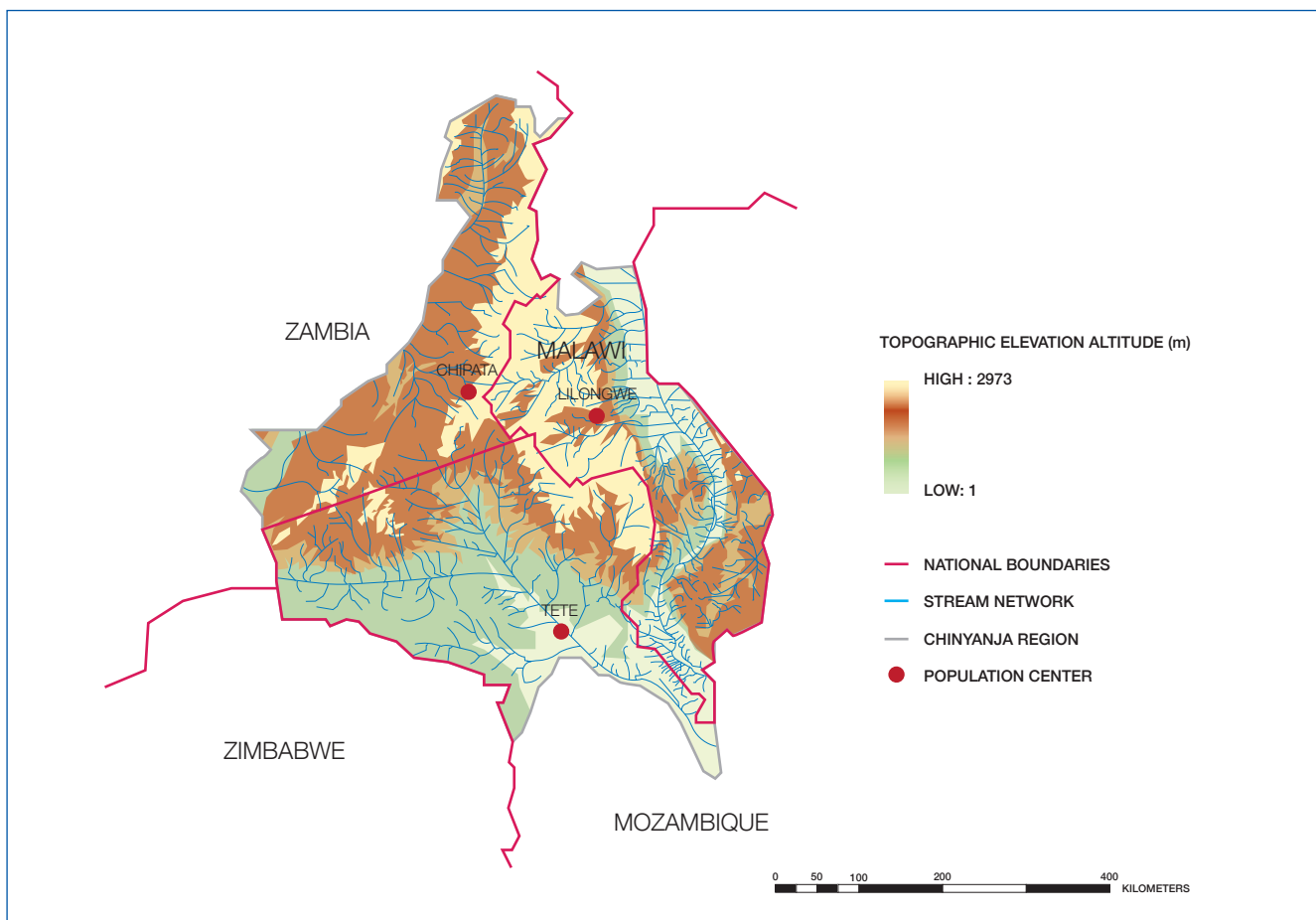


FIGURE 4. TOPOGRAPHIC RELIEF AND DRAINAGE NETWORK OF THE CT.



regimes (Kandji et al. 2006) with interannual rainfall variability reaching 40% (Figure 5). Climate variability and associated drought are the most frequently recurring causes of food insecurity in the region. Of the 24 El Niño events recorded between 1875 and 1978, 17 corresponded to rainfall decline in the region (Rasmussen 1987) and the 1991/1992 El Niño caused a serious drought, putting millions of people on the brink of famine. The recent floods in downstream parts of the Zambezi River, particularly in Malawi, Zambia and Mozambique, and mainly caused by La Niña have equally profoundly affected humans and livestock through drowning and landslides, reduction in crop production, displacement of people, and damage of assets and infrastructures (Kandji et al. 2006). Recently, in early 2013, about 200,000 people were displaced from their homes in the Mozambique lowlands by flooding.

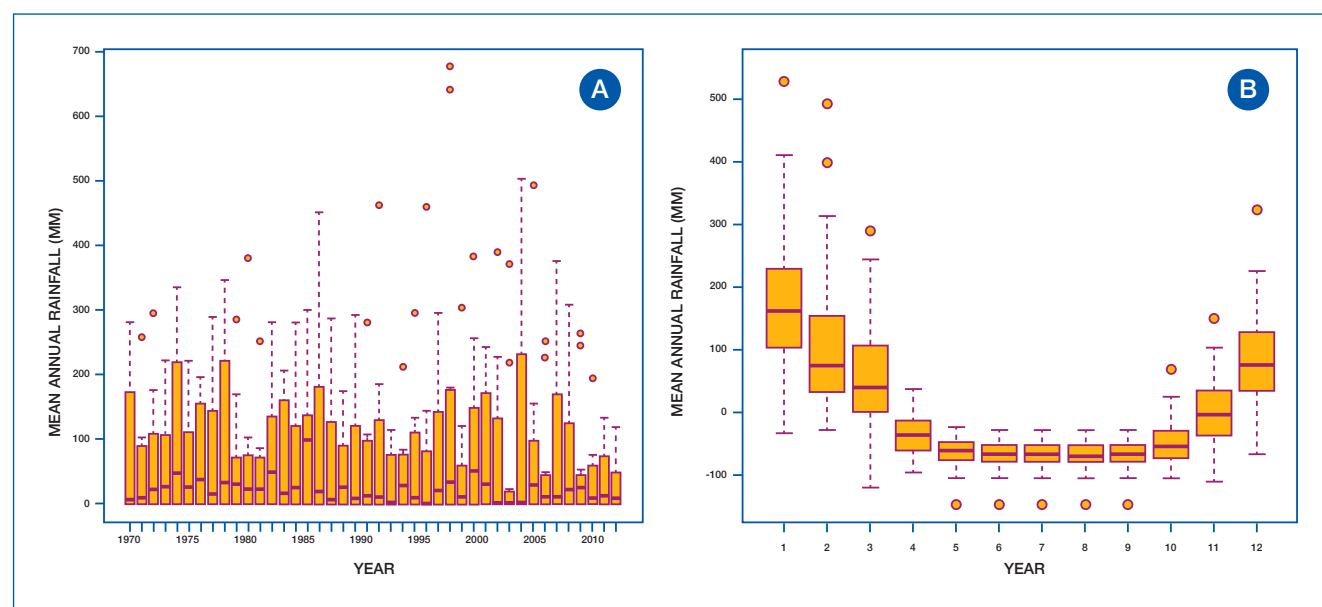
Future climate predictions indicate that the region will be hotter and drier than at present. The annual temperature is expected to increase 1.5 to 3.0 °C by 2050 compared to the 1961-1990 average (Ragab and Prudhomme 2002). The US-based National Centre for Atmospheric Research (NCAR) has predicted a dramatic warming of the Indian Ocean in the future, which implies more and more drought for southern Africa. Monsoons across southern Africa are likely to be 10 to 20% drier than the 1950-1999 average (NCAR 2005). These climatic changes are expected to have an adverse effect on agricultural production, including that of staple crops such as millet and maize, by decreasing the length of growing seasons and thereby yield potentials (Eriksen et al. 2008), resulting in a decline in land productivity and increased incidence of agricultural pests and diseases. Projected sea level rises in low-lying coastal areas in Mozambique and diminishing fisheries resources in large lakes (e.g., Lake Malawi) due to rising water temperatures are expected to further limit local food supplies and overall livelihoods. Various indigenous

and improved climate change adaptation strategies have been suggested to reduce the impacts of climate change on livelihoods and agricultural systems in the region (Davis 2011). Diversification of crop and livestock commodities and farming niches, adopting drought-resistant and short-cycle maturing crop varieties, employing improved agricultural practices and strengthening institutional capacities in climate monitoring and disaster response are among the long list of adaptation strategies. Improved land and water management across the value chain and landscape positions at basin scales would probably bring the highest benefits in terms of climate change adaption, mitigation and sustainability. However, there is very limited institutional capacity for the various adaptation strategies to be available at the farmers' field and facilitate collective action for a wider positive change.

2.4 Expanding market opportunities

As the regional economies, population and cities grow there will be an increasing pressure on the natural resources to satisfy the increasing demand for food, fiber and ecological services. Urban populations in southern Africa are growing at very fast rates due to high rates of rural-urban migration and high birthrates. For instance in Malawi, urbanization is growing at 6.3% per annum. If the current trend continues for the next two decades, there will be more urban than rural people (AfDB 2012), who would demand more high-quality crop and livestock products. This increased demand will be hard to satisfy with the existing extensive and subsistence-oriented farming systems and will likely require sustainable intensification at farm- and landscape scales. In addition, the governments in the region are slowly responding to emerging export markets, particularly to Brazil and China. For instance, one of the commodities most sought after by China is quality plywood and other forest products. In 2012, Mozambique officially exported more than 122,000 m³ of sawn wood and 322,000 m³ of logs to China, though the actual amount is

FIGURE 5. RAINFALL DEVIATION FROM THE AVERAGE FOR BALAKA RAINFALL STATION, MALAWI, CT. THE BARS DISPLAY VARIATIONS WITHIN THE MEAN DEVIATION.



thought to be about eightfold (<http://www.globaltimber.org.uk/mozambique.htm>). Besides contributing to deforestation and associated land degradation, this global trade is expected to undermine the future of local wood industries by depleting the quality forest resources within the next decade unless forest resources are regulated and sustainably managed.

3. THE FARMING SYSTEMS

The CT can be divided into three overlapping farming subsystems:

I. Maize-cassava-beans-fish-based farming subsystem.

This is a predominant subsystem in the CT area-wise, mostly located on the northern side of the Zambezi River, covering most of the districts that receive rainfall of more than 800 mm.yr⁻¹, with a growing period ranging from 140 to 160 days. In this subsystem, farmers produce maize and cassava as major crops intercropped with beans and other legumes (Figure 6a). Climbing beans are the preferred bean types. Other important crops in this system include groundnut and pigeonpea.

Fish is an important source of protein, and in many cases, of cash income for many farmers in this subsystem. Historically, Malawi has deep associations with capture fishing from Lake Malawi, Lake Chilwa and Lake Malombe (Figure 6b). The average fish consumption was 13-14 kg.person⁻¹yr⁻¹ in the 1970s but decreased to 4-7 kg. person⁻¹yr⁻¹ around 2005, mainly due to increasing population, while fish production, especially capture fish production, has remained low (Russell et al. 2008).

FIGURE 6A. MAIZE-BEAN-FISH-BASED SUBSYSTEM.



Source: ICRISAT

FIGURE 6B. SMALL-SCALE AQUACULTURE DEVELOPMENT.



Source: ICRISAT

However, aquaculture has gained recognition and has been promoted among smallholder farmers across Malawi (Russell et al. 2008). International donors and nongovernment organizations (NGOs) often aid such development through construction of farm ponds.

II. **Sorghum-Millet-Livestock subsystem.** This is predominantly in dry, semiarid environments where sorghum and millet are produced accompanied by pigeonpea and potato (Figure 6c). Livestock, particularly goats and cattle, are an integral part of this system and serve as means to overcome drought years. However, livestock markets are underdeveloped and the communities are yet to benefit to any great degree from their stocks. Drought is a common phenomenon in this subsystem, with frequent end-of-season droughts occurring. The system has high potential for production of fruits, particularly mango and citrus, which could be expanded to the wider region, capitalizing on the experiences of Mwanza District in Malawi. This system includes the semiarid districts of Makanga and Moatize in Tete Province, Katete in the eastern province of Zambia and Mwanza and Chewu districts of Malawi.

III. **Livestock-based subsystem.** This subsystem represents the driest and hottest part of the triangle with rainfall below 300 mm.yr⁻¹ and is characterized by high evapotranspiration amounting to 3 times the precipitation amount. It is predominantly covered by savannah grasses and desert bushes (Figure 6d). Some sorghum and millet are grown, but livestock dominates the livelihood

FIGURE 6C. SORGHUM-MILLET-LIVESTOCK SUBSYSTEM.



Source: ICRISAT

FIGURE 6D. LIVESTOCK-BASED SUBSYSTEM IN CT.



Source: ICRISAT

strategy. It is widely practiced in the lower basin of the Zambezi, particularly in the wider Tete Province, including the Changara, and Cahora Bassa districts that border the CT. Some pockets of Malawi and Zambia also share this subsystem.

3.1 Population density

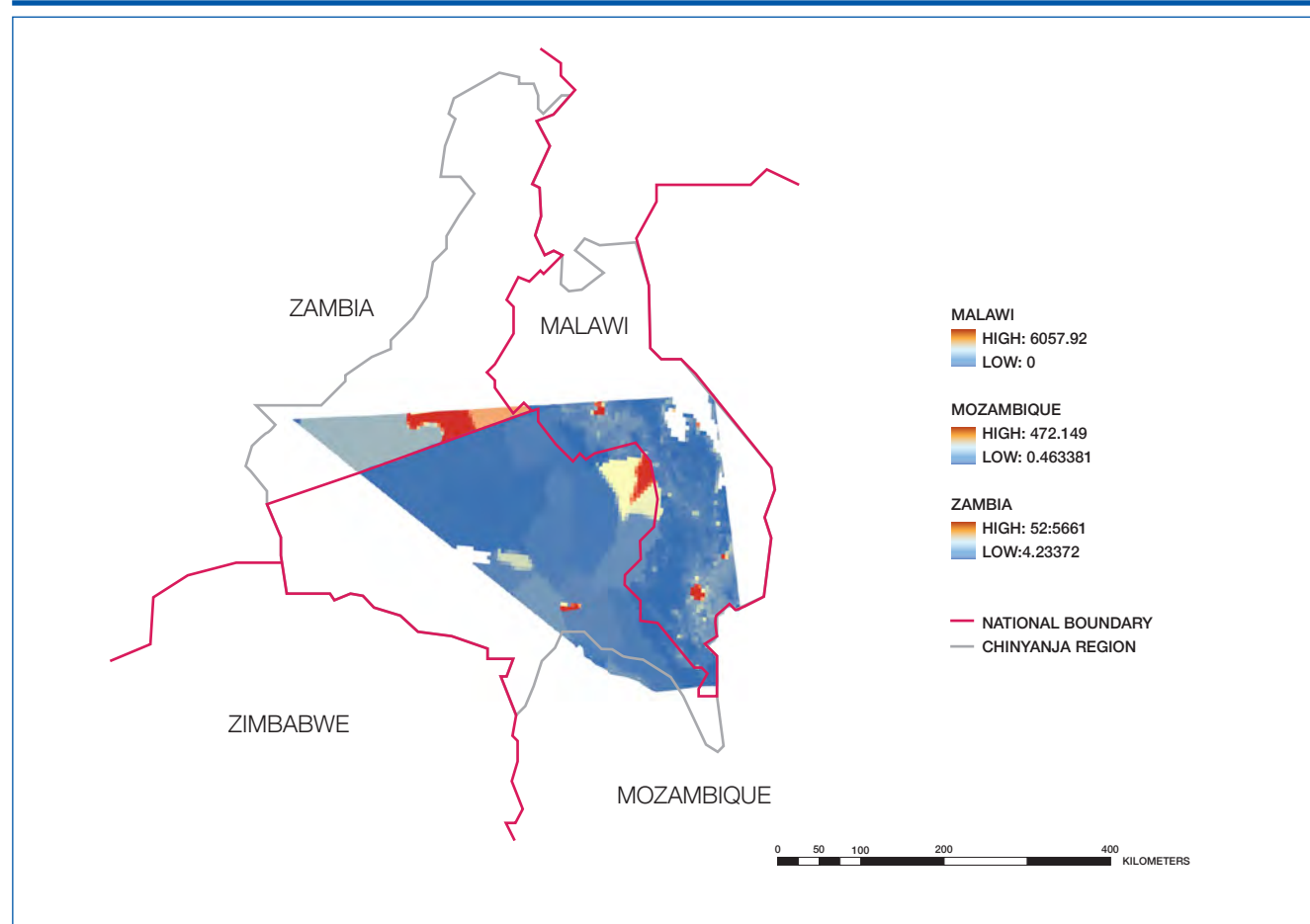
Population density is variable within the triangle, with an average of about 30, 27 and 148 persons.km⁻² in Zambia, Mozambique and Malawi, respectively, with five times more people per unit area in Malawi compared to the other two countries (<http://www.tradingeconomics.com>). The annual population growth in Malawi, Zambia and Mozambique is 3.2, 4.2 and 2.3%, respectively. The population density (Figure 7) varies due to numerous factors. Each of less than 10% of the households in Mozambique and Zambia may have up to 10 ha (World Bank 2006) particularly in the less-populated sorghum-millet-based subsystems, though part of the land is often left fallow due to lack of draft power and working labor to manage the extra fields. Some districts in Mozambique, such as Chifunde and Zumbu, have a very low population density. Though Malawi's fertility rate of 6.7 births.woman⁻¹ in the period 1990-1992 has dropped to 6.3 births.woman⁻¹ in 1998-2000, it still remains one of the highest in the world (FAO Aquastat 2006). Mean landholding in Malawi varies from 0.5 ha in the south to 1.5 ha in central and larger plots in the northern part of the country. The average landholding per household in Zambia and Mozambique is

2.0 ha (Kambewa 2010). The southern part of Malawi, which is part of the CT, has the highest population density (FAO 2006) that is associated with a reduction of the already small landholdings to about a hectare per household. The small size of the farm is commonly mentioned as one of the major causes of food insecurity in Malawi. The implication is that Malawi has to produce more agricultural products per unit of land and water to feed its growing population. Moreover, the region is becoming increasingly characterized by larger numbers of young and increasingly educated 'farmers', with women taking more roles in farming activities. Migration to cities and abroad, particularly to South Africa is apparent and is likely to broaden the income portfolio (via remittances, etc.) of many rural households.

3.2 Agricultural production and productivity in the CT

Although agriculture has been growing at a faster rate globally in the last decade, the region is still one of the most food-insecure parts of southern Africa, where food shortages are common, with food aid being the major coping strategy to feed people during the months when hunger is at its worst. For instance Malawi, which was a net exporter of maize just a few years ago, has seen stocks depleted to a quarter of its annual average after the worst harvest of 2012/13 in 7 years. Meanwhile, maize prices have more than doubled over the past year (<https://www.gov.uk/government/news/southern-africa-facing-disaster-as-food-crisis-looms>). Food insecurity

FIGURE 7. POPULATION DENSITY IN THE CT (DATA SOURCES: CIESIN AND CIAT 2005).



in the region is generally caused by low and stagnant agricultural productivity as expressed by low crop yields (Table 1; Figure 8) and rural poverty. For instance, about 55% of average smallholders in Malawi have farm sizes below 1.0 ha with 25% of them having an average size of only 0.25 ha (Dorward 1999), which is becoming increasingly difficult to satisfy their basic household food requirements with the existing low-input, low-output production practices. Food production on such small plots commonly covers only about 6 to 9 months of the household food demand per year, and varies with weather conditions (drought or wet years). During the rest of the year, smallholder farmers have to depend on off-farm activities to raise the necessary cash for their food supply or rely on food aid. Some communities, particularly in the sorghum-millet-based and livestock-based systems are also selling their livestock, particularly goats, to cover the food-deficit periods. Recent government initiatives for improving food security and tackling poverty have shown mixed results, though the potential effects of these policies on rural livelihoods are yet to be evaluated. For instance, land tenure policies in Mozambique are ranked as one of the major concerns of farmers affecting long-term investments (Amede 2013, unpublished data), while the fertilizer subsidy program of Malawi was instrumental in improving food security and access of rural families by substantially increasing maize yield.

The maize-cassava-beans subsystem is the major source of the staple foods of the region (Madamombe 2006). The major food crops grown in this subsystem are mainly rain-fed, commonly planted at the start of the rains from late October to early December, while a few farmers grow dry-season irrigated crops using surface water, planted at the end of the rainy season from March to September. The most important food crops in the CT are maize and cassava, though sorghum, millet, beans, sweet potato, Irish potato,

groundnut and pigeonpea also contribute to the household food supply. Cotton, tea, macadamia nuts, and tobacco are grown as cash crops. About 55, 54 and 22% of the daily calorie intake in Malawi, Zambia and Mozambique, respectively, stems from maize, while about 6, 12 and 33%, respectively, of the calories in these same countries is obtained from cassava (Haggblade et al. 2009). Maize generally accounts for 60-70% of the total cropped area in Zambia and for over 90% of the total cereal production (Mukunda and Moono 1999) and the production trend has not changed much over the last decade. Crop yield is generally low and below global averages as is the case in most SSA countries, with very small productivity differences among the three countries (Table 1). In general, productivity is the highest in Malawi, followed by Zambia. Despite the availability of virgin land, yield is generally low in Mozambique mainly due to poor agronomic practices. For instance, very low plant population density of maize in farmers' fields, which could be as low as 40% of the recommended density, reduces yield significantly (Amede 1995).

Eastern Zambia and southern and central Mozambique are the maize belts of the region. There is also a general trend that while most of the Mozambican coastal districts are predominantly cassava belts, Tete (particularly Angonia District) is mostly considered a maize belt. The maize belt refers to areas where farmers plant more than three times as much area in maize as other crops. Tobacco in Malawi and Mozambique and cotton in Zambia are the major cash crops. Fertilizer subsidies in Malawi in the last decade have increased maize yield of medium and large-scale farmers substantially from about 1.7 tonnes.ha⁻¹ in the 2000 to about 4 tonnes.ha⁻¹ in 2010 (USAID 2013). However, the production gain has been lost in recent years after the subsidies were removed by the respective governments (Dias 2013). Tobacco production in Mozambique has grown

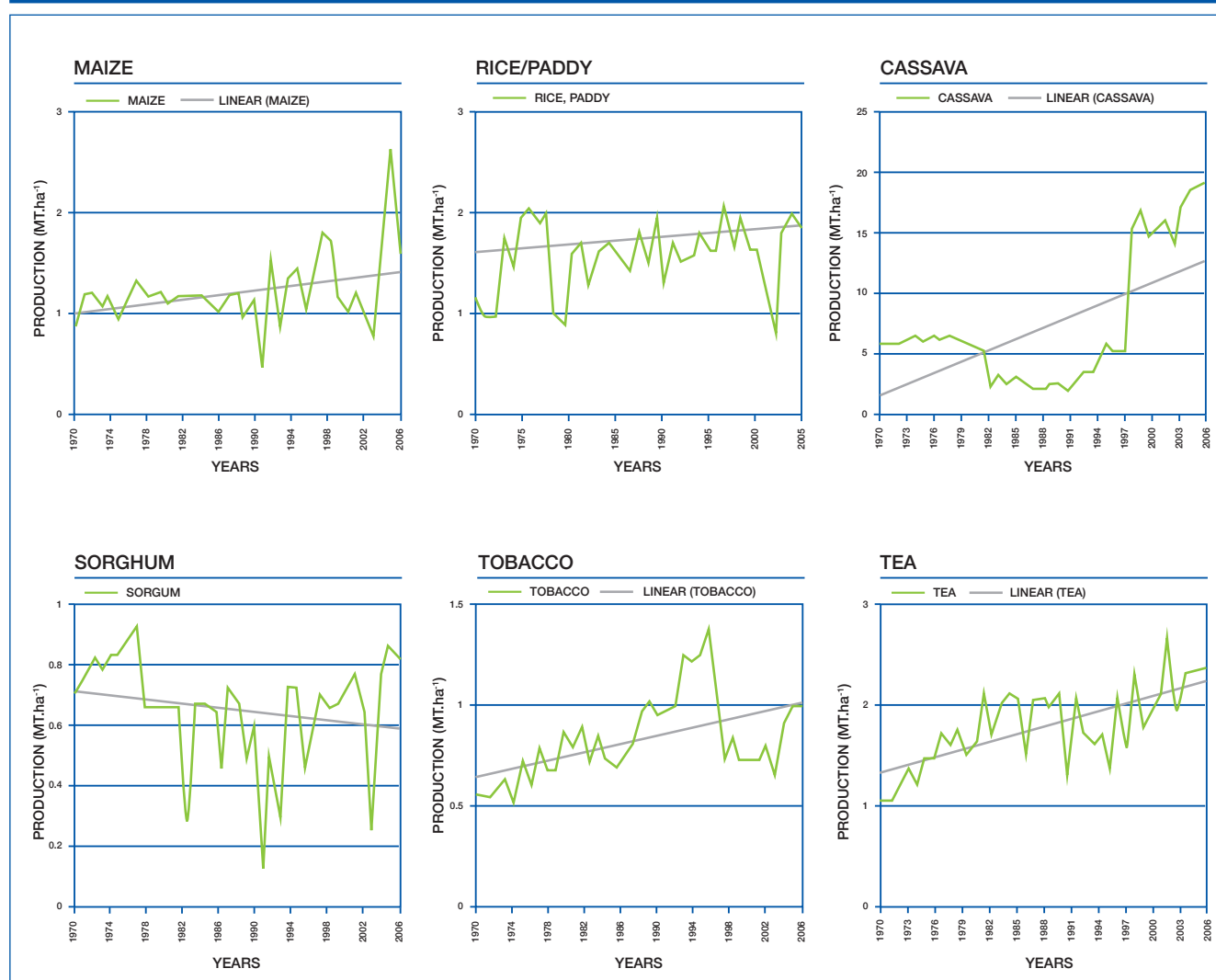
TABLE 1. YIELDS OF VARIOUS CROPS IN ZAMBIA, MALAWI AND MOZAMBIQUE.

CROP TYPE	YIELD, TONNES.HA ⁻¹			
	Zambia ³	Malawi ²	Mozambique ¹	Global average ⁴
Maize	1.38	1.70	0.9	4.91
Sorghum	0.60	1.28	0.4	1.51
Millet	0.85	1.20	0.53	ND
Cassava	5.80	5.13	6.0	ND
Beans	ND	1.15	0.5	0.70
Cotton	0.9	ND	0.5	0.77
Rice	1.12	2.41	1.0	4.43
Ground nut	0.55	1.27	ND	1.79
Pigeonpea	ND	1.41	ND	0.80

¹World Bank 2006; ²NSO 2010; ³Calculated from Chapato 2010; MoAFS 2011; ⁴USDA 2013.

Note: ND – no data.

FIGURE 8. PRODUCTIVITY TREND OF THE MAIN AGRICULTURAL CROPS IN MALAWI, 1970 – 2006 (MOAFS 2011). MT DENOTES MILLION TONNES.



from 1,500 tonnes in 1997 to 50,000 tonnes in 2004 (World Bank 2006). The number of households growing tobacco in Mozambique has also increased to more than 130,000 (Dias 2013), with most of the growth being recorded in the CT.

Moreover, yields of both maize and cassava have increased in the region in recent years (Figure 8), with maize increasing by about 25% in the three countries over the last decade. Cassava yields have increased even more steadily; outputs have roughly doubled since the mid-1990s (Figure 8; Hagglblade et al. 2009). In Malawi, cassava production expanded more than ninefold from the mid-1990s to 2007, surpassing all the other food crops (Kambewa 2010). There are several reasons for the wider expansion of cassava (Hagglblade et al. 2009). The successful control of cassava mealy bug in the three countries has increased yield and productivity considerably. The increasingly active cassava breeding programs of IITA in the region may have also contributed to increased productivity, despite frequent climatic shocks. Moreover, abolishing input subsidies (fertilizer and hybrid seeds) for maize in Malawi and Zambia have forced farmers to diversify their farming and opt for root crops, primarily cassava.

Despite the increase in the production of these two staple crops, and informal cross-country trade, there have been recurrent food deficits in the CT, exposing people to hunger and migration in desperation, though the food gap has varied from country to country and from year to year. Although various reasons have been given for food insecurity in the region, the major problems could be the following:

- Most farmers have been practicing low-input low-output (low-risk) agriculture, with very low land, water and labor productivity. Crop yields are very low, even compared to the SSA average, despite attempts to increase productivity in the last decade.
- Fallowing, the traditional method for maintaining soil fertility is almost non-existent in most of Malawi given land scarcity and high population pressure. Increased demand for land has also reduced fallow periods in other parts of the CT.
- Fertilizer subsidies were making a huge difference in terms of food security in the region. In 2006–2007, Malawi improved maize yields significantly (Figure 8)

and even became an exporter of maize. Other African governments were interested in copying the 'Malawi green revolution' but enthusiasm quickly waned when the direct financial support of donors to the Ministry of Agriculture and farmer organizations dwindled and the government removed fertilizer subsidies. Moreover, investing in fertilizers and seeds alone will not solve the food crisis in the long term unless the parallel investment in complementary services, including market infrastructure and marketing system are established that will allow producers to connect to the wider markets.

- d. Recurrent drought has been a major cause of food insecurity in the region, with particular significance in years such as 2002. On the other hand, there are huge opportunities for developing small-scale irrigation in the Zambezi River Basin using surface water, groundwater and small reservoirs. It is only in Mozambique that the irrigation potential within the Zambezi River Basin is estimated to be about 1.7 Mha of land (FAO 1997). To date, primarily medium- and large-scale farmers growing commercial crops have invested in small-scale irrigation. Both surface water and groundwater irrigation could be the farming of the future, particularly in the Mozambique and Zambian side of the CT given the large areas of farmland suitable for irrigation. However, this potential could be exploited only if policy incentives are in place that would improve access to water, reduce irrigation cost and increase farm returns.
- e. The extension systems vary within the triangle but are generally weak and disorganized in terms of reach and effective service supply. There are relatively strong extension support services to farmers in Malawi compared to those communities from Mozambique or Zambia.

Livestock is an integral part of farming systems, particularly in the sorghum-millet and livestock-based subsystems of the CT. The savannah pasturelands of the CT support a large number of animals, mainly cattle and goats that represent an important livelihood strategy given the high risk of crop production due to the relatively low and unreliable rains and high evapotranspiration rates. For instance, Tete has about 251,000 head of cattle and 243,000 head of goats, which is 20 and 8% of the total number of cattle and goats, respectively, in Mozambique (FAO/WFP 2010). In Muchamba, Tete livestock provided 45% of the families' income for the poorest and nearly 60% for the better-off households (World Bank 2006). On the other hand, the areas in maize-cassava-beans subsystems keep some livestock mainly for draft power, sale in times of need and as a reserve for bad times. There has been a significant increase in the number of livestock in Mozambique (by 28%) between 1999 and 2009, following recovery from the long war. Poultry has also been growing at a rate of 52%.yr⁻¹ for five consecutive years, facilitated by government policy

for import replacement (FAO/WFP 2010). In Malawi, 57% of the households owned or kept livestock or poultry, with male-headed household sowing more than female-headed households. In general, households in the CT are more likely to have kept fewer livestock than those in the other African dryland systems, partly due to resource scarcity (NSO 2010). In general, the very poor households commonly keep some chicken and pigs, while those with a medium resource status can add goats and a few cattle. The better-off households can afford dozens of cattle and goats and large numbers of chicken (Amede 2013, unpublished).

Several factors undermine the potential contribution of the livestock systems to rural livelihoods, among which livestock mortality is the main one. Mortality is commonly caused by feed shortages during drought years, lack of drinking water and the prevalence of animal diseases. Newcastle disease in poultry, African swine fever in pigs and Trypanosomiasis in cattle are the most prevalent livestock diseases in the region (World Bank 2006). These diseases commonly cause mortality and also decrease meat and milk productivity, reduce animal traction power and affect the overall productivity and profitability of the livestock systems. Theft is another disincentive for livestock keepers in the CT. In Mozambique, about 17% of the households had experienced theft of livestock during the period of 2002 and 2007 (NSO 2010).

There is also an increasing trend of conflict between livestock keepers and crop producers, particularly in sorghum-millet-based subsystems, concerning access to pastureland and watering points, which is getting worse in seasons of drought and feed scarcity. In general, the livestock sector has a huge potential for growth to improve the livelihoods of rural communities in the region. However, the sector is receiving only limited policy attention in terms of access to markets, veterinary services, watering points, household credit and overall marketing and processing infrastructure. On the other hand, there is an increasing opportunity to invest in livestock systems due to increasing demand for livestock products to feed the growing middle class population, particularly in towns like Tete and the surrounding areas, where mining has become a major economic activity.

4. NATURAL RESOURCES BASE IN THE C-TRIANGLE

4.1 Soil fertility status and management

Soil fertility status in the CT varies across the three subsystems depending on the landscape position, agroecology, parent material and production practices. Two soil types dominate most of the region, namely the eutric leptosols in the relatively higher altitudes and the alluvial lixosols in the flat plains and valley bottoms. Also, orthic ferralsols, with highly decomposed organic matter and buried genetic horizons, are found in 18% of the CT, mainly around Lake Malawi and

Lake Nyanza, while chromic luvisols occupy about 12% of the CT (ICARDA 2012).

The soils in the high rainfall zones have an inherent low soil-fertility status primarily due to low pH and associated acidity, aluminum toxicity and phosphorus fixation. This problem is severe in eastern Zambia and the hillsides of Malawi as well as in some parts of the Angonia, Macanga and Tsangano districts of Mozambique, where rainfall amount is high, causing high nutrient leaching and an overall nutrient imbalance in the root zone. In Malawi, the over-cultivated sand soils of the Kasungu and the southwest Mzimba plains and the most productive latosols of the Lilongwe-Mchinji plain are showing increasing acidity, nutrient depletion and limited response to application of chemical fertilizers (Saka et al. 1999).

The soils in the drier sorghum-millet-livestock subsystems of the CT present different sets of challenges. Besides decline in nutrient status, they are mostly sodic or saline due to high evapotranspiration rates with limited rainfall to wash down the salts from the root zones. For instance, the Gwembe and Luangwa valleys in Zambia and Moatize in Mozambique have a considerable salt occurrence with the exchangeable sodium percentages in the subsoils usually exceeding 15% (Mukanda and Moono 1999).

One of the major reasons for low agricultural productivity is land degradation and the associated decline in soil fertility (Nabhan et al. 1999). Both human and natural agents have caused nutrient depletion. The farming system used to rely on long-term fallows and slash-and-burn practices to maintain soil fertility and crop productivity. Farmers used to practice *Chitemene*, a shifting cultivation system with fallows as long as 10 to 15 years (Mukanda and Moono 1999; Saka et al. 1999). Increasing pressure from growing human and animal populations in search of additional farmland and grazing areas and increasing demand for charcoal and fuelwood have accelerated deforestation and land degradation. Deforestation has been increasing at an alarming rate, particularly in the last two decades (PFAP II 2005), aggravated by an aggressive expansion of tobacco in the region, particularly in Malawi and Mozambique.

The major natural cause of nutrient removal in high rainfall areas is soil erosion, which has been aggravated by forest clearing, limited investments in soil and water management and lack of institutional arrangements for watershed management. The soils are also mostly unstable, fragile and erosion-prone. Water erosion is considered to be the major source of land degradation in Malawi, with nutrient losses estimated to be 74, 5.5 and 539 kg.ha⁻¹yr⁻¹ of N, P and organic carbon, respectively, with the cost of N and P losses estimated as fertilizer values to be over USD 300 million.yr⁻¹ (Saka et al. 1995), at fertilizer prices prevailing in the 1990s. A recent study by Nakhumwa (2004) showed that the severity of soil erosion and its increasing trend result

in gross annual losses of USD 6.6 – 19.0 million. The most severe degradation and its associated impacts are occurring in the densely populated southern region of Malawi (World Bank 1992; Halle and Burgess 2006). Besides its impact on soil nutrients and food production, erosion is also having a huge negative impact on the hydroelectric supply of Malawi due to siltation. For instance, dredging of some of the hydroelectric power in the Shire Basin costs about USD 3 million (Shela 2000). In addition, ESCOM (the Malawi power supply authority) loses over USD 1.1 million.yr⁻¹ in “lost revenue” due to power outages caused by silt, weeds and trash related to land degradation (GEF 2010). Due to these challenges, the Shire Basin has recurrently been identified as an area of national priority for agricultural development and power generation (World Bank 2013). In Mozambique, the average nutrient losses from agricultural fields are estimated to be 34.1, 6.1 and 24.6 kg.ha⁻¹yr⁻¹ of N, P, K, respectively (Folmer et al. 1998), which is threatening agricultural production given the very low current application rates of chemical fertilizers used by farmers. This value could be even higher in the mountainous parts of the CT, where rainfall is higher, erosion is more severe and farmers rarely adopt soil and water conservation practices. The nutrient loss is aggravated by limited application of organic residues (particularly in the drier middle altitude plateau) because of the view of farmers that the weather is not conducive to fast biomass decomposition (Amede, 2013, unpublished). Even in communities with experience in the use of organic manure, organic fertilizer was applied only on 35% of the plots once, and on only 5% of the plots twice, while 60% of the maize plots did not receive any organic fertilizer (NSO 2010). However, there is an increasing trend of applying crop residue in farms in recent years, particularly in the wetter agroecological zones, though the biomass used is commonly low-quality maize stover and the quantity is often not sufficient.

Relative to its neighbors, Malawi and Tanzania, Mozambique does not have a long history of its government promoting the adoption of inorganic fertilizer by smallholder farmers (Benson et al. 2012). The total amount of fertilizer used in Mozambique was estimated at 51,400 metric tons, and 90% of this fertilizer was applied to tobacco and sugarcane (Benson et al. 2012). Farmers are reluctant to apply chemical fertilizers for food crops due to high fertilizer costs, which are higher in Mozambique relative to costs in other coastal countries in Africa. Most importantly, there is limited market regulation to ensure quality of inputs. There is a general concern that the chemical fertilizers available in the stores could be easily adulterated. There is also lack of expert knowledge about what type of fertilizer mix would best fit where within the different agroecological zones. For instance, ammonium sulfate could aggravate acidity if applied in soils with low pH while it could be appropriate in saline or sodic soils. Moreover, the major fertilizer inputs that have been applied in the respective countries are predominantly nitrogen and phosphorus, creating long-term nutrient

imbalances. Costly ameliorative measures such as liming and corrective fertilizer compounds are currently in demand though small-scale farmers could not easily cover the costs of these measures. The implication is that application of the conventional fertilizers may not necessarily improve crop yield unless accompanied by supplementary plant nutrients as well as expert advice on the appropriateness of fertilizer use on a case-by-case basis.

The farming practices have also been affecting soil fertility status. Land management practices vary from country to country in the CT. Following the colonial government, soil conservation policies and the legacy of the first Malawian President Mr. Kamuzu Banda, soil conservation ridges became part of the Malawian agricultural system. This practice has been similarly adopted in eastern Zambia, which shared colonial rules. However, the difference in land management between Malawi and Mozambique is very clear across the border, whereby the concept of soil conservation and fertilizer use rarely crossed borders beyond Malawi.

The high-value market crops are strongly competing with food crops for fertile land, labor and other inputs, which could affect the volume and quality of food production. As indicated above, in section 4.1, farmers have been allocating virgin land for tobacco production, a crop known for its high nutrient demand, due to the high returns of tobacco leaves per unit of investment compared to food crops. The relatively resource-rich farmers are usually the ones growing tobacco and allocate the highest share of the available resources of labor and fertilizer for tobacco farming, commonly at the expense of other food crops. Tobacco growers have been opening up new land in search of fertile land, with an aggressive expansion in Mozambique in the last 10 years. Moreover, tobacco-curing requires a lot of biomass, causing the cutting of trees and disturbing environmental goods and services. It should be noted that most of the tobacco companies with leaf operations (e.g., Mozambique Leaf Tobacco, MLT) work closely with their contracted farmers to ensure that appropriate soil fertility management practices are used by providing fertilizer inputs on a credit basis and associated technical support. It is only better-affording tobacco farmers, who receive technical assistance and inputs, including seeds and fertilizers. Moreover, the governments in the respective countries have popularized maize production since independence to the point that monocropping of maize has become the norm in some areas of the CT, which has resulted in further decline of soil fertility and overall soil degradation (Mukanda and Moono 1999). Monocropping usually causes nutrient mining from the same soil horizon and aggravates soil erosion.

There is very little literature on the socioeconomic aspects of soil fertility management in the CT. One of the very few studies conducted (Njuki et al. 2008) reported that three major soil fertility management interventions have been adopted in the CT, namely application of inorganic fertilizers, early planting

and incorporating crop residues into the soil, with about 48% of the farmers practicing these technologies in Malawi. In Zambia, they found that crop rotation and manure are the most commonly used soil fertility management options, with 86 and 47% farmers using them, respectively. On the other hand, in Tete, 85% of the farmers leave crop residue in their farms while fewer than 50% practiced early planting. Fewer than 5% of the farmers use inorganic fertilizers (FAO/WFP 2010).

Crop returns from application of fertilizers and adoption of the abovementioned technologies in Malawi and Zambia have been very low and disappointing, discouraging farmers from purchasing fertilizers. Njuki et al. (2008) reported that input distribution alone would not improve agricultural productivity; communities with stronger bridging and linked social capital have significantly higher adoption and dissemination of these technologies than other communities. Proactive social capital was found to be strongly correlated with adoption of soil fertility management options.

In fact, in a recent review done by the International Food Policy Research Institute (IFPRI) on the rate of returns from agriculture-related investments in the region, fertilizer returns did not make it to the list of priorities, while improved crop varieties had a return of 35 to 70% (Alston et al. 2000). Chapato (2010) has even boldly concluded that fertilizer subsidies both in input and output markets in the region are unsustainable as they may create market distortions. However, the low returns could be also due to other yield-limiting factors. Low soil-water-holding capacity accompanied by high evapotranspiration could reduce nutrient uptake and yield. In some soils, e.g., the calcareous savanna soils, the most important yield determinants could be micronutrients (e.g., zinc) while in the high rainfall areas aluminum toxicity and P-fixation are to be expected. Moreover, the drier parts of the CT experience recurrent soil water deficits that reduce crop yields, when the drought period coincides with the flowering (maize) and key tuber extension (root crops) periods.

4.2 Agricultural water management

Despite being in the catchment one of the most water-abundant tributaries of the Zambezi River Basin, agriculture in Chinyanja is mainly rain-fed, with irrigated agriculture contributing to less than 10% of the produce (FAO 1997). The unpredictable climate of the CT means that the risk of crop loss in rain-fed agriculture exceeds 50% and can reach up to 75% in the drier southeastern zones of the CT, including most parts of Tete. On the other hand, the western and northern parts of the triangle have more appropriate conditions for rain-fed agriculture, where the probability of good harvests during the wet season is 70-95% (FAO Aquastat 2006).

Irrigation development is considered as a strategy for poor small-scale farmers to get out of poverty by shifting towards market-oriented agriculture (FAO 1997). Higher-value crops

are grown in the valley bottoms mainly under irrigation or the dambo (wetland) system. In the dambo system, crops use residual moisture along with some supplementary irrigation to ensure adequate water supply during the growing period. Farmers also practice spate irrigation, furrow irrigation and in a few cases motorized pumps to deliver water to fields. The relatively higher-income and middle-income farmers are commonly the ones using motorized pumps while the low-income farmers predominantly use furrow irrigation or manual treadle pumps to transfer water from small springs. The food crops commonly grown under irrigation include maize, rice, sweet potatoes, Irish potatoes, beans, leafy vegetables, tomatoes and onions. This is also where most farmers use external inputs (fertilizers and pesticides), particularly for growing cash crops such as tobacco and cotton. Most farmers have agricultural land to grow food crops and a few cash crops but not everyone has a garden area because of limited access to irrigation water.

Malawi's renewable water resource is estimated to be 17.28 km³yr⁻¹, of which about 16.14 km³yr⁻¹ are produced internally, drained from the rivers within the country (FAO Aquastat 2006). About 91% of the country is within the Zambezi River Basin, over 90% formed by the Shire Basin. According to the Department of Irrigation in Malawi, the estimated irrigation potential in the country is about 450,000 ha while only 63,000 ha have been fully developed, of which 77% is used by commercial estates whilst only 23% is used by smallholders (Peters 2004; MoAFS 2011), who produce mainly cereals (mostly rice and maize) and horticultural crops. Among those parcels that were irrigated, 62% used watering cans, 14% used flooding, 11% were gravity-fed and 6% used treadle pumps (NSO 2010). Peters (2004) estimated that about 11,500 ha of the small-scale irrigation are under farmer-run self-help irrigation schemes while 3,200 ha are under government-run irrigation schemes. The irrigated area in estates is used for export- or high-value crops such as sugarcane (45%), tea (44%) and coffee (11%) (MoAFS 2011). Moreover, about 62,000 ha of land are estimated to be used for traditional wetland cultivation using residue moisture, mainly during the dry seasons as the areas are waterlogged and inaccessible during the rainy season.

There is no formal classification of smallholder irrigation schemes in Malawi but they are informally classified as farmer-run self-help schemes or government-run irrigation schemes. The latter schemes are commonly targeting smallholder farmers but are managed and rehabilitated, where necessary, by the government, commonly using donor funding. Due to the fact that there was limited participation in the design, construction and management of the irrigation schemes, government-run irrigation schemes managed by settlers and smallholders are underperforming and are the least diversified in terms of market opportunities. Their landholdings are also small, even by Malawi standards, each being between 0.1 and 0.3 ha (MoAFS 2011) – too small to support substantial livelihoods.

Zambia has a huge irrigation potential, estimated to be about 2.75 Mha of land (FAO Aquastat 2006), with a large portion of it being in the CT. However, the total area currently under irrigation is estimated to be only about 10% of the potential, and is mostly practiced by large- and medium-scale farmers using surface water irrigation (Evans et al. 2012). Only 15,000 ha of land are estimated to be irrigated with motor pumps though the region holds a high groundwater potential that could be exploited by increasing access to motor pumps. Most of the smallholder-irrigation schemes produce food crops, such as rice, maize and horticultural crops but they are usually underperforming due to poor scheme infrastructure, inadequate water supply, and inefficient use of the available water (MoAFS 2011). The high rainfall from December to March commonly saturates the soil and creates seasonally waterlogged low-lying dambos. There is potential for developing and expanding small reservoirs in the region for multiple uses, namely drinking for livestock, fishery, household irrigation and other domestic uses (Evans et al. 2012).

Mozambique has more than 100 river basins, with most of the rivers having highly seasonal, torrential flow regimes, with high flows during 3-4 months and low flows for the remainder of the year, corresponding to the distinct wet and dry seasons (FAO Aquastat 2006). Among these, the Zambezi River Basin is the most important one in Mozambique. It accounts for about 50% of the surface water resources of the country and about 80% of its hydropower potential, including the Cahora Bassa Dam (FAO Aquastat 2006), the second largest dam in Africa. The main source of water for irrigation in Mozambique is surface water. Irrigation in Mozambique is at the stage of its infancy despite being a downstream country with large seasonal flows of the region's big rivers, including the Limpopo and the Zambezi. The irrigation potential is estimated to be above 3 Mha but only a small part of it is being developed, primarily for large-scale production of sugarcane, rice and vegetables in the downstream, central and southern provinces. Tete Province, which is within the CT, has limited surface water flows, except in districts in higher altitudes (e.g., Angonia). Small-scale irrigation is very much limited to surface water irrigation for producing tobacco, vegetables and a few rice fields. Mozambique could expand its provision of water to smallholder farmers, particularly in the CT, to mitigate the potential effects of recurrent drought. With the increasing market opportunities in Tete and its surroundings, thanks to the expanding mining sector, small-scale irrigation could help farmers to produce high-value agricultural products, access regional markets and improve their capacity to respond to emerging demands and climatic shocks. Vegetables, fruits, dairying and small ruminant production seem to be feasible entry points. In terms of irrigation technology, motor pumps could play an important role in getting water to farmers' fields although the governments in the three countries are promoting the use of treadle pumps because of the level of low maintenance requirements and operational cost.

In general, there is an increasing trend to use water for multiple purposes in the CT, particularly in Malawi through integrating fishponds into farming practices, drinking for livestock, irrigation farming and household use. Those farmers who have adopted aquaculture have doubled their household income and increased household food production by about 150% (Worldfish 2013). Adoption of fishponds has been growing in number by about 25%.yr⁻¹ since 2000, and is increasingly practiced in the regions, particularly in the lower Zambezi River Basin (Worldfish 2013). Governments have also acknowledged the challenge of promoting this practice in areas where the total rainfall amount is low and access to the Zambezi River or its tributaries is limited. However, increased integration of fishponds into farming systems along with increasing demand for irrigation water has created fierce local competition among and between communities. Expansion of small-scale irrigation systems coupled with ineffective institutions for water governance for multiple demands has led to frequent water shortages and local conflicts among communities. Increased adoption of small reservoirs in CT could be an important investment in the region to improve access to water, sustain multiple uses, support soil and water conservation, drought proofing and supplementary irrigation during dry spells.

The overall trend in the high rainfall areas of the CT is to promote small-scale irrigation and to integrate irrigation into the social and economic context. However, insufficient institutional capacity both at the central and local levels is the major constraint hampering the development of the small-scale irrigation subsector. The institutions dealing specifically with irrigated agriculture are severely constrained by insufficient qualified human resources and an inadequate budget. A point of concern for the development of irrigation as a whole is the lack of flexibility of the legal and political framework concerning access to, and use of, land and water.

4.3 Forest and dryland savannah management

Miombo forests are the most common forest types in the CT (White 1983). In some districts the natural dryland forests, mainly Miombo woodlands, cover up to 75% of the landscape (Figure 8). Miombo forests are common in Africa and they consist of single-storied woodlands with a light, closed canopy, dominated by trees of the genera *Brachystegia*, *Julbernardia* and *Soberlinia* (Stromgaard 1985; Campbell et al. 1996). They occur on nutrient-poor soils and in areas with distinct wet and dry seasons (annual rainfall 700-1,400 mm). The Miombo woodlands provide an extensive range of ecosystems goods and services, from the provision of food, fuel, medicine and construction materials to large-scale carbon and water management services (Ryan et al. 2011). More than 100 million people live in, or obtain resources from, Miombo, and up to 50% of income for the rural poor in some areas is dependent on the woodlands (Campbell et al. 2007).

Given the high cover of forests and the importance of related forest products in the region, forests benefit communities by providing income, food security, reduced vulnerability, reduced erosion and stability of the productivity of the landscape. This is particularly critical for some of the poorest forest-adjacent communities, who depend for their livelihoods on forest products (PFAP II 2005). The emergence of rural towns and the ongoing expansion of major cities have also created market opportunities for forest products such as bush meat and charcoal. The search for timber and fuelwood, however, has been causing deforestation. The Miombo woodlands are also suffering from ecological degradation caused mainly by human intervention. Deforestation for construction, fuelwood and charcoal production is the major factor that contributes to the decline of Miombo woodlands (Abbot and Homewood 1999; Brouwer and Falcao 2004). Conversion of woodlands to continuous cultivation and grazing due to population pressure also play a significant role in the degradation of Miombo woodlands (Chidumayo 2002; Ryan et al. 2011). In Zambia, forest losses could reach about 850,000 ha every year (PFAP II 2005). As mentioned in the previous chapter, the expansion of tobacco as a cash crop has contributed profoundly to deforestation in the CT. Considering their economic importance, woodland degradation could result in huge economic and social crises. Their potential for carbon sink and other essential ecosystem services will also be compromised unless preventive measures are taken to stabilize the situation.

In Tete Province, which has an estimated 3.3 Mha of forest cover, deforestation has been increasing, from 16,000 ha in the 1980s to 27,000 ha.yr⁻¹ at the end of the 1990s (De Wit and Norfolk 2010). In some districts, e.g., Tsangano, the forest cover has been reduced from about 50 to 11% in the last 10 years due to land clearing for tobacco farming (Oswin Madzonga, personal communication). The deforestation rate has intensified since then due to increasing legal and illegal export of timber to China and other emerging economies.

As most of the natural forests in the CT are located on customary lands, local chiefs and community leaders manage them. Any attempt to improve the management of forest landscapes, reduce deforestation and benefit the local people may need to adopt an inclusive strategy whereby the chiefs and community leaders are part of the decision-making process and the communities are involved in some sort of joint forest management.

5. MARKET LINKAGES

Market participation in the region is very low, and only about one-third of the farmers sell any surplus to the market (Haggblade et al. 2009; Grant et al. 2012). Infrastructure for trade is inadequate in much of the CT. To get to the market, about 38% of the farmers spend between 3 and 8 hours, 17% take between 8 and 12 hours, and 23% take more

than 12 hours (ICARDA 2012). Lack of roads and bridges in rural areas, limited rural roads connecting small towns with bigger towns, limited access to railways and ports, and the poor management of cross-country routes all represent serious impediments to trade. The transport system in the CT is poor and expensive to use. For instance in Malawi, only 30% of the farmers have access to a gravel road and only 8% to a tarmac road. About 56% of villages are without tarmac or gravel roads and are located about 4 km or more from the nearest all-season road (NSO 2010). About 53% of these villagers transported farm produce to the market on their heads, 35% by bicycles, and 6% by ox or donkey carts and only 5% have access to public transport (NSO 2010). The situation is even worse on the Mozambican part of the CT. Moreover, air transport between major towns within the region is probably one of the most expensive in the continent.

Interregional trade within the CT and trade within the wider southern African Region have been limited to a few agricultural products, notably maize for local and regional markets, and cashew, tobacco and cotton for international markets. Estimates of total informal trade for maize in the region range from 100,000 to 200,000 tonnes.yr⁻¹ (World Bank 2006) and the numbers are expected to increase in the future. Mozambique has been the major exporter of maize in the region, with about 50% of the informal transactions passing through Malawi. For instance in 2004, Mozambique supplied more than 90% of maize imports to Malawi (World Bank 2006). In a relatively normal year (good rains), northern Mozambique exports about 50,000 tonnes of maize to Malawi through informal markets, with additional imports of 20,000 tonnes from southern Tanzania to Malawi (Govreh et al. 2008). The average maize import at aggregate national level during the same period was between 8 and 15% (Grant et al. 2012). This regional trade has been mainly cross-border, largely informal and seasonal, and varied from year to year depending on the weather conditions, political environment and security situations in the respective countries. The recent ban by the Malawian government on exporting food crops, particularly legumes, through the formal channels has created a market disincentive, distorting prices and breaking market linkages. In fact, farmers may be forced to practice more informal cross-border trades involving middlemen.

With the exception of tobacco, cashew and cotton there is limited market information, experience and formal market linkages, although this is slowly changing. Strong informal market linkages have contributed to increased food availability in food-deficit districts. There is a common understanding that intra-regional trade in agricultural products could expand with aligning of customs, trade and sanitary and phytosanitary requirements and by reducing the amount of burdensome paperwork requirements and informal marketing costs. The rapid expansion of supermarket chains would also change marketing patterns and quality standards for both fresh and packaged foods in the CT (USAID 2006).

6. LAND TENURE AND USE IN THE CT

There are three major categories of land-tenure systems in the CT, namely public land, private land and customary land. The land under customary tenure could represent up to 85% of the total landholdings (Nabhan et al. 1999), though there are differences between countries and within countries. In Zambia, the land-tenure system is both customary and state land/leasehold tenure. State land tenure is defined as reserved or gazetted land (national forests, local forests, and parks), towns, and permanent commercial farms, while customary land means traditional land or "open land" (non-gazetted) where traditional chiefs and their village headmen decide on how the land is to be used (Olson 2007). In Mozambique, land is the property of the state.

National and foreign investors can obtain concessions (effectively leases, known as DUATs), for unused land for 100 years, subject to community consultations (The Oakland Institute 2011). Communities and individuals have permanent occupation rights. The Land Law recognizes customary rights and gives them formal legal rights, whilst also encouraging the growth of private sector in the regions (De wit and Norfolk 2010). The Land Law policy is aimed at allowing local communities and the private sector investors to negotiate agreements around land use rights, while the state role is limited to ensuring that certain minimum standards are applied in these negotiations, that rights' registration complies with technical standards and that the taxation system functions effectively. Malawi farmers have a more formalized ownership and user rights than the other two countries. Land that is not under any form of use is considered as communities' property, which is under the jurisdiction of the local chief (Saka et al. 1999). But the governments can declare customary land as public land as deemed necessary and allocate it to investments when the need arises. This policy is creating insecurity to local communities, putting pressure on the farming systems, reducing the fallow periods and the time required for soil fertility replenishment and squeezing crop and livestock farmers to increasingly smaller landholdings. Moreover, the system of land inheritance varies, whereby patrilineal or matrilineal system of inheritance is practiced depending on the cultural setup of each community. The consequence is increasing land scarcity, which became the source of local conflicts. For instance in 2006/2007 in Malawi, 47% of villages had conflicts over land, 29% between family groups and households, 20% between villages and 5% between villages and estates (NSO 2010). This is partly due to the weak institutional capacity to enforce land laws in the respective countries. The general trend is that state ownership has been increasing in the region with the view of expanding investment and public ownership of resources.

7. RESEARCH AND DEVELOPMENT (R&D) INSTITUTIONS IN THE CT

7.1 Research

The research system in the three countries is mainly public with the national agricultural research institutes being the major actors in technology generation and dissemination, though agricultural universities and NGOs play an important role.

There has been an increasing investment in agricultural research in southern Africa, though most projects and programs are dependent on external funding. The lags between investing in R&D and reaping some return on that investment can be quite long, since some investments are slow to come forth and, whereas, some are comparatively short-lived, others last a long time or are used in subsequent R&D, leading to further cycles of invention and streams of benefits (Alston et al. 2000). The lack of immediate impact of research on food security and livelihoods has been a real concern for both public and private institutions in the three countries. It is one possible reason why national governments rarely invest in research infrastructure and operation beyond paying salaries.

In Malawi the Department of Agricultural Research Services (DARS) of the Ministry of Agriculture (MoA) is mandated to undertake research on a wide variety of crops and livestock, but other specialized institutions carry out research on high-value export commodities such as tea, tobacco and sugar. DARS has research sites and stations in most districts of the country, with 11 research stations, and 20 substations (MALD 1993). Chitedze Research Station, near Lilongwe is the centre for germplasm development, pastures and forage work. MoA has also mandated the University of Malawi to conduct specific disciplinary research. Bunda College of Agriculture carries out research on beans, rabbits, pigs and socioeconomics. Chancellor College works with DARS on cassava pests, soil pests and cassava detoxification. The Department of Animal Health and Industry carries out research on poultry and goat breeding. Contract research funding is also provided to other organizations for research activities where DAR does not have sufficient resources. External funding for research may go through GoM or direct to the implementing agency. Details of research objectives are laid out in the Agricultural Research Master Plan and Action Plans (MALD 1993) and are yet to be updated.

In Mozambique, the Instituto De Investigasau Agraria de Mozambique (IIAM) is the major country-wide institution responsible for development and dissemination of agricultural technologies, together with partners. They have been developing improved varieties of maize, cassava, sorghum, groundnut, pigeonpea and other crops in close collaboration with various CGIAR centers. Despite its thin presence on the ground, given a vast country and a

relatively small number of staff, IIAM has been responsible for parts of the CT through its research center, based in Angonia, Tete Province. On the other hand, water management at the national level is the responsibility of the National Water Directorate (DNA), while at the regional level the five Regional Water Administrations (ARAs) are the major players. Their major engagement is in controlling irrigation systems and collecting water fees (World Bank 2006), although most of the ARAs are not fully operational due to lack of capacity and funding. The only operational ARA was ARA-Sul (South), which is in charge of the southern part of the country, where most problems of flooding and water management exist. In areas not yet covered by a functional ARA, the Provincial Directorates of Public Works and Housing are the responsible authorities (World Bank 2006).

The Zambian Agricultural Research Institute (ZARI), one of the oldest research centers in the region, has conducted research on various agricultural and nonagricultural issues that are relevant to rural communities, ranging from biotechnology through to production and food processing. They have some strong breeding and agronomic research programs. In the CT, the Msekera Regional Research Station, located in Chipata District, eastern Zambia, represents ZARI. The station is engaged primarily in development and testing of germplasm, improved agronomic practices and soil fertility management. It has three substations that are located in different agroecologies of eastern Zambia.

Total Land Care (TLC) conducts research on various themes across the CT covering Malawi, Mozambique and Zimbabwe. TLC is engaged mostly in land management research including conservation agriculture, irrigation and rehabilitation of degraded landscapes and promoting sustainable land use and management practices.

7.2 Extension services

The Ministry of Agriculture and its division, the Department of Agricultural Extension Services (DAES), along with the University of Malawi have primarily provided the agricultural extension service in Malawi. Chitedze and Bvumbwe research stations also play an important role along with international partners, mainly the CGIAR centers. Apart from government ministries, NGOs, Farmer-Based Organizations (FBOs), multilateral organizations, and the private sector also play important roles in the national extension system. The public extension system comprises 2,175 staff members and is managed by a team of 18 senior staff, along with 142 subject matter specialists providing countrywide backstopping support (IFPRI 2011a). Field-level extension workers constitute the bulk of staff (92%), with 88% holding a secondary school diploma, and 21% being female (IFPRI 2011a). On the other hand, private-sector organizations in Malawi are contributing to promote particular commodities. There are three private-sector firms

that provide support in terms of inputs and technical advice to farmers in Malawi, including Alliance One International and Malawi Bio Energy Resources LTD (IFPRI 2011a).

In Mozambique, the public extension service for supporting smallholders was created very recently, in 1987, due to the long civil wars and the history of colonial systems targeting large commercial farmers. The National Directorate for Agricultural Extension (DNEA) is one of the four national directorates of the Ministry of Agriculture (MINAG), and plays a lead role in the extension system. The other key players are the Ministry of Fisheries, the Agricultural Research Institute of Mozambique (IIAM) and the University of Eduardo Mondlane, Faculty of Agriculture and Fisheries. During its initial phase of development (1989-1992) extension was entirely carried out by the public sector with assistance from international NGOs, and agencies such as the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Development Programme (UNDP) (IFPRI 2011b). In response to the emerging new extension landscape, a National Extension Master Plan (1999-2004) was developed to focus on the adoption of Unified Extension Services (SUE) encompassing crop production, livestock and natural resources management, and the development of an integrated National Agricultural Extension System (SISNE) with a partnership between public and private extension services, including outsourcing. However, Mozambique public extension services have been facing difficulties in reaching the beneficiaries in this vast country with very limited and de-motivated staff, though the number of extensionists increased from 693 in 2009 to 1,340 in 2011 (IFPRI 2011b). Moreover, the capacity of the staff is relatively weak with only 4% holding university degrees. On the other hand, private Joint Venture Companies provide strong extension support to their outgrowers, with a focus purely on high-value commodity crops, mainly cotton, tobacco and cashew. The support includes inputs such as seeds, fertilizers, herbicides and pesticides, and technical advice to farmers. In addition, they provide complementary informational extension services to promote their commodity. In an attempt to support communities, USAID/Mozambique has been promoting the formation of farmer associations. Given the isolation of most smallholders in Mozambique and the weak capacities of both the commercial sector and the government, there is a strong case for strengthening farmer associations (USAID 2006). Associations could play an important role in facilitating local innovation, input delivery, promoting efficient extension systems and facilitating collective action among farming communities. The presence of strong cross-border social linkages could be used as a stepping-stone to strengthen cooperation between institutions at various scales and to collectively address livelihood challenges.

In Zambia, like the other two countries, extension is hosted under the Ministry of Agriculture and Cooperatives, which is governing the Zambia Agricultural Research Institute, the

Department of National Agricultural Information Services, the Ministry of Livestock and Fisheries and the University of Zambia, which could play an important role in revitalizing the extension system. Major agribusiness firms including the Zambia Cotton Ginners Association and the Grain Trade Association are also involved in some form of extension along with a large number of NGOs and farmer organizations. The Zambian National Farmers' Union and the Radio Farm Forums groups are also strong grassroots institutions. In countries where radio sets are still expensive for the ordinary villager, joint arrangements like 'radio farm forums' would bring radio to the villages in the form of community radios through a free gift by external projects or purchase by communities (Neuarath 1962). The setting of the agriculture sector differs from that of the other two countries in that there is a dual structure, where a small number of large commercial farms, concentrated along the railway line, coexist with scattered subsistence smallholders and a few small commercial farmers who face severe difficulties accessing input and output markets (IFPRI 2011a,b). Since the late 1990s, the agriculture policy has been transformed from heavy government interventions to a slowly liberalized private sector, aimed at reducing government's role in various agricultural production, extension and marketing service provisions. The Ministry of Agriculture, Fisheries and Forest has been promoting public-private partnerships through the creation of agricultural trusts with the mandate to manage and provide research, advisory and training services. However, the Agricultural Sector Investment Program (ASIP), designed to facilitate the transition to a market-oriented agriculture, has not yet produced the desired outcomes.

The largest partnership that has targeted the three countries in general, and the CT in particular, was the ongoing USAID/SA Rural Livelihood Diversified Strategic Programme, which underpinned the Initiative to End Hunger in Africa (IEHA) a US Presidential Initiative to cut hunger in half by the year 2015. It was a 5-year initiative aimed at revitalizing southern African research networks by working in close partnership with NARS to improve and diversify rural livelihoods in the CT region through the formation of a broad consortium. Other major institutions in the region, beyond those described above, are listed in Table 2.

7.3 Local chiefdoms

Despite weak formal institutional support, there are various local institutions engaged in input distribution, marketing and collective action at various levels in all the countries of the CT. The traditional authorities, sub-traditional authorities, group village chiefs and village chiefs play an important role in the agriculture sector, particularly in organizing communities, disseminating agricultural interventions and guiding farmer organizations. The paramount chief is the highest order of the traditional institutions, which has a very strong influence both on policies and local investment flows to the localities.

TABLE 2. INVENTORY OF CURRENTLY KNOWN* INSTITUTIONS THAT HAVE BEEN WORKING ON AGRICULTURAL R&D IN THE CT.

	NAME OF INSTITUTION	REGION/ZONE	MAJOR AREAS OF INVOLVEMENT IN THE REGION
1	IITA (International Institute for Tropical Agriculture)	Malawi, Mozambique, Zambia	Development and dissemination of cassava and soybean varieties/ Technologies
2	CIAT (International Centre for Tropical Agriculture)	Malawi, Mozambique, Zambia	Development and dissemination of bean varieties/technologies across the region; development of soil fertility management options
3	ICRAF (World Agroforestry Centre)	Eastern Zambia, southern Malawi	Dissemination and impacts of fertilizer tree fallows in farms and landscapes
4	MSU (Michigan State University)	Malawi, Mozambique, Zambia	Spatial pattern of population, food production, consumption and inter-regional trade; market information and flows; pulses value chain
5	ICRISAT (International Crops Research Institute for Semi-arid Tropics)	Malawi, Mozambique, Zambia	Development and dissemination of groundnut and pigeonpea varieties/technologies; establishment of community seed systems; improved crop-livestock integration
6	Total Landcare	Malawi and Tete Province in Mozambique	Community-based land and water management, irrigation for horticultural crops, improved land use, rehabilitation of degraded lands
7	CIP (International Potato Center)	Predominantly in Mozambique	Development and dissemination of orange-fleshed sweet potato varieties/ technologies
8	World Fish Centre	CT, predominantly in Malawi	Improved water use and governance, multiple use of water, intensification through fish farming
9	IWMI (International Water Management Institute)	CT, mainly in Malawi and Mozambique	Hydrological modeling; community-based multiple-use water services; irrigation management
10	ILRI (International Livestock Research Institute)	Mozambique	Livestock feed systems and livestock value chains
11	Care International	Malawi, Mozambique, Zambia	Improved farming methods, with focus on conservation agricultural interventions
12	SNV- Mozambique	Tete Province, Mozambique	Small-scale processing and marketing of cashew; improved value chains; maize-pigeonpea agronomic practices
13	ECRP (Enhancing Community Resilience Programme)	Malawi	Resilience to climate variability and change; risk management and climate change adaptation
14	Mozambique Leaf Tobacco (subsidiary of the Universal Leaf Tobacco Group)	Mozambique	Providing inputs and improved production practices for tobacco growers, organizing farmer cells, and marketing
15	IIAM (Instituto De Investigação Agrária de Mozambique)	Mozambique	Development and dissemination of agricultural technologies, mainly maize, beans, groundnut, pigeonpea, soil fertility issues
16	DAR (Agricultural Research Department)	Malawi	Development and dissemination of agricultural technologies, mainly maize, beans, groundnut, pigeonpea, soil fertility issues, flooding management
17	Msekera Research Centre, Zambia Agricultural Research Institute (ZARI)	Zambia	Development and dissemination of agricultural technologies, mainly maize, beans, groundnut, pigeonpea, soil fertility issues

*This list may not be exhaustive as it reflects the authors' knowledge based on available information at the time. It is a work in progress that can be adapted further as more information becomes available.

8. MAJOR INSTITUTIONAL CHALLENGES IN AGRICULTURAL DEVELOPMENT

The challenges for these various public and private extension service providers across the CT, are the following (partly extracted from USAID 2006):

- a. **Limited flow of knowledge and technology to resource-poor farmers.** Besides the fact that most parts of the CT are far away from the centers of power of the respective countries, and with poor road infrastructure,

scaling and dissemination of good practices are constrained by the limited number of extension staff on the ground (particularly in Mozambique), limited financial capacity and limited access to farm inputs. Good access to technologies and good practices are mostly limited to large- and medium-scale farmers. Moreover, the common perception that there will be transfer of knowledge from large- and medium-scale to resource-poor farmers is unfounded because better-off farmers tend to concentrate on high-value commercial crops with different levels of high input-high output farming whereas small-scale farmers are primarily growing subsistence food crops, with low input-low output scenarios.

- b. **Slow movement towards sustainable intensification.** Despite the availability of improved technologies and practices in the region, the current production is very low and rarely satisfies household demands. The low net return per hectare and per animal has kept farmers in a poverty trap. Harris and Orr (2013) indicated that small-scale farmers are unlikely ever to intensify their systems given the small landholdings, and high level of climatic and market risks. This could be particularly true in countries like Malawi, where high population density, small plot size, and low soil fertility are threatening livelihoods. There is a need to improve productivity and efficiency of the agricultural system at farm and landscape scales through integrated use of farm inputs, land, water and farm labor.
- c. **Disciplinary, piecemeal approaches.** It is widely acknowledged that rural poverty and resource degradation cannot be tackled through single interventions or individual institutions. It rather calls for a systems approach and collective action. On the other hand, most projects focus on specific commodities, without considering interlinkages between components and systems. Integrated approaches such as watershed management and landscape planning are nonexistent. If multiple actors were involved they could bring differing competencies to the table that would help farmers to innovate and adopt technologies and good practices.
- d. **Lack of a shared vision.** There is a general understanding that sustainable impact of projects could be achieved only when the projects are planned and implemented in close partnership with the national institutions and key players. Moreover, the impact of projects could be achieved long after the projects are completed, i.e., once farmers fully internalize and start investing their own resources and getting convincing returns. It requires a mechanism for ensuring sustainable institutional support and a smooth transition to local institutions.
- e. **Poorly functional local institutions.** There is a need to strengthen the capacity of local institutions to disseminate improved technologies. The current farmers' associations in the respective countries need to be organized and facilitated to ensure that their engagement would enable local action to improve land, water and vegetation management at farm and watershed scales. The current institutional setup rarely includes community priorities in planning and implementation of development projects and programs. Moreover, most programs in the region are run and managed by large NGOs, with top-down approaches, without creating local capacity or fostering institutional innovation. Although the NGOs are playing a vital role in organizing small-scale farmers, there is still a significant risk that if these international NGOs leave the scene there will be very little capacity left to carry on the development process.
- f. **Challenges of targeting.** Most projects have failed to achieve the intended objectives because they failed to treat gender as an important issue and provide appropriate support to women and other vulnerable groups. There is also limited capacity to internalize gender-related issues and integrate them into the design and implementation of projects.
- g. **Weak linkages between actors.** There have been multiple and parallel initiatives in the region, sometimes with conflicting approaches. Various donors and NGOs promote differing philosophies, objectives and activities on the ground that may not necessarily be in alignment with government development directions. There is commonly poor linkage between various ministries within the government structure and also between departments and divisions within the ministries and local governments. For instance, in Mozambique, beyond the fact that the government extension service is understaffed, there appears to be little effort to create useful linkages between the various officers at different levels. The major hurdles seem to be poor communication, lack of a joint forum for learning and planning, and weak monitoring systems. Formation of local and national forums would serve as a platform for sharing knowledge, identifying gaps and providing comprehensive policy recommendations that would help avoid past mistakes. The Conservation Agriculture Platform that IIAM of Mozambique has been facilitating through the support of USAID was trying to facilitate linkages and cross-institutional learning.
- h. **Weak regional synergies and poor communications.** Though the CT is on the intersection of the three countries, Mozambique in particular may not have benefited from the regional experiences to date, primarily due to language barriers. They have rarely benefited from training and competences available in the neighboring countries. One other noticeable feature of the CT is poor communication between actors, which undermines development efforts in multiple ways. Better communication would prevent duplication of efforts and would also promote joint learning and sharing of insights, and dissemination of information between actors, which may lead to more informed decision making.

9. RESEARCH FOR DEVELOPMENT PRIORITIES IN THE CT

Poor soil fertility, high rates of soil erosion, low levels of input use, deforestation and unsustainable land use practices have created pressure on the food security and livelihoods of people in the CT. With increasing population pressure and climate change, the difficulty of achieving food security will likely increase unless alternative management options and productivity-enhancing mechanisms are devised. The region has also been hit by recurrent droughts and flooding

in the last decade, and their intensity is expected to be even more severe given the increasing climate change predictions in southern Africa (Davis 2011). Both extreme events have been destroying livelihoods in recent years, particularly in downstream communities. For instance, in Chokwe, Mozambique, floods in 2012 and 2013 destroyed the farms and livelihoods of more than 100,000 people. The negative effects are due to multiple factors including high rainfall intensity in upstream countries, and limited landscape management interventions, aggravated by recent deforestation by people seeking farmland and forest products.

9.1 Integrated watershed management

One area of intervention to enhance agricultural productivity and minimize negative effects is integrated watershed management. This aims to reduce erosion, regulate runoff, decrease unproductive water losses (runoff, evaporation, conveyance losses, deep percolation) from a system, as well as increasing the water use efficiency of productive enterprises (Amede et al. 2011). Unlike conventional approaches, it focuses more on the institutions and policies than on the technologies; it capitalizes on rainwater harvesting principles, storing and efficiently utilizing water in the soils, farms, landscapes, reservoirs and other facilities. It is an effective strategy to improve the vegetation cover of hillsides, reduce negative effects on downstream farms and water facilities and will help to manage the consequences of climate change (e.g., floods and droughts) by combining water management with land and vegetation management at landscape scales. Landscape management using integrated watershed management approaches would increase resilience of systems by capturing, storing and efficiently utilizing runoff and surface water emerging from farms and landscapes for production and ecosystem services. This is particularly critical for the CT, where about 70% of the land falls within drought-prone arid and semiarid zones. Weak institutional linkages, sectoral policy and fragmented investments have affected cross-institutional learning, local action and policy implementation in managing water resources in the region. On the other hand, there is very limited experience and institutional arrangement to date to employ watershed management practices in the CT. Various national and international institutions are engaged primarily in promoting crop varieties and related commodities. The limited forums created were mostly one-off, donor-dependent, top-down events and meant for conveying donor interest and government policies. There is a need to develop collective action and joint investment in multiple small watershed sites that could be used for wider influence and policy change.

9.2 Sustainable agricultural intensification

As presented in Table 1, crop yield in this region is far below the global average; it is rain-fed-dependent and extremely vulnerable to climatic shocks. The production level is not meeting the increasing household and market demands in all the three countries. Land and water productivity (returns per unit of investment) is extremely

low. The consequence is that more and more forest is deforested in search for fertile land. Increasing population pressure and changing climate have been aggravating the challenge of food security, forcing some community members to migrate to towns and neighboring countries, particularly to South Africa. There is also a government-induced 'maize-poverty trap' by shifting priorities to maize production at the expense of other commodities. This calls for employing sustainable intensification of the systems, particularly in the maize-cassava-beans farming subsystem through improving production practices, diversifying crops, increased use of farm inputs, diversifying crops for efficient utilization of land and water resources across seasons, improved integration of crop and livestock commodities as well as ecosystem services and improved linkages to market opportunities. According to Pretty et al. (2011) sustainable production systems would exhibit: i) utilizing crop varieties and livestock breeds with a high ratio of productivity to the use of externally and internally derived inputs; ii) harnessing agroecological processes such as nutrient cycling, biological nitrogen fixation, allelopathy, predation and parasitism; iii) minimizing the use of technologies or practices that have adverse impacts on the environment and human health; iv) making productive use of human capital in the form of knowledge and capacity to adapt and innovate and social capital to resolve common landscape-scale problems; and v) quantifying and minimizing the impacts of system management on externalities such as biodiversity and dispersal of pests, pathogens and weeds.

9.3 Agriculture-power interaction

About 98% of Malawi's electricity comes from hydropower from the Shire River. Only about 7% of the population is connected to the national power grid. However, the river, which starts from Lake Malawi, has dried up many times in the last decades due to siltation and drought, affecting power generation and downstream irrigation. Aquatic weeds and sediment disposal from upstream agricultural fields are two major reasons for decreasing power supply in the recent years. Siltation has also reduced fish farming and income of smallholders. There has been an increasing deforestation and removal of trees from river banks. ESCOM Hydroelectric Power on the Shire River has been spending millions of US dollars to desilt the river barrages and sustain power generation activities. What types of institutional arrangements are required between ESCOM, ministry of Agriculture and Ministry of Environment to improve productivity and minimize negative effects on agriculture, power generation and ecosystem services?

9.4 Policies and institutions

For improved land management and agricultural intensification to be sustainable and beneficial in the long-term, appropriate policies and institutions need to be developed and existing ones strengthened. With regard to enabling policies, we observe that one major

challenge affecting implementation of some soil and water management practices has been lack of their coordination on the ground. For instance, in Zambia and Malawi although the irrigation policy allows farmers to farm along river banks the environmental policy discourages the growing of crops there as a measure to curb siltation which eventually results in drying up of rivers. In most cases, this has ended up confusing farmers. In Zambia, by-laws are weak or nonexistent on uncontrolled burning, indiscriminate cutting of trees, and protection of contours, water rights and catchment areas. Some of the policies in all the countries sharing the CT have never been enacted since they were formulated and are redundant while others are outdated. In Mozambique the implementation of the Land Law provided a measure of stability for smallholders although its implementation has been problematic. One basic problem is how to strike a balance between the conflicting demands of extensive, low-productivity, subsistence agriculture and those of capital-intensive, commercial agriculture in order to promote broad-based higher productivity. The law did not help strike this balance with clear criteria that could be applied in a transparent, unambiguous and accountable fashion.

Though there is difference among countries, research and extension in the region are weak and generally underfinanced. The situation seems to be particularly alarming in Mozambique, where farmers have rare access to research and extension services. For instance in Moatize District of Tete, farmers claimed they have never received any improved crop or livestock technology except for livestock vaccination during national campaigns. It is partly due to the limited number of researchers for the vast country and also limited policy support for technology generation and dissemination despite the attempts of IIAM to outreach farmers.

9.5 Markets and value chains

For agriculture to bring about growth and reduce poverty, well-functioning markets are essential. More effective markets increase the accessibility of inputs for users, facilitate exchange of commodities between buyers and sellers, encourage producers to improve management practices (and increase innovation) for improved productivity and profitability, and may increase the willingness of farmers to take risks (as they have clear information of where to get inputs and a fair idea of the selling price of their products). Well-functioning markets clearly reveal the trends in supply and demand, and these guide the actions of individuals, for example, where to invest, or where to offer their labor. In addition, prices reflect changes in the demand and supply of goods and services, which give

a general direction for buyers and sellers. However, the potential contributions of markets to achieve the above and contribute to poverty reduction are limited in SSA due to a variety of reasons. A detailed understanding of the functioning, coordination and impediments of markets across the value chain is therefore necessary.

Moreover, market infrastructure in the CT is rudimentary and expensive, as also presented in section 5. It has a limited road network with about 40% of the population taking more than 8 hours to get to a bigger market (ICARDA 2012). There is a need to invest in market infrastructure and to facilitate cross-border trade that would improve input-output markets and enable communities to invest in their farms and systems.

9.6 Creating innovation capacity

Agricultural research has not been very successful in improving resource-poor farmers' livelihoods in SSA, as evidenced by the current level of food insecurity in the region. This is partially due to approaches to agricultural research, which have generally followed a 'linear approach'. The linear approach to agricultural R&D (Pan and Hambly-Odame 2010) looks at knowledge development/production and application as separate activities, carried out respectively by researchers and farmers where researchers are in charge of producing knowledge, and extension agents are expected to transfer the knowledge to farmers, who are expected to adopt it (Nederlof et al. 2011). In this approach there is limited interaction and learning among different stakeholders. More recently, the Innovation System approach has brought the understanding that innovation emerges from the interactions between multiple stakeholders; i.e., researchers, advisory service-providers, NGOs, farmers organizations and private-sector actors (Hall et al. 2006; Waters-Bayer et al. 2009). Innovation system refers to 'the dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion and utilization of technology' (Hall et al. 2006).

In the sphere of agricultural R&D, innovation systems depict a dynamic network of stakeholders interacting and learning together towards the generation, dissemination and continuous adoption of a technological output. The interaction among these institutions and stakeholders leads to knowledge generation, application and sharing such that innovation is generated. Francis (2006) and Agwu et al. (2008) likened the innovation system approach in agriculture to an invisible orchestra characterized by coherence, harmony and synergy.

REFERENCES

- Abbot, J.I.O.; Homewood, K. 1999. A history of change: Causes of miombo woodland decline in a protected area in Malawi. *Journal of Applied Ecology* 36: 422–433.
- AfDB (African Development Bank). 2012. *Africa's demographic trends*. Briefing notes for AfDB's long-term strategy. Briefing Note 4. 11 p.
- Agwu, A.E.; Dimelu, M.U.; Madukwe, M.C. 2008. Innovation system approach to agricultural development: Policy implication for agricultural extension delivery in Nigeria. *Africa J. Biotechnology* 7(11): 1604–1611.
- Ajayi, O.C.; Franzel, S.; Kuntashula, E.; Kwesiga, F. 2003. Adoption of improved fallow technology for soil fertility management in Zambia: Empirical studies and emerging issues. *Agroforestry Systems* 59: 317–326.
- Akinnifesi, F.K.; Makumba, W.; Kwesiga, F.R. 2006. Sustainable maize production using Gliricidia/Maize intercropping in Southern Malawi. *Experimental Agriculture* 42: 1–17.
- Alston, J.M.; Chang-Kang, C.; Marra, M.C.; Pardey, P.G.; Wyatt, T.J. 2000. A meta-analysis of rates of return to agricultural R&D. *Ex pedeherculem?* IFPRI Research Report 113. Washington, DC: International Food Policy Research Institute (IFPRI).
- Amede, T. 1995. Yield gain and risk minimisation in Maize through cultivar mixtures in the southern rift valley, Ethiopia. *Experimental Agriculture* 31:161–168. UK.
- Amede, T. 2013. Socio-economic characteristics of dryland farmers in Moatize, Tete Province, Mozambique. ICRISAT-Mozambique (Duplicated).
- Amede, T.; Tarawali, S.; Peden, D. 2011. Improving water productivity in crop livestock systems of drought prone regions. *Experimental Agriculture* 47(1): 1–6.
- Benson, T.; Cunguara, B.; Moges, T. 2012. *The supply of inorganic fertilizers to smallholder farmers in Mozambique: Evidence for fertilizer policy development*. IFPRI discussion paper 0129. December 2012. Washington, DC: IFPRI.
- Brouwer, R.; Falcao, M.P. 2004. Wood fuel consumption in Maputo, Mozambique. *Biomass and Bioenergy* 27: 233–245.
- Campbell, B.; Frost, P.G.H.; Byron, N. 1996. Miombo woodlands and their use: Overview and key issues. In: *The Miombo in transition: Woodlands and welfare in Africa*, ed. Campbell, B. Bogor, Indonesia: Center for International Forestry Research (CIFOR), pp. 1–10.
- Campbell, B.M.; Angelsen, A.; Cunningham, A.; Katerere, Y.; Sitoe, A.; Wunder, S. 2007. *Miombo woodlands – opportunities and barriers to sustainable forest management*. Bogor: CIFOR. http://www.cifor.cgiar.org/miombo/docs/Campbell_Barriers_and_Opportunities.pdf (accessed on September 13, 2013).
- Chapato, A. 2010. Agricultural productivity in Zambia: Has there been any progress? ACF /FSRP Research Presented to the Zambia National Farmers Union Congress Mulungushi Conference Center, Lusaka, 6 October, 2010. http://fsg.afre.msu.edu/zambia/ZNFU-Agricultural_productivity_FRSP.pdf (accessed on February 8, 2014).
- Chidumayo, E.N. 2002. Changes in miombo woodland structure under different land tenure and use systems in central Zambia. *Journal of Biogeography* 29: 1619–1626.
- CIESIN (Center for International Earth Science Information Network, Columbia University; CIAT (Centro Internacional de Agricultura Tropical). 2005. *Gridded population of the world, Version 3 (GPWv3): Population density grid*. Palisades, NY: National Aeronautics and Space Administration (NASA) Socioeconomic Data and Applications Center (SEDAC). <http://sedac.ciesin.columbia.edu/data/set/gpw-v3-population-density> (accessed on July 1, 2013).
- Cotula, L.; Vermeulen, S.; Leonard, R.; Keeley, J. 2009. *Land grab or development opportunity? Agricultural Investment and international deals in Africa*. London: International Institute for Environment and Development; Rome: Food and Agriculture Organization of the United Nations (FAO); Rome: International Fund for Agricultural Development (IFAD).
- Davis, C.L. 2011. *Climate risk and vulnerability: A handbook for southern Africa*. Pretoria, South Africa: Council for Scientific and Industrial Research. 92p. http://www.sarva.org.za/sadc/download/sadc_handbook.pdf (accessed on May 21, 2013).
- De Wit, P.; Norfolk, S. 2010. *Recognizing rights to natural resources in Mozambique*. Washington, D.C.: Rights and Resources Initiatives. http://www.rightsandresources.org/documents/files/doc_1467.pdf (accessed on April 30, 2013).
- Dias P. 2013. *Analysis of incentives and disincentives for tobacco in Mozambique*. Technical notes series. Rome: FAO.
- Dorward, A. 1999. Farm size and productivity in Malawian smallholder agriculture. *Journal of Development Studies* 35 (5): 141–161.
- Eriksen, S.; O'Brien, K.; Rosentrater, L. 2008. Climate change in Eastern and Southern Africa: Impacts, vulnerability and adaptation. Report 2008:2. *Global Environmental Change and Human Security*, 25p. Oslo.
- Evans, A.E.V.; Giordano, M.; Clayton, T., eds. 2012. *Investing in agricultural water management to benefit smallholder farmers in Zambia*. AgWater Solutions Project country synthesis report. Colombo, Sri Lanka: International Water Management Institute (IWMI), 37p. (IWMI Working Paper 150). doi: 10.5337/2012.212 (accessed on July 24, 2013).
- FAO (Food and Agriculture Organization of the United Nations). 1997. *Irrigation potential in Africa: A basin approach*. FAO Land and water bulletin 4. ISBN 92-5-103966-6. <http://www.fao.org/docrep/w4347e/w4347e00.htm#Contents> (accessed on November 4, 2013).
- FAO AQUASTAT. 2006. *Malawi, Zambia and Mozambique*. http://www.fao.org/nr/water/aquastat/countries_regions/malawi/index.stm (accessed on March 5, 2013).
- FAO/WFP (World Food Programme). 2010. Crop and food security assessment mission to Mozambique, Special report. FAO global information and early warning system. <http://www.fao.org/docrep/012/ak350e/ak350e00.htm> (accessed on March 25, 2014).
- Folmer, E.C.R.; Geurts, P.M.H.; Francisco, J.R. 1998. Assessment of soil fertility depletion in Mozambique. *Agriculture, Ecosystems and Environment* 71: 159–167.
- Francis, J. 2006. *National innovation system relevance for development*. Training of Trainers Workshop for ACP Experts on Agricultural Science, Technology and Innovation (ASTI) system 2nd- 3rd, October 2006.
- GEF (Global Environmental Facility). 2010. *Private public sector partnership on capacity building for SLM in the Shire River Basin*. Washington, D.C., USA: Global Environmental Facility.
- Govreh, J.; Haggblade, S.; Nielson, H.; Tscierley, D. 2008. *Maize market sheds in eastern and southern Africa*. A report prepared by Michigan State University for the World Bank. East Lansing, MI, USA: Michigan State University.
- Grant, W.; Woolfard, A.; Louw, A. 2012. Maize value chain in the SADC region. Technical Report. AECOM International Development. Submitted to USAID Southern Africa trade hub, 45p.
- Haggblade, S.; Longabaugh, S.; Tshirley, D. 2009. *Spatial patterns of food staple production and marketing in South East Africa: Implication for trade policy and emergency response*. East Lansing, MI, USA: Michigan State University, ISBN 0731-3483.
- Hall, A.W.; Janssen, E. Pehu; Rajalahti, R. 2006. *Enhancing agricultural innovation: How to go beyond the strengthening of research systems*. Washington, D.C.: World Bank.
- Halle, B. and Burgess, J. 2006. *Commission of the European Communities EC Framework*. Belgium: AGRIFOR Consult.
- Harris, D.; Orr, A. 2013. Is rainfed agriculture really a pathway from poverty? *Agricultural Systems (in press)*.
- ICARDA (International Center for Agricultural Research in the Dry Areas). 2012. *Integrated agricultural production systems for improved food security and livelihoods in dry land areas*. Dryland systems programme, Inception phase report. Beirut, Lebanon: ICARDA, 76p.

- ICMM (International Council of Mining and Metals). 2012. The role of mining in national economies. *InBrief*, October 2012.
- IFPRI (International Food Policy Research Institute). 2011a. *Agricultural extension and advisory services in Malawi*. Agricultural extension and Advisory services worldwide. <http://www.worldwide-extension.org/africa/malawi/-malawi> (accessed on July 03, 2013).
- IFPRI. 2011b. *Agricultural extension and advisory services in Mozambique*. <http://www.worldwide-extension.org/africa/mozambique/s-mozambique> (accessed on July 03, 2013).
- IPCC (Intergovernmental Panel on Climate Change). 2007. *Climate change 2007. The physical science basis; summary for policy makers*. <http://www.pnud.cl/recientes/IPCC-Report.pdf> (accessed on June 24, 2013).
- Kambewa, E. 2010. Improving rural livelihoods in Southern Africa. *The SARRNET cassava component. An impact assessment report*. Ibadan, Nigeria: International Institute for Tropical Agriculture, 34p.
- Kandji, S.T.; Verchot, L.; Mackensen, J. 2006. *Climate change and variability in southern Africa: Impacts and adaptation in the agricultural sector*. Nairobi, Kenya: World Agroforestry Centre (ICRAF) and United Nations Environment Programme (UNEP).
- Krywkow, J. 2010. Enhancing adaptive capacity in the Chinyanja triangle of South-East Africa. *TIAS Quarterly*. No 2, 2010, June/July. <http://www.tias.uni-osnabrueck.de/publications/newsletter2010> (accessed on February 8, 2013).
- Madamombe, I. 2006. *Is cassava Africa's new staple food?* Africa Renewal, July 2006. <http://www.un.org/africarenewal/magazine/july-2006/cassava-africa%E2%80%99s-new-staple-food> (accessed on March 10, 2013).
- MALD (Ministry of Agriculture and Livestock Development). 1993. *Agricultural Research Masterplan*. Lilongwe, Malawi: MALD.
- MoAFS (Ministry of Agriculture and Food Security). 2011. *Malawi agricultural sector-wide approach*. A prioritized and harmonized agricultural development agenda, 2011-2015. Lilongwe.
- Mukanda, N.; Moono, D. 1999. Zambia. 337-353 pp. In: *Integrated soil management for sustainable agriculture and food security in Southern and East Africa. Proceedings of the expert consultation, Harare, Zimbabwe, Dec. 1997*, ed. Nebhan, H.; Mashali, A.M.; Mermut, A.R. 1999. Rome: FAO. 415p.
- Myburgh, M.; Brown, J. 2006. *The potential of information and communication technology as an enabler for agricultural and community development in the Chinyanja Triangle*. Dennesig, South Africa: Agribusiness in Sustainable Natural African Plant Products (ASNAPP).
- Nabhan, H.; Mashali, A.M.; Mermut, A.R. 1999. *Integrated soil management for sustainable agriculture and food security in Southern and East Africa: Proceedings of the expert consultation, Harare, Zimbabwe 8-12 December 1997*. Rome: FAO.
- Nakhumwa, T.O. 2004. Dynamic costs of soil degradation and determinants of adoption of soil conservation technologies by smallholder farmers in Southern Malawi. PhD thesis. Pretoria, South Africa: University of Pretoria.
- NCAR (National Centre for Atmospheric Research). 2005. *A continent split by climate change: New study projects drought in southern Africa, rain in Sahel*. Boulder, CO: National Center for Atmospheric Research. Press Release, May 24, 2005.
- Nederlof, E.S.; Wongtschowski, M.; van der Lee, F., eds. 2011. *Putting heads together. Agricultural innovation platforms in practice*. Bulletin 396. Royal Tropical Institute, Amsterdam: KIT Publishers.
- Neurath, P.M. 1962. Radio rural forums as a tool of change in Indian villages. *Economic Development and Cultural Change* 10: 257-283.
- Njuki, J.M.; Mapila, Mariam A.T.J.; Zingore, S.; Delve, R. 2008. *The dynamics of social capital in influencing use of soil management options in the Chinyanja triangle of Southern Africa*. <http://hdl.handle.net/2263/10188> (accessed on February 14, 2013).
- NSO (National Statistical Office). 2010. *National census of agricultural and livestock 2006/2007. Main report, April 2010*. http://www.nsomalawi.mw/images/stories/data_on_line/agriculture/NACAL/Nacal%20Report.pdf (accessed on May 7, 2013).
- Olson, G.K. 2007. Forest and farming: An analysis of rural livelihood programmes for poverty reduction in Eastern Zambia. MSc thesis, University of Montana, Missoula, Montana. https://www.cfc.unt.edu/grad/Degrees/ICD/pdf/Olson_Zambia_Prof_Paper.pdf (accessed on April 29, 2013).
- Pan, Prasad L.; Hambly-Odame, H. 2010. Creative commons: Non-proprietary innovation triangles in international agricultural and rural development partnerships. *The Innovation Journal: The Public Sector Innovation Journal* 15(2): Article 4.
- Peters, P.E. 2004. Informal irrigation in Lake Chilwa Basin: Stream-bank and wetland gardens. Final research report under BASIS-CRSP, funded by USAID. Madison, WI, USA: University of Wisconsin-Madison.
- PFAP (Provincial Forestry Action Program) II. 2005. *Program completion report: 2000-2005*. Lusaka, Zambia.
- Pretty, J.; Toulmin, C.; Williams, S. 2011. Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability* 9 (1): 5-24.
- Ragab, R.; Prudhomme, C. 2002. Climate change and water resources management in arid and semi-arid regions: Prospective and challenges for the 21st century. *Biosystems Engineering* 81: 3-34.
- Rasmussen, E.M. 1987. Global Climate Change and Variability: Effects on Drought and Desertification in Africa. In: *Drought and hunger in Africa: Denying famine a future*, ed. Glantz, M.H. Cambridge: Cambridge University Press.
- Russell, A.J.M.; Grötz, P.A.; Kriesemer, S.K.; Pems, D.E. 2008. *Recommendation domains for pond aquaculture. Country Case Study: Development and status of freshwater aquaculture in Malawi*. WorldFish Center Studies and Reviews No. 1869. Penang, Malaysia: The WorldFish Center, 52p.
- Ryan, C.M., Williams, M., Grace, J. 2011. Above and below ground carbon stocks in a miombo woodland landscape of Mozambique. *Biotropica* 43:423-432.
- Saka, A.R.; Bunderson, W.T.; Lowole, M.W.; Kumwenda, J.D.T. 1999. Malawi. Pp. 231-246. In: *Integrated soil management for sustainable agriculture and food security in southern and East Africa. Proceedings of the expert consultation, Harare, Zimbabwe, Dec. 1997*, ed. Nebhan, H.; Mashali, A.M.; Mermut, A.R. 1999. Rome: FAO. 415p.
- Saka, A.R.; Green, R.I.; Ngongola, D.H. 1995. *Proposed soil management action plan for Malawi. Final technical report prepared for the World Bank*. Washington, DC: World Bank.
- Shela, O.N. 2000. *Naturalisation of lake Malawi levels and Shire River flows. Challenges of water resources research and sustainable utilization of the lake Malawi Shire River system*. 1st WARFSA/WaterNet Symposium: Sustainable Use of Water Resources, Maputo. <http://www.bscw.ihe.nl/pub/bscw.cgi/d2607929/SHELA.PDF> (accessed on June 11, 2013).
- Stromgaard, P. 1985. Biomass, growth, and burning of woodland in a shifting agriculture cultivation area of south central Africa. *Forest Ecology and Management* 12 (3-4): 163-178.
- The Oakland Institute. 2011. *Understanding land investment deals in Africa: Country reports, Zambia/ Mozambique*. http://www.oaklandinstitute.org/sites/oaklandinstitute.org/files/OI_country_report_zambia.pdf (accessed on June 2, 2013).
- Twomlow, S.; Mugabe, F.T.; Mwale, M.; Delve, R.; Nanja, D.; Carberry, P.; Howden, M. 2008. Building adaptive capacity to cope with increasing vulnerability due to climatic change in Africa: A new approach. *Physics and Chemistry of the Earth* 33 (8-13): 780-787.
- USAID (United States Agency for International Development). 2006. *Presidential Initiative to end hunger in Africa (IEHA): Evaluation report on Mozambique and Southern Africa Regional Programme*, pp. 36-97. <http://expeng.anr.msu.edu/uploads/files/127/presaidfricaPDACI810.pdf> (accessed on December 4, 2012).
- USAID. 2013. *Malawi climate change vulnerability assessment, September 2013. African and Latin American resilience to climate change project*. http://community.eldis.org/.5b9bfce3/Malawi%20VAFinal%20Report_12Sep13_FINAL.pdf. (accessed on February 8, 2014).
- USDA (United States Department of Agriculture). 2013. *Foreign agricultural services. World agriculture production*. <http://www.fas.usda.gov/wap/current/default.asp> (accessed on December 15, 2013).

- Waters-Bayer, A.; Sanginga, P.C.; Kaaria, S.; Njuki, J.; Wettasinha, C. 2009. Innovation Africa: An introduction. In: *Innovation Africa: Enriching farmers' livelihoods*, eds., Sanginga, P.C.; Water-Bayer, A.; Kaaria, S.; Njuki, J.; Wettasinha, C. London: Earthscan, pp. 1-8.
- White, F. 1983. The vegetation of Africa. A descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa. *Natural Resources Research (Paris)* 20: 1-356.
- World Bank. 1992. *Malawi Economic Report on Environmental Policy, Vol. II*. Project appraisal document. Washington, DC: World Bank.
- World Bank. 2006. Mozambique agricultural development strategy; stimulating small holder agricultural growth. AFTSI, Agriculture, Environment, and Social Development Unit, Africa Region. Report No. 32416-MZ.
- World Bank. 2013. *Shire River Basin Management Program*. Nairobi, Kenya: World Bank.
- Worldfish. 2013. Sustainable water usage in the Chinyanja Triangle. <http://www.worldfishcentre.org/our-research/ongoing> (accessed on April 6, 2013).





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