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Impacts of Climate Change on Rice Production and Resiliency Strategies in Mang’ula B

1. Introduction

Tanzania is a country with remarkably rich biodiversity including many endemic species of plants and animals (Burgess et al. 2006). Yet, it is also a country with many development challenges and a large population living in poverty (Rowhani et al. 2011). Meeting the needs of conservation of biodiversity as well as the needs of a growing population presents many challenges. Near the Udzungwa Mountains region of the Eastern Arc Mountains, an area with high levels of biological endemism, a fast growing population largely dependent on agriculture lives in the Kilombero Valley right at the border of conservation areas (Rovero 2007). In the future, as population continues to grow, this is likely to present a challenge to food security of the people in the region. In addition to the obstacle that population growth creates for food secutiry, climate change will present difficulties as well. Changes in precipitation, temperature and seasonal variability are projected to negatively impact agricultural yields across East Africa (Case 2006). In the villages in the Kilombero valley, where many people are dependent on subsistence agriculture, climate change will greatly threaten food security. Without resiliency to climate change, this could lead to necessary expansion into protected conservation areas (Harrison 2006). However, if appropriate resiliency strategies are developed now, it may be possible to better ensure food security as well as conservation of biodiversity in the future even in light of challenges of population growth and climate change.

This paper focuses specifically on the effect of temperature increase on rice production in the village of Mang’ula B. Temperature was chosen as the climate change variable because it has the most reliable models for the future compared with precipitation levels and seasonal variability. In addition, the effects of temperature increase on rice production are well studied, so it was possible to draw predictions for future rice yields in Mang’ula B based on different climate scenarios. Rice was selected as the focus crop because it is the most common crop grown in Mang’ula B and because it is also an important dietary staple. This means the impact of rice production on food security is especially significant, and developing resiliency strategies to ensure continued rice growth despite climate change is vital.

1. Regional Climate Change

Africa’s climate is already changing and will continue to do so at an alarming rate in the decades to come. Temperatures in Africa are very likely to rise by a larger degree in all regions and during all seasons than the global average temperature increase (Christensen et al. 2007). In the past century, average temperatures in Africa rose by 0.7 degrees Celsius, which breaks down to about 0.05 degrees Celsius per decade. In the current century, temperatures are projected to rise between 0.2 – 0.5 degrees Celsius per decade (Case 2006). Tanzania specifically is projected to warm 2 – 4 degrees Celsius by 2100 with the warmest temperatures in the interior of the country during the dry season (Rowhani 2011). Variability of precipitation and seasons are also expected to increase. Based on moderate warming scenarios, East Africa will likely see a 5 – 20% increase in precipitation during rainy seasons and a 5 – 10% decrease in precipitation during dry seasons. Both rains and droughts will likely become more intense in the future. It is likely that the increase in precipitation during the rainy seasons will occur in sporadic large rainstorms rather than regular rains. Increasing temperatures and droughts may lead to desertification in the region (Case 2006). In addition to increasing average temperatures, the number of days and nights considered to be hot based on the current averages is expected to increase. By the 2060s, 19 – 40% of days annually will be considered hot by current standards, and by 2090 19 – 65% of days annually will be considered hot. The occurrence of hot nights will likely increase faster than the occurrence of hot days at 30 – 68% of nights by the 2060s and 47 – 99% of nights by the 2090s (Lizcano et al. 2010).

Due to lack of infrastructure, capital, and secure economic systems, Africa is one of the most vulnerable continents to climate change and climate variability and has some of the lowest levels of adaptive capacity (Boko et al. 2007). Threats of climate change are not the only challenge facing the continent. Many regions suffer from widespread poverty and disease as well as rapid population growth (Case 2006). High population density and growth rates are projected to double the demand for food, water, and land in Africa in the next 30 years (Davidson et al. 2003). This may be especially harmful as the impacts of climate change in East Africa could potentially reverse socio-economic progress or worsen existing conditions (Case 2006). For example, climate change caused temperature increases and precipitation variability will have implications for water availability and food security. Already, food crises per year in Africa have tripled from 1980 – 2000 (Case 2006). The majority of agriculture in Tanzania is smallholder rain fed agriculture, and a large portion of the population relies on agriculture for subsistence, income or a combination of the two (Arndt et al. 2012). As a result, decreasing crop yields due to climate change will likely also lead to deteriorating food security (Arndt et al. 2012).

Figure 1 (Low Scenario assumes a 0.2 degree Celsius increase per decade; High Scenario assumes a 0.5 degree increase per decade)

1. Mang’ula B: Setting and Background

The Eastern Arc Mountains in Tanzania are home to high levels of rich biodiversity with over 150 endemic or near endemic vertebrate species, 800 endemic plant species, and likely hundreds of endemic invertebrates (Burgess et al. 2007). Within the Eastern Arc Mountains, the Udzungwa Mountains are consistently marked as one of the most important areas for conservation prioritization (Burgess et al. 2007). The Udzungwa Mountains have the greatest amount of forest cover and altitudinal range in the East Arc as well as particularly high endemism and number of threatened species (Rovero 2007). The Udzungwa Mountains also provide important ecosystem services for communities both in the region and across Tanzania. Two hydroelectric installations in the Udzungwa Mountains, the Kihansi and the Kidatu, are the source of 70% of Tanzania’s hydroelectric power and 52.6% of total energy (Rovero 2007). The mountains also provide clean water year round for agricultural and domestic use in the Kilombero Valley (Rovero 2007). As of the 2002 census, the livelihoods of 323,000 people living in the Kilombero Valley relied on water from the Udzungwa Mountains (Rovero 2007). The Udzungwa Mountains also create a microclimate that increases rainfall in the valley, which is beneficial for agricultural production (Rovero 2007).

The populations located in the Kilombero Valley are dense and quickly growing and mostly reliant on a mixed wage-subsistence economy in which subsistence agriculture is supplemented with small earnings (Harrison 2006). The villages in the valley are bordered by protected areas in the Udzungwa Mountains as well as commercial agriculture areas, meaning there is little room for expansion of already scarce land for subsistence agriculture (Kikula et al. 2003). The village of Mang’ula B is one of the villages closest to Udzungwa Mountains National Park. According to the latest available census data from 2002, the population of Mang’ula B was 3,992 with a 2.31% annual growth rate (Harrison 2006). The livelihoods of 90% of the people in Mang’ula B are dependent on agriculture, which could threaten the biodiversity of Udzungwa Mountains National Park if reduced agricultural yields due to climate change force expansion (Harrison 2006). Additionally, with or without expansion into currently protected areas, climate change could have significant negative impacts on food security for the village.

1. Regional and Local Agriculture

Agriculture in Tanzania represents 46% of the GDP and is the largest work sector in the country (Rowhani et al. 2011). The majority of the agricultural industry is made up of rural smallholder farmers. Of the 12.5 million people in Tanzania living below the national poverty line, the vast majority are involved in agriculture (Rowhani et al. 2011). Despite its relative importance in Tanzania’s economy, agriculture is underdeveloped, mostly rain-fed, and low intensity (Rowhani et al. 2011). Few external inputs and chemical fertilizers are used in the forms of agriculture in the Kilombero valley (Kassie et al. 2013). As a result, agricultural plots require long fallow periods to replenish nutrients lost through crop growth and erosion. Population growth and competition for land make it more difficult to allow for fallow periods, so continuous cropping has become more common. This leads to increasing soil degradation and low agricultural productivity, which creates a vicious cycle of growing pressure on the land to meet necessary food supplies (Kassie et al. 2013). Especially in areas with high levels of population growth, this will have negative implications for food security, likely to be exacerbated by other pressures in the future.

Mang’ula B has a mixed wage-subsistence economy in which subsistence agriculture is supplemented with small earnings and 90% of villagers participate in agriculture (Harrison 2006). Common crops grown in Mang’ula B include rice, maize, banana, pigeon peas, cow peas, sweet potato, cassava, yams, sesame, and millet. The most common crop and the crop that takes up the most agricultural land is rice. After the rice is harvested, maize and other crops like cassava, sweet potatoes and sometimes pigeon peas are planted in ridges in the fields. Due to the fact that the rice crop relies on water, its ideal growing conditions are in low lying areas and areas with more water access, while the distribution of other crops is less restricted (Mohamed Kambi, personal communication, 2016). Rice is also one of the main dietary staples in Mang’ula B and makes up a large portion of daily calories. The average household of 5 people consumes approximately 200 kilograms of rice per year (Mohamed Kambi, personal communication, 2016). Because rice is so important for both farming livelihoods and subsistence needs, changes in production can have serious implications for the village.

Agricultural inputs and chemical fertilizers are available, but are only utilized by approximately 25% of the population due to high costs. When fertilizers are used they have significant positive impact on crop yields. For the long-grain rice crop, use of agrochemicals and fertilizers in water-logged fields can produce yields of 1,620 kg (12 bags) per acre. Without agrochemicals or water-logged fields, yields are only 270 kg per acre, or 16% of the amount that is produced with agrochemicals. For the short-grain rice crop, yields are 2,025 kg per acre with agrochemical use on water-logged fields and 335 kg per acre without agrochemical use or water-logged fields (See Figure 2; Mohamed Kambi, personal communication, 2016). Villagers refer to the agricultural land as “tired” and recognize the benefits of agricultural inputs, but are constrained by lack of financial means. In addition, access to water-logged rice fields is restricted because these fields are expensive to rent for planting and few villagers can afford this. The yields with use of agrochemicals and water-logged fields therefore present an idealized situation, but a situation which is not the reality for most of the village.

Figure 2 (AC refers to agrochemical use; WL refers to water-logged land)

In late March, rice prices are 1,200 Tsh per kilogram for short-grain rice and 2,000 Tsh per kilogram for long grain rice. Accounting for kilogram yields per acre and prices per kilogram, one acre of long-grain rice with agrochemicals and water-logged fields (LA) can produce a profit of 3,240,000 Tsh, while one acre of long-grain rice with no agrochemicals or water-logged fields (LN) can produce a profit of only 540,000 Tsh. One acre of short-grain rice with agrochemicals and water-logged fields (SA) can produce a profit of 2,430,000 Tsh, while one acre of short-grain rice with no agrochemicals or water-logged fields (SN) can produce a profit of only 402,000 Tsh (See Figure 3). Short-grain rice is more productive in kilogram yields per acre, but prices per kilogram for long-grain rice are significantly higher. This means that despite being less productive in kilograms per acre, an acre of long-grain rice still earns more for a farmer than an acre of short-grain rice. Although long-grain rice is more desirable and profitable per acre, the majority of the rice grown in Mang’ula B is short grain rice as it is more affordable to plant and easier to grow (Mohamed Kambi, personal communication, 2016).

Figure 3 (AC refers to agrochemical use; WL refers to water-logged land)

Currently, one of the main threats to rice production in Mang’ula B is the prevalence of pests and diseases. In particular, cases of bacterial rice blight have devastated crops throughout the village, and many farmers complain of the damage it causes. According to local knowledge, this rice blight had previously not existed in the area, but has recently emerged with rising temperatures. Pesticides and insecticides to treat the rice blight are available, but due to high costs they are not accessible to the majority of villagers (Mohamed Kambi, personal communication, 2016).

Soil erosion is another threat to agricultural productivity. In Tanzania, the most common tillage method is flat cultivation, which causes tillage erosion and water erosion during heavy rains as well as exposing soil to crusting, increasing runoff and reducing soil moisture. This results in loss of nutrients in the top soil as well as overall decreased soil fertility (Paavola 2008). Diversification of crop types is rarely an option due to lack of access to markets and lack of investment capability (Paavola 2008). This means that decreases in specific crop yields could potentially spiral downward without a safety net of other livelihood options.

The rice crop is dependent on the rainy and dry seasons and variations in timing or amount of precipitation have significant impacts on crop yields. If there is too much rain, the rice fields flood and the yields decrease. If there is too little rain, the rice does not get enough water to grow and the yields decrease. The planting and harvesting of the rice crop is determined by the timing of the rainy and dry seasons. Changes in timing of the long and short rainy and dry seasons may force farmer to plant too late or harvest too early, which will also result in reduced yields (Mohamed Kambi, personal communication, 2016).

1. Climate Change Impacts on Rice

Changing temperatures and variability of precipitation will have significant impacts on yields of rice crops. Climate change of greater than 2 degrees Celsius is likely to negatively impact rice yields (IPCC 2014). In addition, increasing periods of drought and high temperatures will likely lead to decreased soil fertility and moisture (Paavola 2008). Rice is a crop that relies on consistent water, so these changes could be detrimental for rice yields. Droughts and decline in water availability will shorten growing seasons and decrease crop yields. In past years of significant drought, rice crop yields have declined seasonally by 50 – 75%, while years with regular rains saw rice crop yields increase by 25% in comparison to years with more variability (Paavola 2008). In the Morogoro area, river flows are projected to become more seasonal with minimal flows less than half of current minimums and maximum flows more than double current maximums (Paavola 2008). This means that ground water levels will likely decline and at the same time severe floods will become more common. The combination of flooding in the wet season and droughts in the dry season along with increased temperatures and evapotranspiration rates will further decrease overall soil moisture (Paavola 2008).

The shift from regular precipitation to more unpredictable and extreme rainfall events may also have negative effects on rice yields by damaging the crop in several ways. First, heavy rainfall and flash floods may knock grains from the stalk causing them to rot in the field close to harvest time (Paavola 2008). Even if the grain is not knocked from the stalk, flooding from heavy rainfall can be disastrous for rice crops. During any stage of growth if a rice plant is fully submerged in either short-term or long-term flooding it is unlikely to recover (IRRI 2015). There is also concern that rising temperatures will increase the occurrence of agricultural pests and diseases in the area. Observations by farmers in the region have shown that warmer temperatures have already coincided with an increase in rice diseases as well as increased problems due to ants and other insects in rice paddies (Mary and Majule 2009).

Based on research conducted by Peng et al. (2004) in the International Rice Research Institute Farm located in the Philippines, rice yields decrease by 7% with every 1 degree Celsius increase in temperature. The reasons for this are only partially understood. With increasing temperature, plant maintenance respiration increases. This results in a reduced amount of assimilates available for plant growth, which results in decreased yields. However, this does not account for the observed degree of yield loss with temperature increase (Peng et al. 2004). Despite the fact that the specific reasons are unknown, it is clear that temperature change greatly impacts rice production. Models for temperature rise in East Africa due to climate change are well studied, and can be used to make predictions for future rice yields in the region.

Without adaptive strategies, the combination of direct and indirect effects of climate change are likely to be disastrous for Tanzania’s rice production. Yield predictions in this paper focus on the impacts of increasing temperature, but pests and diseases and variability in seasons and precipitation will also have significant impacts. However, the models available for precipitation under climate change scenarios are less predictable by nature of increasingly variable timing and amounts of rainfall. This means modeling precipitation over many decades is less likely to be reliable. In addition, the effects of changing seasonal patterns on rice growth and yields in the area are less well studied. There is also little research available on the pests and diseases that are affecting the rice crops in Mang’ula B. Attempting to predict changes in the spread of the pests and diseases for decades in the future without more information would likely be inaccurate. Therefore, although the situation in reality is far more complicated, only temperature was chosen as the climate change factor in determining rice yield models.

1. Methods

In the next century, temperatures in Tanzania are projected to rise between 0.2 – 0.5 degrees Celsius per decade (Case 2006). For the purpose of this study, these numbers were used to establish two climate scenarios. The Low Scenario assumes a 0.2 degree Celsius increase in temperature per decade, while the High Scenario assumes a 0.5 degree Celsius increase in temperature per decade. Using 2016 as a baseline, temperature increase was calculated under the Low Scenario and the High Scenario for 2050, 2080, and 2100. Based on the amount of temperature change and assuming a 7% decline in rice yields per 1 degree Celsius increase, percent change in rice yields was calculated for each year and climate scenario. The changes in yields also assumed 2016 as a baseline. Using the percent change and current rice yield data for Mang’ula B, future yields were predicted for each year and climate scenario. These calculations were repeated for each rice type: SN, SA, LN, and LA. These yield results were measured in kilograms per acre.

Future rice consumption was calculated based on population growth and current consumption. In Mang’ula B, the average household of 5 people consumes 200 kilograms of rice per year. Based on this number, the average annual rice consumption is 40 kilograms per person (Mohamed Kambi, personal communication, 2016). According to the 2002 census data and 2012 unpublished census data, the population growth rate of Mang’ula B was calculated to be 2.31%. This growth rate was used to predict population for 2016, 2050, 2080, and 2100. The population was multiplied by the consumption rate of 40 kilograms per person to find the total consumption of the village in kilograms per year. This was repeated for each year in the model.

The total amount of agricultural land in Mang’ula B is 1052.03 acres, and 417.18 acres or about 40% of that land is dedicated to rice cultivation (Schumacher 2015). The yield predictions in kilogram per acre were multiplied by the total acreage of rice cultivation, 417.18 acres, to find the totally rice production. This was repeated for each year, scenario, and rice type. Data on the distribution of rice types and agricultural methods is not known, so for the sake of the models each assumed 100% of the land was cultivated the same way.

1. Results

In the Low Scenario, temperatures increased from 2016 levels by 0.68 degrees Celsius by 2050; 1.28 degrees Celsius by 2080; and 1.68 degrees Celsius by 2100. In the High Scenario, temperatures increased from 2016 levels by 1.7 degrees Celsius by 2050; 3.2 degrees Celsius by 2080; and 4.2 degrees Celsius by 2100. Based on the Low Scenario temperature increases, rice yields decreased from 2016 levels by 4.76% by 2050; 8.96% by 2080; and 11.76% by 2100. Based on the High Scenario temperature increases, rice yields decreased from 2016 levels by 11.9% by 2050; 22.4% by 2080; and 29.4% by 2100. These percentage decreases were assumed to be equal across both rice types with or without agrochemicals and water-logged fields.

Due to the fact that the majority of farmers in Mang’ula B farm short-grain rice and do not have financial access to agrochemicals or water-logged fields, the overall yield models used results for SN. However, long-grain rice and use of agrochemicals were also calculated and considered in population models for comparison purposes. Yields for SN were 335 kilograms per acre in 2016 (Mohamed Kambi, personal communication, 2016). For the overall yield models under the Low Scenario, yields were 319.0875 kilograms per acre for 2050; 304.984 kilograms per acre for 2080; and 295.604 kilograms per acre for 2100. In the High Scenario, yields were 295.135 kilograms per acre in 2050; 259.96 kilograms per acre in 2080; and 236.51 kilograms per acre in 2100 (See Figure 4). Yields for SA were 2,025 kilograms per acre in 2016 (Mohamed Kambi, personal communication, 2016). In the Low Scenario, yields were 1,931.61 kilograms per acre in 2050; 1,843.56 kilograms per acre in 2080; and 1,786.86 kilograms per acre in 2100. In the High Scenario, yields were 1784.025 in 2050; 1571.4 in 2080; and 1429.65 in 2100. Yields for LN in 2016 were 270 kilograms per acre (Mohamed Kambi, personal communication, 2016). In the Low Scenario, yields were 257.148 kilograms per acre in 2050; 245.808 kilograms per acre in 2080; and 238.248 kilograms per acre in 2100. In the High Scenario, yields were 237.87 kilograms per acre in 2050; 209.52 kilograms per acre in 2080; and 190.62 kilograms per acre in 2100. Yields for LA were 1,620 kilograms per acre in 2016 (Mohamed Kambi, personal communication, 2016). In the Low Scenario, yields were 1,542 kilograms per acre in 2050; 1,474.848 kilograms per acre in 2080; and 1,429.488 kilograms per acre in 2100. In the Low Scenario, yields were 1,427.22 kilograms per acre in 2050; 1,257.12 kilograms per acre in 2080; and 1,143.72 kilograms per acre in 2100.

Figure 4 (Low Scenario assumes a 0.2 degree Celsius increase per decade; High Scenario assumes a 0.5 degree increase per decade; Rice yields were calculated based on a 7% decrease per 1 degree Celsius temperature increase for short-grain rice without agrochemicals or water-logged fields)

Based on 2.31% growth rate from 2012 census data, the current population of Mang’ula B is approximately 5,515. The population for 2050 is 12,099; the population for 2080 is 17,621; and the population for 2100 is 38,401. Assuming annual rice consumption remains consistent at 200 kilograms per 5 person household, the total rice consumption for 2016 is 220,640 kilograms, the consumption for 2050 is 483,960 kilograms, the consumption for 2080 is 704, 840 kilograms, and the consumption for 2100 is 1,536,040 kilograms. With 417.18 acres of land for rice cultivation, total production in 2016 for SN is 139,755.3 kilograms. Assuming area of rice cultivation stays consistent at 417.18 acres, in the Low Scenario for SN, total production is 133,116.923 kilograms in 2050; 127,233.225 kilograms in 2080; and 123,320.077 kilograms in 2100. In the High Scenario for SN, total production is 123,123.585 kilograms in 2050; 108,450.113 kilograms in 2080; and 98,708.9598 kilograms in 2100. Total production in 2016 for SA is 844,789.5 kilograms. In the Low Scenario for SA, total production is 805,829.060 kilograms in 2050; 769,096.361 kilograms in 2080; and 745,442.255 kilograms in 2100. In the High Scenario for SA, total production is 744,259.55 kilograms in 2050; 655,556.652 kilograms in 2080; and 596,421.387 kilograms in 2100. Total production for 2016 for LN is 112,638.6 kilograms. In the Low Scenario for LN, total production is 107,277.003 kilograms in 2050; 102,546.181 kilograms in 2080; and 99,392.3006 kilograms in 2100. In the High Scenario for LN, total production is 99,234.6066 in 2050; 87,407.5536 in 2080; and 79,522.8516 kilograms in 2100. Total production in 2016 for LA is 675,831.6 kilograms. In the Low Scenario for LA, total production is 643,662.016 kilograms in 2050; 615,277.089 kilograms in 2080; and 596,353.804 kilograms in 2100. In the High Scenario for LA, total production is 595,407.64 kilograms in 2050; 524,445.322 kilograms in 2080; and 477,137.11 kilograms in 2100 (See Figure 5).

Figure 5 (Low Scenario assumes a 0.2 degree Celsius increase per decade; High Scenario assumes a 0.5 degree increase per decade; Rice yields were calculated based on a 7% decrease per 1 degree Celsius temperature increase and current yield data)

1. Resilient Rice Strategies

In recent years, research has been conducted by the International Rice Research Institute (2013) to develop rice strains with higher yields and greater resistance to various threats. Strains specific to East Africa have been developed and tested in partnership with local groups and agencies such as the Tanzania National Rice Research Program and the Agricultural Research Institute (ARI)- KATRIN. Two of the most promising strains for East Africa are the IR05N 221 strain, and the IR03A 262 strain. The IR05N 221 strain is referred to as Komboka, which means “to be liberated”, and the IR03A 262 strain is referred to as Tai, which means “eagle”. The Komboka strain and the Tai strain yield 2,386.3 kilograms per acre and 2,753.4 kilograms per acre respectively (IRRI 2013). Both of these yields are significantly higher than current yields of common short and long-grain rice strains in Mang’ula B even with agrochemicals and water-logged fields (See Figure 6).

Figure 6

The Komboka and Tai strains are desirable to farmers for reasons other than yields as well. The Komboka variety has an aroma that makes it more appealing to farmers and customers in some parts of the country and therefore makes it marketable. The Tai variety is nonaromatic, and therefore may be better fitted for areas of the country that value aroma less (IRRI 2013). People in Mang’ula B have a moderate association between rice aroma and quality, so the Komboka variety may be more suitable, particularly for commercial markets (Mohammed Kambi, personal communication, 2016). Both the Komboka and the Tai strains are valued for the quality of their grains. They have long, slender, translucent grains, which remain soft after overnight storage and therefore have a favorable texture for cooking (IRRI 2013). This makes these strains more favorable than previous hybrid varieties, which were seen as undesirable because they lacked flavor (Mohamed Kambi, personal communication, 2016).

Several traits of these rice varieties make them more resilient to threats. First, both Komboka and Tai strains can be grown twice a year: once during the rainy season from January to May and again during the dry season from August to December (IRRI 2013). This can help increase total annual yields, and decrease seasonal vulnerability especially as seasons become more variable. If one crop harvest is damaged due to unpredictable patterns of drought and precipitation, there will still be another harvest in the same year. Both rice strains also exhibit levels of heat and drought tolerance, which will be important to adapt to climate change. Compared to current popular short-grain and long-grain rice strains, Komboka and Tai ripen faster by one to two weeks (IRRI 2013). This can also help to build resilience against changes in seasons. If the rice crop can be harvested sooner after planting, it may decrease the chance of occurrence of severe weather events that could damage yields. Both Komboka and Tai strains also exhibit moderate resistance to common rice diseases including leaf blast and bacterial leaf blight. Bacterial rice insecticides are affordable only to a small portion of the population. Therefore, in the present conditions, little can be done to combat rice blight (Mohamed Kambi, personal communication, 2016). The conditions and spread of rice blight are likely to increase with climate change (Paavola 2008). Therefore, implementing a strain of rice with resistance to blight could have important impacts on current and future yields.

1. Challenges in Implementing Resilient Rice in Mang’ula

Although Komboka and Tai rice strains have higher current yields, more desirable grains, and resiliency against climate change and disease, there are still obstacles in introducing them to Mang’ula B successfully. Cost would likely be a significant constraint. Due to the fact that both strains were only introduced commercially in Tanzania in 2014 and have not yet entered the market in this region, there is no information on the cost of the seeds or the price at which the harvested grain sells. Currently, the majority of farmers in Mang’ula B do not buy seeds annually, but rather store from the end of each harvest to plant for the next season. This is less productive, but the initial costs of planting the rice crop are lower each year (Mohamed Kambi, personal communication, 2016). This indicates that farmers are unlikely to adopt strategies with upfront costs even if the benefits exceed the costs in the long run. The fact that the majority of farmers in Mang’ula B plant short-grain rice without agrochemicals is also evidence of this. Short-grain rice is cheaper to plant than long-grain rice, and it is cheaper to go without agrochemicals. However, this strategy decreases yields and profits. Although the exact costs of Komboka and Tai are unknown, they are likely to be initially higher than more common strains due to their high yields and desirability. If farmers remain unwilling to face upfront costs, this could limit the adoption of these new strains.

There are several possible reasons farmers may be reluctant to pay upfront costs even in situations of long-term benefit. There is little access to financial capital in the region (Harrison 2006). In villages where agriculture is the main source of income, such as in Mang’ula B, the time immediately following the harvest is when villagers have the greatest access to capital, and the time farther from the harvest, such as before planting for the next season, is when villagers have the least access to capital and therefore the highest financial vulnerability (Harrison 2006). This financial vulnerability could influence decisions not to choose agricultural options with upfront costs at the beginning of the planting season. In addition, the risk of various threats to agricultural yields could prevent farmers from choosing long-term benefits over short-term costs. For example, if a farmer spends money on a better seed variety, but loses the crop due to rice blight, drought, or flooding, it will result in an overall loss. Because there is little access to financial capital to begin with, a loss of this sort would likely be significant and could prevent recovery from the crop loss. For similar reasons, farmers may resist adoption of new rice strains simply because they are unfamiliar. Farmers may be more willing to face lower yields and known risks than to adopt a new strain with potentially higher yields but unknown risks.

Successful implementation of Komboka and Tai rice strains in Mang’ula B would have to address these challenges. Although prices of these rice grains are unknown, the productivity and desirability would make it likely that they are higher than those of currently used grains. If this is the case, the initial cost to switch rice strains may be significant, but it will likely pay itself back quickly. And while the initial cost may exceed what local farmers are able or willing to pay, it may be a reasonable amount for a government or N.G.O aid program. Such a program could help the village of Mang’ula B transition to resilient strains of rice by offsetting the initial costs of the switch. This would only require temporary financial support, because the high yields, resiliency, and desirability of the new rice strains would likely soon offset the cost of purchasing seeds.

Incorporating education aspects into a program like this would also benefit resiliency. Farmers would learn all the advantages of the new rice strains compared to the old to understand the reasons for the change. In addition, other climate change resilient agricultural practices could be taught. For example, sustainable agriculture practices such as legume intercropping, legume crop rotations, conservation tillage, soil and water conservation practices, and animal manure usage could be combined to create further adaptive capacity to climate change. Education will increase awareness of these techniques and their benefits (Kassie et al. 2013). Education programs can also teach villagers about the likely impacts of climate change in the area and how they will affect agriculture. This knowledge can empower villagers to make decisions and adapt to climate change.

The challenges and potential solutions presented in this section only describe possible situations. More research on the cost of rice seeds, the price of harvested rice, and the socio-economic context of Mang’ula B are necessary to draw accurate conclusions about any obstacles or solutions of introducing Komboka and Tai varieties of rice to the village.

1. Conclusions

Climate change is already impacting the village of Mang’ula B. Farmers have noticed increases in temperature accompanied by increased incidences of rice blight. Amount of precipitation and timing of the rainy and dry seasons has also become increasingly variable. In the future, climate conditions will continue to change. Within this century, temperature in Tanzania will increase between 2 – 4 degrees Celsius (Rowhani et al. 2011). This will significantly lower yields for the rice crop. Although less exact predictions are available, it is likely that changes in precipitation will lead to more frequent seasonal droughts and floods, which will also reduce rice yields.

The village of Mang’ula B is almost entirely reliant on agriculture. 90% of villagers rely on agriculture for subsistence, livelihood, or a combination of the two (Harrison 2006). Because subsistence agriculture is so widespread in the village, many villagers do not have anything to fall back on if agriculture fails. Rice is one of the main crops grown in Mang’ula B and is also an important dietary staple. Therefore, it is important to maintain a steady and healthy rice crop. However, due to the direct and indirect impacts of climate change, this may no longer be possible in the future. This threat to food security is further multiplied by steady population growth in the village. The population of Mang’ula B is growing at 2.31% per year. The growing population means rice consumption levels are increasing as yields are going down due to climate change. By some yield estimates depending on the type of rice, consumption has already outstripped production, meaning all villagers are not able to get the desired amount of rice in their diets. In the future, as population continues to grow and yields for all types of rice continue to decline, it will become more and more difficult to meet consumption needs with rice. The climate scenarios used to develop these yield estimates are by no means the most extreme. In fact, they are conservative to moderate possibilities for the future. This means the situation for agricultural production and food security could in fact be worse than modeled.

The development of resilient and productive rice strains in Tanzania is a promising method of adapting to the threat of climate change. Previous hybrid rice plants have been rejected due to lack of flavor and susceptibility to disease. However, recently developed strains have been able to combine several areas of resilience along with high yields and desirable flavor and grain quality. The Komboka and Tai rice plants are resilient to rice blight, which affects many farms in Mang’ula B. These plants are also fast growing and maturing, which builds resilience against extreme weather and temperature and allows for multiple harvests in a year. The Komboka and Tai are also both significantly more productive per acre than varieties currently used in Mang’ula B.

Adopting new rice strains will not in itself be sufficient to ensure food security in Mang’ula B. It will be necessary to conduct more research not only on resilient rice varieties, but also on other agricultural and economic climate change plans. These strategies will not be simple and may be initially costly or require cultural or social adaptation. However, developing resiliency to climate change is necessary. If no action is taken, the implications of climate change on food security in Mang’ula B will be disastrous. In addition, waiting to address the problem will likely make it more difficult to find and implement solutions. Without resiliency solutions, it will also become harder to ensure the continued protection of the important biodiversity in the nearby Udzungwa Mountains. Under threats to food security, resource extraction or encroachment on protected areas may increase. Therefore, it is important to address climate change while there is still time to build resiliency. These changes are already beginning to occur, and crop consumption is already beginning to overtake agricultural production. In order to ensure the best chance for the future, the time to build resiliency to climate change is now.

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