Land Policy, African Agriculture, Food Security, Climate Change Adaptation and Mitigation

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Abstract

In this thesis I attempt to answer the question, *'what role can land reform play in improving African agriculture's ability to contribute to climate change adaptation, carbon mitigation, and food security?'* This question is designed to explore the feasibility of using international carbon markets as a sustainable development strategy to improve adaptation and food security, in addition to mitigation, in three African countries: Ethiopia, Kenya, and South Africa. In all cases I found that land policies could discourage African agriculture to contribute to climate change adaptation, carbon mitigation, and food security. There are several ways that African countries could start to improve the incentives for carbon mitigation projects with adaptation and food security co-benefits. First, improve tenure security and land access. Second, define carbon rights. Third, examine the capabilities of African farmers to ensure they have the skills and resources to implement agricultural mitigation projects with adaptation and food security co-benefits.

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Executive Summary

In this thesis I attempt to answer the question, *'what role can land reform play in improving African agriculture's ability to contribute to climate change adaptation, carbon mitigation, and food security?'* This question is designed to explore the feasibility of using international carbon markets as a sustainable development strategy to improve adaptation and food security, in addition to carbon mitigation, in Africa.

I use a multi-disciplinary case study approach to examine this question for the case of Ethiopia, Kenya, and South Africa. I use seven criteria to methodically answer this question:

1. Identify how climate change is likely to affect agriculture in that country;
2. Description of land policy institutions and administration;
3. Multi-disciplinary analysis of the evolution and sustainability of land policy;
4. Impact of land policy on economic development and food security;
5. Anticipated impact of land policy on farmers decision to adopt adaptation strategies;
6. Anticipated impact of land policy on farmers decision to mitigate carbon;
7. Opportunities for improvement of land policy in terms of improving development, food security, adaptation, and carbon mitigation benefits.

In all cases I found that land policies could discourage African agriculture to contribute to climate change adaptation, carbon mitigation, and food security. In Ethiopia, tenure security is weak and all land is owned by the government. This reduces the incentive to invest in long-term projects that improve adaptive capacity, agricultural production, and carbon mitigation.

In Kenya, land policies are based on colonial-era policies that protected property rights. However, land-grabbing is common, even property with legal title is vulnerable to

expropriation. As a result, there are limited incentives for Kenyan farmers to invest in projects that deliver climate change adaptation, carbon mitigation, and food security co-benefits.

In contrast, South Africa has strong property rights protection, but only if the farm is not in the homelands. In the homelands, traditional leaders decide land policy but are unaccountable to anyone. As a result, South African farmers may benefit from investing in joint adaptation, mitigation, and food security projects. However, because the commercial farm sector is dominated by 60,000 wealthy white farmers, using agricultural mitigation projects to improve adaptation and food security would only benefit a small percentage of South Africa's rural population.

There are several ways that African countries could start to improve the incentives for carbon mitigation projects with adaptation and food security co-benefits. First, improve tenure security and land access. Tenure security is important to encourage long-term investment. Land access is important to allow nomadic pastoralists to flexibly adapt to climate change.

Second, define carbon rights. In all countries examined, no country has defined who owns carbon. This creates investment uncertainty for agricultural carbon mitigation projects because it is unclear if the carbons can be sold and therefore generate a return for investors. Rectifying this situation would substantially improve the investment climate in agricultural mitigation projects.

Third, the capabilities of African farmers should be examined to ensure they have the skills and resources to implement agricultural mitigation projects with adaptation and food security co-benefits. In some cases, these skills may be variations of current farming techniques. However, in all cases, farmers will need to understand how agricultural activities contribute to carbon emissions and mitigation. Furthermore, educating farmers on how they can monetize their activities through international carbon markets is an important step to encouraging farmers to participate in agricultural carbon mitigation projects.

Other policy implications would depend on the specific country circumstances. For example, in South Africa, commercial farm land cannot be sub-divided. Therefore, it would be advisable that policy-makers examine their land policy context to ensure that policy reforms contribute to an improved outcome - not only in terms of improving food security, climate change adaptation, and carbon mitigation – but also in terms of the country's sustainable development.

1. Introduction

Agriculture is seen as a potential solution to climate change because of agriculture's role in managing the majority of the world's land (The Terrestial Carbon Group, 2008). Terrestrial carbon sequestration is thought to be able to provide 25% of the mitigation required to meet the 2°C target (Lal, 2009). Furthermore, terrestrial carbon sequestration is also thought to improve the productivity of agriculture through moisture retention and increasing the soil's carbon content (FAO, 2010). This could have positive linkages with improving food security and rural development in developing countries. This opens the exciting prospect that agriculture in the developing countries could implement a sustainable development policy that simultaneously improves food security, climate change adaptive capacity, carbon mitigation, and development.

However, for agriculture in developing countries to be a realistic solution for climate change, the land policy of developing countries would have to allow such activities at scale. Land policy is how land allocation, tenure, and investment are governed. It can be done by formal and informal means. This is especially pertinent in Africa where there may be multiple, overlapping land institutions governing land.

In this thesis, I attempt to answer the question, *'what role can land reform play in improving African agriculture's ability to contribute to climate change adaptation, carbon mitigation, and food security?'* This research question is essentially examining is there a need for land policy reform in African countries to generate and capture the benefits from agricultural mitigation projects with food security and adaptation co-benefits. African countries were chosen because

Africa is considered the most vulnerable region in the world to climate change (Parry, Canziani, Palutikof, van der Linden, & Hanson, 2007; Thornton et al., 2006). In this thesis, I concentrate on farm-level impacts of land policy; hence, I will concentrate on the production component of food security. Similarly, I will also be focusing on farm-level adaptation strategies rather than strategies that could be taken by government.

The thesis is structured in the following way. In section 2, I review the literature for climate change, land policy in developing countries, and land policy and climate change. In section 3, I describe the method used to analyze the case studies. In section 4, I analyze the case studies. Section 5 is where I draw some general policy implications. And I conclude in section 6.

2. Literature Review

The literature on the interactions between land reform, African agriculture, food security, and climate change adaptation and mitigation has developed independently in three main strands:

1. Agriculture and climate change;
2. Land policy in developing countries; and
3. Land policy and climate change.

In this literature review, I examine the literature through these three strands. In the first, I examine the literature in terms of the climate change impact on agriculture, agriculture's impact on climate change, food security and human development, adaptation strategies, mitigation strategies, and the synergies between adaptation and mitigation in agriculture. In the second strand, I restrict my attention to land policies in Africa, particularly in the case study countries of Ethiopia, Kenya and South Africa. In the third strand, I look at the emerging literature on land policy and climate change.

2.1.Agriculture and Climate Change

Agriculture is a fundamental activity that is vital for humanity's survival. It produces the food that sustains the world's populations. It also produces the world's fiber used to manufacture the garments that clothes us. Agriculture also has the closest relationship with the earth's natural resources of all humanity's activities. Its impacts on land, water and ecosystems are disproportionately greater than other human activities. Of all of human activities, agriculture is also the most vulnerable to environmental changes, especially climate change.

Agriculture is both a key contributor to climate change and a sector that will be disproportionately affected by climate change. Agricultural cropping and livestock-raising activity accounts for 13.5% of the global total emissions (IPCC, 2007a). A further 17.4% of global carbon emissions is attributable to land use change and forestry activities from land clearing. In total, agriculture may be responsible for over 30% of global emissions, more than emissions from energy supply.

Hotter temperatures as a result of climate change will affect agriculture production and therefore the supply of food. Climate change's impact on food security will be especially problematic for the most vulnerable developing countries. Diminished water security would also severely affect human well-being in addition to food production. Furthermore, the degradation of natural resources would also increase vulnerability of humanity to the impacts of climate change.

Developing countries will be particularly affected by climate change impact on agriculture for several reasons. First, 70% of developing countries' population is employed in agriculture so any impact on agriculture would affect a large proportion of the world's population (Parry et al., 2007). Secondly, agriculture in developing countries has lower adaptive capacity because of lower access to technology and advanced knowledge. Third, many developing countries are dependent on the export income of agricultural products so any impact that would have an impact on agriculture would also have a large impact on these countries' economies and their capacity to adapt (Bates, 2005). Fourth, reduced availability of food could affect the well-being and productivity of a country's population. In the worst case, this could lead to humanitarian catastrophes such as famines. Fifth, negative impacts on agriculture could cause tensions within and between neighboring developing countries such as migrating rural populations or conflicts over water.

Clearly, developing countries have an interest in the impacts of climate change on agriculture because of its impacts on short-term food and water security and longer term implications for development. Developed country also has an interest because of the mitigation opportunities from agriculture.

This paper will examine opportunities for global cooperation to adapt to climate change and synergies with mitigation and sustainable development.

2.1.1. Impacts

Agriculture is both affected and is affected by climate change. The mechanism with which agriculture is affected by climate change is through climate change's impact on crop production for food or pasture. There are four key ways crop production is influenced by climate change (Fischer, Shah, & van Velthuizen, 2002; Kurukulasuriya & Rosenthal, 2003):

1. **Changes in temperature and precipitation** – Climate change may change the duration and frequency of rainfall and therefore the duration of the growing season. Climate change is also expected to increase average temperatures, which affects soil moisture and ultimately the growth and survival of crops.
2. **Carbon effect** – Plants use the photosynthetic process to convert water and sunlight into nutrients. Increasing the carbon concentration in the atmosphere can have a positive effect on crop yield and water use efficiency by increasing the rate of photosynthesis (Kurukulasuriya & Rosenthal, 2003). C_3 crops (e.g. wheat, rice and soy beans) benefit more from increased atmospheric carbon than C_4 plants (e.g. maize, millet, sorghum, grass, and many weeds).
3. **Water availability** – Increased temperatures affects water availability in two ways. First, in a positive way by increasing the rate of runoff by increasing the melting of glaciers or increased rainfall in some regions. Second, in a negative way by increasing the rate of evaporation which reduces soil moisture and runoff as well as increased droughts.
4. **Increased frequency of extreme events** – Climate change is expected to increase the frequency of droughts, floods and other extreme events through changes in precipitation and temperature.

These four channels directly affect production by influencing the yield. Through yield impacts, climate change affects the productivity of agriculture. That is, climate change affects the efficiency of agricultural production systems to convert inputs such as land, water, labor and capital into agricultural products.

Agriculture can affect climate change through the reduction of carbon sinks or increasing emissions. Land and forests are significant carbon sinks and currently sequester X amount of carbon per year. Agriculture directly affects carbon sinks through land use conversion from natural ecosystems to agricultural land (e.g. land clearing, draining of peat lands). Agricultural production can also contribute directly to emissions through methane emissions from ruminant livestock (e.g. cattle, pigs, sheep, goats), methane and nitrogen emission from manure, nitrogen from fertilizer use and production, carbon release from land clearing, methane emissions from rice, and carbon emissions from farming equipment and irrigation (Seeberg-Elverfeldt, 2010).

This section will be organized in terms of reviewing the impacts from the source and how it is transmitted to agricultural production. How agriculture influences agriculture in terms of atmospheric concentrations of greenhouse gases will be discussed. The impact on agricultural production will then be traced through in terms of broader impacts first on food security and human development, and then onto broader economic impacts at the national and international level. This is to illustrate the overall impact of climate change on agriculture and how it affects downstream human activities.

2.1.1.1. Climate Change Impact on Natural Resources

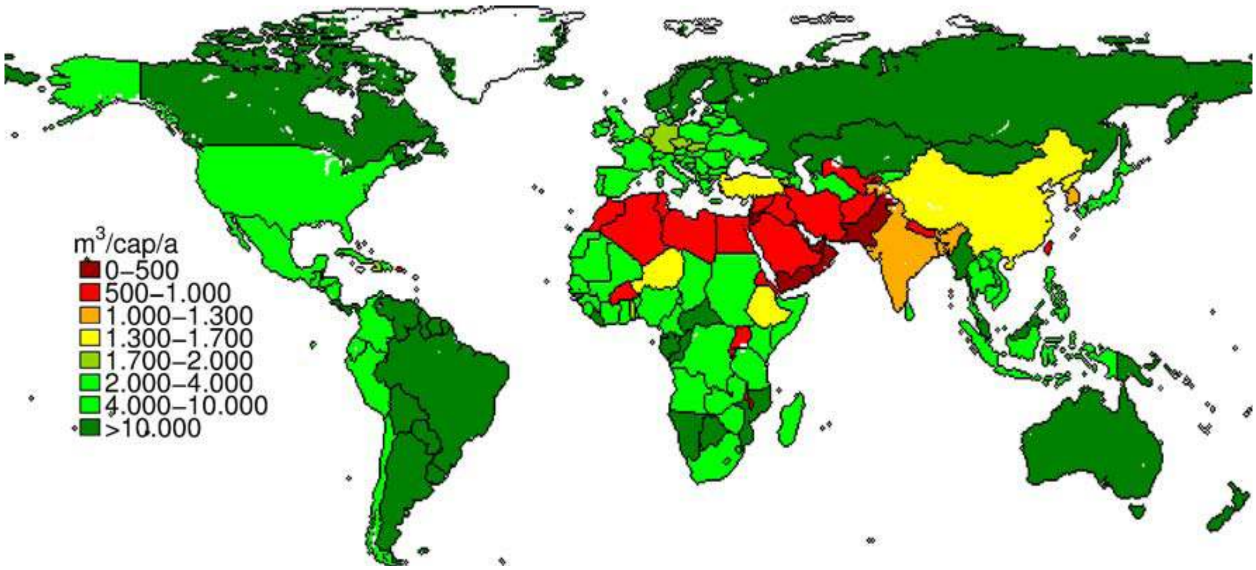
Agricultural production relies on natural resources, primarily land and water. Land determines the suitability of agricultural production by the extent of soil fertility. Water availability determines the extent of production through crop yields. Climate change is expected to affect agricultural production by changing the capacity of land and water to support agriculture. In some cases, climate change may destroy the ability of land to be used for agriculture. In other cases, climate change may turn previously unproductive land into valuable agricultural land. The impacts of climate change on natural resources will differ from region to region.

Under climate change, land in Africa is projected to become less suitable for agriculture (Fischer et al., 2002). Other regions are also expected to experience reduction in land suitability for agriculture (e.g. South America, Southeast Asia). Conversely, North America and the Russian Federation are expected to experience an *increase* in land suitable for agriculture.

Water is also expected to be affected by climate change and the impacts are expected to be region-specific (Fischer et al., 2002; IPCC, 2007b; Nelson, Palazzo, Ringler, Sulser, & Batka, 2009). In an agricultural context, water can be thought of as ‘blue’ or ‘green’ water (Falkenmark, Rockstrom, & Karlberg, 2009). Blue water is defined as runoff stored in aquifers, lakes, wetlands and reservoirs. Green water is infiltrated rainfall in the unsaturated soil layer forming soil moisture. Green water can be further categorized as non-productive flow (evaporation) or productive flow (i.e. used by plants). Falkenmark et al. (2009) estimated that rainfed agriculture consumes 5000 km^3/year of green water while irrigated agriculture consumes 2000 km^3/year. Climate change is expected to increase evapotranspiration which would decrease both green and blue water (Falkenmark et al., 2009).

Mapping of water endowment per capita shows that there are countries that are particularly vulnerable to increased water scarcity (Figure 1). Water scarcity is defined by Falkenmark et al (2009) as less than 1300 m^3 of water per year. Currently, the most vulnerable countries are in North Africa and the Middle East. India is marginally water scarce at 1,000-1,300 m^3 per year and China is slightly less water scarce. This implies that increased water scarcity from climate change could be particularly problematic for the world’s two most populous nations.

Figure 1 Map of Water Resources per capita (both green and blue water)



Source: Falkenmark et al. (2009).

2.1.2. Impacts of Climate Change on Agricultural Production

As the discussion on land and water suggests, the impact on agriculture production would differ between regions. Climate change impacts will also differ by crops and livestock species.

2.1.2.1. Crop Yield

Easterling et al. (2007) found that crop productivity would differ by latitude. Crop productivity would improve in high latitude countries (i.e. cooler and wetter climates) than mid- to low-latitudes. Nelson et al. (2009) modeled climate change impacts by crops and regions. In the absence of carbon fertilization, irrigated cropping is expected to experience greater production declines than rainfed agriculture. Carbon fertilization reduces production declines or reinforces positive production effects of climate change. However, the magnitude of carbon fertilization is subject of debate (Easterling et al., 2007; Muller, Bondeau, Popp, Waha, & Fader, 2009). At a global level, irrigated agriculture is expected to be more vulnerable to climate change.

However, local impacts may be different from global averages. For example, in sub-Saharan Africa, irrigated maize is expected to cope better with climate change (Nelson et al., 2009).

Muller et al. (2009) modeled crop yields and food self-sufficiency. Crop yields are estimated to increase with carbon fertilization by 8%-22% globally by 2050 but decline if there was no carbon fertilization effect. Even with the yield increases under carbon fertilization, food self sufficiency is projected to decline because population growth is faster than increases in crop yield.

2.1.2.2. Livestock

Climate change impacts on crops and increased temperatures are expected to have a negative impact on livestock production (Easterling et al., 2007; Nelson et al., 2009). Carbon fertilization is expected to reduce the quality of feed which leads to lower nutrition availability for livestock (Easterling et al., 2007). Increased temperatures also reduces livestock productivity and leads to reduced supply of livestock products through heat stress (Easterling et al., 2007). Furthermore, higher temperatures and higher frequency of extreme events also increases the probability of livestock mortality (Easterling et al., 2007). These combined effects leads to higher prices of livestock products globally as a result of reduced supply (Nelson et al., 2009). However, carbon fertilization may reduce the price increases.

2.1.2.3. Agricultural Pests and Diseases

Some studies have suggested that increased carbon fertilization could make crop plants more vulnerable to pests and diseases (Easterling et al., 2007; Muller et al., 2009). Increased temperatures could also create favorable conditions for pests and diseases to move from low latitude regions (i.e. tropical regions) to mid- to high-latitude regions (Easterling et al., 2007).

The global impacts of on agricultural production because the increase in pests and diseases outbreaks have not been integrated in global models (Easterling et al., 2007).

2.1.3. Impact of Agriculture on Climate Change

Agriculture, forestry and other land uses (AFOLU) sectors contribute over 30% of global greenhouse gas emissions in 2004 (World Bank, 2010d). Livestock production and deforestation are the main sources of AFOLU greenhouse gas emissions. Land can also be used to store carbon through soil and plants (Nelson, 2009; World Bank, 2010d). This section will review how agriculture influences climate change through direct emissions from production, and indirectly from deforestation. Mitigation opportunities will be discussed in 2.1.7.

2.1.3.1. Agriculture Emissions

In 2005, global agricultural emissions were estimated at 5.1-6.1 Gt carbon equivalent per year (CO_2-eq/year) (Smith et al., 2007). Of the global total, 3.3 Gt CO_2-eq/year is from methane, 2.8 Gt CO_2-eq/year from nitrogen, and the rest from carbon dioxide. The significance of agriculture's greenhouse gas composition is the higher global warming potential of methane and nitrogen compared to carbon dioxide. Methane and nitrogen have 62 and 275 times the global warming potential of carbon dioxide when they are first released into the atmosphere (Robertson & Grace, 2004). Agriculture is also a major source of both methane and nitrogen (IPCC, 2007a). Methane is emitted from ruminant livestock (i.e. cattle, sheep and pigs) and rice grown in flooded conditions (Smith et al., 2007). Nitrogen is emitted from application of nitrogen-based fertilizers (Smith et al., 2007). Carbon dioxide is emitted from use of farm machinery and irrigation pumping (Robertson & Grace, 2004; Seeberg-Elverfeldt, 2010).

Agriculture also directly contributes to reducing land's capacity to sequester carbon (Nelson, 2009). Unsustainable soil management practices have released 30-40 metric tons of carbon per hectare. Furthermore, drainage of wetlands and peat swamps has resulted in even more carbon release. Restoring these degraded lands has potential to reduce carbon emissions.

2.1.3.2. Deforestation

Deforestation is estimated to have contributed 5.8 Gt CO_2-eq/year during the 1990s (Nabuurs et al., 2007). Agricultural expansion is a key driver of deforestation, especially in developing countries (Nelson, 2009). Deforestation activities has cleared 7.3 million ha/year (net of reforestation and afforestation efforts) (Nabuurs et al., 2007).

Globally, deforestation is driven by demand and supply factors. Increased demand for food from rich countries has encouraged agricultural expansion in countries with forests (e.g. Indonesia and Brazil) (Chomitz, Buys, De Luca, Thomas, & Wertz-Kanounnikoff, 2007). In these countries, agricultural technology is based on shifting agriculture rather than intensive agriculture. As a result, agricultural expansion is driven by farmers accessing new, fertile land to meet growing demand for food (Nelson, 2009). Other local factors also influence deforestation rates such as government policies (Chomitz et al., 2007; Geist & Lambin, 2002).

2.1.3.3. Ecosystems and Biodiversity

Agriculture contributes to ecosystem and biodiversity loss by converting ecosystems from a natural to a production landscape (TEEB, 2009). This may have the unanticipated consequence of undermining local communities' ability to adapt to climate change by removing natural means of protection (TEEB, 2009; World Bank, 2010d). For example, mangrove swamps were found to be a cost-effective means of protecting local coastal communities in Southern Thailand (TEEB, 2009).

2.1.4. Food Security and Human Development

This section will review the literature on how climate change impacts will affect developing countries. Specifically, how would climate change affect food security in the near term? Longer term, how would climate change effects on agriculture affect long-term developmental goals such as improved health and education outcomes?

2.1.4.1. Food Security

Developing countries, particularly those in sub-Saharan Africa, North Africa and Middle East, and Latin America and Caribbean, are expected to suffer a decline in food self-sufficiency (Muller et al., 2009). This is mostly due to higher population growth relative to crop yields. Developing countries are particularly vulnerable to climate change because of a relatively higher economic dependence on agriculture: 13% of developing countries' GDP is from agriculture compared to 2% for developing countries (Fischer et al., 2002). Because of this, developing countries are estimated to have 70-80% of the cost of climate change imposed on them (World Bank, 2010d).

Sub-Saharan Africa has consistently been identified as the most vulnerable region to climate change because of its economies relatively higher reliance on agriculture (Fischer et al., 2002; IPCC, 2007b; Muller et al., 2009; Nelson, 2009; World Bank, 2010d). Agriculture comprises 23% of sub-Saharan Africa's GDP and 70% of the labor force (World Bank, 2010d). 40% of sub-Saharan Africa is also classified as undernourished (Fischer et al., 2002). Higher population growth is expected to exacerbate climate change impacts (Fischer et al., 2002; Muller et al., 2009). Inadequate infrastructure and increased water scarcity compounds sub-Saharan Africa's vulnerability (IPCC, 2007b; World Bank, 2010d).

As mentioned before, climate change is expected to cause a decline in agriculture production globally (Nelson et al., 2009). Combined with population growth, the combination of higher demand and lower supply would lead to higher food prices globally. Poor countries are expected to suffer from facing higher food prices (World Bank, 2010d). However, agricultural producers in these countries may benefit from higher prices (Nelson et al., 2009).

2.1.4.2. Human Development

Decline in food availability per capita is expected to lead to higher malnutrition in vulnerable countries, specifically in sub-Saharan Africa but also in Latin America and Asia (Nelson, 2010). This decline in food leads to lower per capita calorie availability in these regions by 2050: 21% decline in sub-Saharan Africa, 15% in Asia and 10% in Latin America (Nelson, 2010). Child malnutrition increases by 25 million by 2050: 10 million in Africa, 11 million in Asia and 6.4 million in Latin America (Nelson, 2010).

Decline in calorie availability would have long-term implications for developing countries' labor productivity (Fischer et al., 2002). Malnutrition can affect labor productivity in two ways. First, it can lower educational attainment by impairing children's ability to learn. Secondly, it can increase vulnerability to pests and diseases which requires time to recover from and reduces the time available for work (World Bank, 2010a).

2.1.5. Economic Impacts

The economic impacts reviewed here are those of a national and international dimension. These are impacts that are felt beyond the rural household level such as impacts in global food markets or on urban residents.

2.1.5.1. Trade Impacts

As mentioned before, climate change is expected to lower global food supply (Nelson et al., 2009). This would lead to higher prices for food which would harm consumers but would benefit producers. Higher food prices may have two consequences. First, the higher food prices may result in greater land use change as producers seek to increase production by adding more land (Falkenmark et al., 2009). This would have the undesirable consequences of increasing emissions from land use change in addition to increased emissions from agricultural production.

The second outcome is that higher prices would lead to increased production and trade of agricultural products. This outcome may be possible but it relies on using thin agricultural markets to meet food deficits (World Bank, 2010d). Therefore, the scope of international trade to reduce the impact of food insecurity may be limited (Falkenmark et al., 2009). Furthermore, the countries that are likely to experience food insecurity are poorer countries. If economic growth does not result in the higher incomes that is needed to pay higher food prices, these countries may experience significant developmental issues in terms of limited calorie availability (Nelson, 2010).

2.1.5.2. Internal and International Migration

Rural population have historically responded to climate variability by migrating temporarily to find other sources of income (Kurukulasuriya & Rosenthal, 2003). Migration may become permanent if climate change has adverse long-term consequences. This could lead to large scale movements of rural populations within a country or internationally. Possible consequences may be urban overcrowding or ‘climate refugees’ moving from poor, vulnerable countries to richer countries.

2.1.5.3. Rural Development

The economic impacts of climate change on developing countries’ rural areas depend on local circumstances (World Bank, 2010d). While agricultural producers may benefit from higher prices, this is only true if climate change does not adversely affect their land and water. Therefore, countries with natural resource base that are vulnerable to climate change impacts are likely to experience adverse impacts. This would then lead to migration of labor and capital away from regions with little economic viability to areas with more potential.

2.1.6. Policies and Solutions

Clearly, climate change is expected to have a significant impact on agriculture production. Fortunately, there are new techniques that allow farmers to mitigate their emissions and to adapt to climate change impacts. In some cases, these farming strategies could increase farm productivity. There is an opportunity for both developing and developed agriculture industries to improve their productivity and reduce their carbon emissions.

This chapter will examine mitigation and adaptation options at the farm level. The review will not be exhaustive but will focus on key measures to provide an idea on how these options work. It will then identify synergies between mitigation and adaptation strategies. This will be followed by a review of national level strategies to facilitate the adoption of these mitigation and adoption strategies. This chapter will finish with a discussion of international strategies that will enable national governments to implement policies to promote farm-level mitigation and adaptation.

2.1.7. Mitigation

Farms can reduce emissions in three key ways: 1) increase soil sequestration, 2) reduce methane emissions from livestock, 3) grow biofuel crops, or 4) reduce land use changes. We will discuss each in turn.

2.1.7.1. Soil Sequestration

Restoring the carbon sink potential of degraded agricultural soils has the potential to lower atmospheric carbon concentrations by 50 ppm (Nelson, 2009). Zero tillage cropping methods can restore carbon to the soils as well as increase crop productivity through conserving soil moisture (Kurukulasuriya & Rosenthal, 2003). Use of biochar to capture carbon and to supplement soil nutrients also has similar effects. Both these strategies can be implemented in developing and developed countries. The ultimate effect of these techniques depends on local soils and conditions (Robertson & Grace, 2004; Smith et al., 2007).

Methods like zero tillage may not be widely adopted in developing countries because of the requirement to leave plant residue on fields to decompose. Farmers in developing countries often collect these residues for animal feed or fuel (Smith et al., 2007). Subsistence farms in developing countries not only provide food for the household but also energy. Accounting for the multiple benefits from subsistence agriculture would improve adoption rates of mitigation strategies.

2.1.7.2. Reducing Livestock Emissions

Ruminant livestock are responsible for a third of global methane emissions (Smith et al., 2007). Improving the feed quality for livestock can reduce methane emissions and improve livestock productivity (Nelson, 2009). Improved feeding practices can be implemented in developing countries (Nelson, 2009).

Consumer trends away from meat may also help reduce emissions from livestock production systems (Nelson, 2009). Emphasizing the health aspect of reducing meat intake could result in significant methane emissions reductions.

2.1.7.3. Biofuels

Biofuels can help reduce carbon emissions by displacing fossil fuels used in transport activities (Smith et al., 2007). Second generation biofuel crops, such as algae, jatropha, sweet sorghum or willow, have sustainable development benefits by being cultivable in marginal agricultural areas which reduces competition with food crops and also provide farmers with an adaptation strategy (World Bank, 2010d).

However, biofuels have significant disadvantages as a mitigation strategy. First generation biofuel crops have been found to cause food insecurity by diverting land and water from food production to biofuels production (Smith et al., 2007). There is also doubts that first generation biofuel crops have produced emission reductions (Fargione, Hill, Tilman, Polasky, & Hawthorne, 2008).

2.1.7.4. Reducing Emissions from Deforestation and Degradation (REDD)

REDD is accepted as the lowest cost means of reducing emissions in the short-term because it has the potential to mitigate large amounts of carbon and conserving forests does not require new technologies (Nabuurs et al., 2007). Reducing agriculture's contribution to deforestation and degradation requires addressing the root causes. Specifically, deforestation is carried out by shifting cultivators who extract all the soil nutrients from one area and move to a virgin forested area to continue farming (Chomitz et al., 2007). Developing sustainable production systems to encourage shifting cultivators to maintain their holding instead of shifting is a possible solution to deforestation caused by agriculture (Nelson, 2009). Providing shifting cultivators with alternative income sources may also discourage deforestation (Nelson, 2009).

2.1.8. Adaptation

Historically, farmers dealt with climate variability through semi-nomadism; that is move to another location to avoid the worst effects of poor weather (Kurukulasuriya & Rosenthal, 2003). However, given growing populations and the lack of available land, semi-nomadism is no longer a suitable strategy to adapt to climate change. In this section, several commonly proposed adaptation strategies are reviewed: diversification, productivity growth, and irrigation.

2.1.8.1. Farm Diversification

A farm can be thought of as an investment portfolio where crops and livestock represent different investments. By owning a diversified portfolio, farmers can reduce the risks from one crop or livestock type (Kurukulasuriya & Rosenthal, 2003). In some cases diversification can provide pest and disease resistance such as crop rotations. Diversification can also provide productivity benefits by allowing soil to regenerate nutrients extracted by one crop type.

Farm diversification may not be feasible in a developing country context (Kurukulasuriya & Rosenthal, 2003). First, most farmers in developing countries farm small plots and do not have the land to cost-effectively diversify their plants or livestock. Secondly, managing different types of crops or livestock may be beyond the training of farmers or prohibitively expensive. Third, traditions may prevent adoption of new crop varieties or livestock types.

2.1.8.2. Productivity Growth

Productivity growth is an attractive adaptation solution to climate change because it results in producing the same output for lower use of inputs (Alston & Pardey, 1996). Greater agricultural production efficiency increases farmers' resilience because it allows production even during droughts or other adverse climatic conditions (Fischer et al., 2002). This is an attractive option for developing countries because it would strengthen food security with climate change.

A technological breakthrough is seen as the main way of implementing productivity growth (World Bank, 2010d). The Green Revolution is commonly cited as an example of an agricultural technological breakthrough that lead to high productivity growth (Nelson, 2009; Smith et al., 2007; World Bank, 2010d). Genomics is seen as a future 'green revolution' (Smith et al., 2007).

While the Green Revolution was successful in increasing output, it was a high input system that required large amounts of water and fertilizer. Such high input systems would be counterproductive for adaptation because it would expose farmers to higher risks from increased water scarcity and fertilizer prices.

Finding ways of transforming agriculture from high-input, intensive systems to less environmentally damaging systems is important for ensuring the sustainability of agricultural production (World Bank, 2010d). Technological breakthroughs may be one way such as genomics. Or the development of low technology systems suited to specific agro-ecology zones is also another option.

2.1.8.3. Irrigation

Improving irrigation infrastructure would improve water use efficiency by reducing evapo-transpiration (World Bank, 2010d). This would allow irrigated agriculture to maximize the use of increasingly scarce water resources. Irrigated agriculture is able to produce more output than similar rainfed systems. Furthermore, if water supplies are reliable, irrigated agriculture would be better able to adapt to climate change by 'smoothing' production between wet and dry years.

Modeling of climate change impacts has shown that irrigated agriculture is more vulnerable to production declines than rain fed systems (Nelson et al., 2009). Experience with agriculture from arid regions have shown that if governance arrangements are weak, than allocation of water may be inefficient and results in future water scarcity (World Bank, 2010d). For example, Australian water authorities had over-allocated water and are now in the process of reducing water entitlements to reduce water withdrawals.

2.1.8.4. Weather Index Insurance

Index insurance is one promising adaptation strategy to improve developing countries' resilience to climate change and to strengthen food security (Hellmuth, Osgood, Hess, Moorhead, & Bhojwani, 2009). The essential idea of index insurance is to provide payouts to farmers during adverse weather events. An insurer does this by selecting a weather-based index (e.g. rainfall in a specific locality) and the 'trigger' level at which value the weather index has to reach before payouts can be made (Hazell, Balzer, Clemmensen, Hess, & Rispoli, 2010; Hellmuth et al., 2009; Vincent, 2010). In return, the farmer pays a premium to transfer the weather risk to the insurer.

Index insurance represents an improvement for farmers and insurers over agricultural insurance (Agriculture and Rural Development Department, 2005). First, it is based on a public, objective, and verifiable criteria. This eliminates the need and cost of using field inspectors to verify losses. Second, index insurance does not distort incentives to maximize production. Crop insurance programs have suffered from moral hazard problems because payouts were linked to yield. Farmers could and did manipulate yield to obtain payouts (Goodwin & Smith, 1995). Third, because the payout trigger is easily observable, payouts can be made more rapidly which is especially valuable during a disaster (Hazell et al., 2010; Hellmuth et al., 2009). Fourth, index insurance can cover for highly covariate or systemic risks by making it easier for the insurer to transfer part of the risk to reinsurers. This is because reinsurers do not need to perform costly due diligence because of the objective nature of weather indexes (Agriculture and Rural Development Department, 2005).

Index insurance can help farmers in developing countries to adapt to climate change by opening up other options for adaptation by improving access to credit markets (Hazell et al., 2010; Hellmuth et al., 2009). Use of index insurance improves credit market access because it reduces the credit risk of the farmer; i.e. it improves the chances of the farmer repaying the lender. For example, in Malawi, index insurance was linked with credit for fertilizers. The insurance was to insure the lender's repayment rather than the farmer's crop. As a result, the farmer obtained the credit to purchase fertilizer which would increase production and the bank was guaranteed repayment (Hazell et al., 2010). Obtaining credit allows farmers to improve their resilience to climate change by improving their productivity and income by increasing inputs use, adopting advanced technologies, or changing crops or livestock breeds.

Index insurance can also reduce the impact of catastrophic natural disasters (Hazell et al., 2010; Hellmuth et al., 2009). This is because payouts can be made quickly. This feature can help finance more rapid post-disaster recovery and reduce the vulnerability of households to post-disaster economic and human losses.

Despite these promising features, not much is known on how index insurance would perform once it has been scaled up (Hazell et al., 2010). There is a large information gap on how index insurance affects rural households' livelihoods, incomes, poverty and vulnerability. It is also not known how index insurance would perform after a natural disaster in terms of protecting assets and income.

Basis risk can also undermine the value of index insurance for farmers (Agriculture and Rural Development Department, 2005; Hazell et al., 2010; Hellmuth et al., 2009). Basis risk in this context is where the farmer experiences an adverse weather event but does not receive a payout or vice versa. This problem can arise if the farm is located far from a weather station.

Some index insurance programs have used subsidies to encourage uptake (Agriculture and Rural Development Department, 2005; Hazell et al., 2010; Hellmuth et al., 2009). Subsidizing premiums is a highly controversial subject in this area. Subsidies in general are a solution to a willingness to pay issue. In the case of farmers, the issue may not be income but to cash flow. One way to resolve the cash flow problem is to link the insurance with credit, that is have a contract where the insurance premium is paid by a loan. The farmer can then pay off the loan with cash flows from selling the crops. An example of this is a credit-linked index insurance program in Malawi (Hazell et al., 2010). In general, subsidies should be used cautiously because they may result in a waste of resources or crowd out more effective risk-management approaches. For example, in India, banks are required to sell subsidized area-yield insurance which crowds out the introduction of index insurance (Hazell et al., 2010).

In conclusion, index insurance is one possible adaptation strategy. However, it should not be used to crowd out existing adaptation strategies (Vincent, 2010). Also, a supportive environment, as outlined by Hazel et al. (2010)'s 8 principles is required to ensure that index insurance can be used effectively within a country.

2.1.8.5. Climate Forecasting

The agricultural development community has been divided on the benefits of improving climate forecasting in developing countries (Hansen, 2002). On the one hand, improved climate forecasting could assist agricultural development by allowing farmers to make optimal planting decisions given the likely climate (Barrett, 1998). In contrast, farmers in developing countries do not optimize planting decisions but instead adopt "buffer" or precautionary strategies because the climate uncertainty is too great to risk food security in one season (Barrett, 1998; Hansen, 2002). As a result, this farmers are trapped in poverty because they only produce a low, but consistent income and do not generate enough profits to invest in farm improvements and equipment (Hansen, 2002).

Critics of improving climate forecasts argue that climate forecasting is too unreliable to provide farmers with the information to optimize planting decisions (Hansen, 2002). For example, before the 1997/98 droughts in Southern Africa, widely-disseminated forecasts of droughts prompted farmers to reduce their plantings (Dilley, 2000). However, when it eventuated that the drought was not as severe as forecasted, farmers were unable to take advantage of more favorable conditions because banks deny credit, and suppliers refused to provide farm inputs (Dilley, 2000; Hansen, 2002).

Critics also contend that what is important is not the forecasts, but the *impact* on agriculture and food security (Barrett, 1998; Hansen, 2002). How the climate affects agricultural production is not known with certainty, instead policy may have a greater impact on food security than the climate. For example, government policy to stockpile food as insurance against droughts may be more valuable for food security than climate forecasting (Barrett, 1998).

Hansen (2002) argues that improved climate forecasting can deliver benefits for food security and agricultural production if five conditions are met:

1. Climate forecasts must meet a need that is real and perceived;
2. Viable options that depend on climate forecasts must exist;
3. Climate forecasts must be at relevant spatial and temporal scales to impact;
4. Forecasts must be interpreted correctly by the target audience; and
5. There must be institutional commitment to producing and disseminating climate forecasts to the target audience.

To deliver benefits from improving climate forecasting, decision-makers (e.g. policy-makers, farmers) should perceive there is a need such as sensitivity to climate shocks. Identifying all relevant decision-makers who could use this information can be challenging but is required to maximize the benefits of improving climate forecasting. Identifying potential beneficiaries is also important because they may be different from decision-makers – e.g. children and urban consumers. Identifying groups that would be adversely affected by improved climate forecasting is also important to reduce the negative impacts. An example of such a group are Zimbabwean farmers who were denied credit during the 1997/98 drought (Hansen, 2002).

Viable options that are sensitive to climate variables must exist to justify the investment in improved climate forecasting. However, identifying these options is not trivial. For example, the range of options may not be fully known by researchers or farmers. Furthermore, once identified, quantifying the benefits of management options may be difficult because of the impossibility of incorporating all climatic, agro-ecological, and economic interactions in normative models. Hansen (2002) suggests a hybrid participation-quantitative iterative approach where: first, researchers elicit how farmers would manage a given climate event; second, researchers use models to evaluate the benefits and risks of each option; and finally, researchers and farmers collaboratively evaluate and refine these options. This hybrid approach results sharing insights between the two groups that would not have been otherwise possible.

Improved climate forecasts should be at the appropriate spatial and temporal scale to allow decision-makers to learn the relevant impacts of climate on food security. Sophisticated Global Climate Models (GCMs) are highly accurate but produce forecasts at the resolution of 8000 km^2. However, recent advances in climate forecasting have reduced the resolution to 200 km^2 with plans to reduce this further to 50 km^2 (IRIN, 2010). Forecasts should also be produced in a timely manner to provide decision-makers to prepare for positive or negative weather events (Barrett, 1998; Hansen, 2002; Ziervogel et al., 2008).

Decision-makers must interpret the climate forecasts correctly to deliver the benefits for agricultural production and food security. However, there is debate amongst experts if the climate forecasts should be provided free of interpretation or with interpretation (Hansen, 2002). On the one hand, farmers may have superior knowledge to meteorologists or researchers on the impact of climate on their farm's output. However, farmers may be less likely to use climate forecasts if it is not expressed in terms that they can understand (i.e. agricultural terms).

Finally, benefits from improved climate forecasting are enhanced the longer the forecasts are generated and used. This requires institutional commitment to producing and disseminating climate forecasts to farmers. Specifically, this requires cooperation between national meteorological and agricultural agencies. In most Governments, these two agencies are separated at the Ministry level. This results in different organizational cultures and mandates. Meteorological agencies are mandated to produce weather information whereas agricultural agencies have the responsibility of enhancing farmers' capabilities. Nevertheless, these agencies have complementary goals and capabilities. Meteorological agencies would enhance their support by broadening their "customer base" and agricultural agencies benefit from strengthening the agricultural sector.

In summary, there are benefits from investing resources to improve climate forecasting by strengthening agricultural production and food security. However, these benefits may not be achievable unless the five conditions identified by Hansen (2002) exist.

2.1.9. Synergies between Mitigation and Adaptation

While this review has not been exhaustive, synergies exist between mitigation and adaptation (Nelson, 2009). The key nexus appears to be between mitigation options and improving productivity. Mitigation strategies that also provide production (and also financial) benefits to farmers are more likely to be adopted and therefore would have a greater impact in reducing greenhouse gas emissions (World Bank, 2010d). Examples of this are farming techniques such as zero tillage that improve productivity through soil moisture retention and also reduce emissions by composting crop residue.

2.2. Land Policy in Africa

Land policy in Africa varies greatly depending on the legacy of colonialism. For example, in South Africa, land policy is a product of favoring large-scale commercial, white-owned farms, even after the fall of apartheid in 1994 (Didibhuku & Khosa, 2008; Lahiff, 2009; van den Brink, Thomas, Binswanger, Bruce, & Byamugisha, 2006; van den Brink, Thomas, & Binswanger-Mkhize, 2009). In Ethiopia, which did not experience significant colonialism, customary institutions competes with the formal Ethiopian government land policy (Helland, 2006; UN OCHA Pastoralist Communication Initiative, 2007).

Experiences with colonialism also determine official attitudes towards foreign and non-African ownership of land. In South Africa, a systematic land reform process aims to re-allocate 30% of white-owned agriculture land to Africans by 2014 (Didibhuku & Khosa, 2008; Lahiff, 2009; van den Brink et al., 2006; van den Brink et al., 2009). In Zimbabwe, acceleration of land reform was accompanied by violence against white farmers (Alden & Anseeuw, 2009). In contrast, Botswana and Mozambique encouraged white Zimbabwean farmers to settle in their country to escape the violence (Alden & Anseeuw, 2009).

The key generalization that can be made of African land policy is that it is characterized by competing claims between traditional owners or users, non-African owners, resettled Africans, non-agricultural interests (e.g. mining, ecotourism), and the landless, *inter alia* (Amanor, 2008; Binswanger-Mkhize, Bourguignon, & van den Brink, 2009; Helland, 2006; Kanyinga, 2009; Kanyinga, Lumumba, & Amanor, 2008; Knox, Caron, Goldstein, & Miner, 2010; Lahiff, 2009; Mitchell, 2010; Quan & Dyer, 2008; van den Brink et al., 2006). These overlapping claims can, and have, lead to conflicts over ownership. In many cases, the patterns of conflict are the result of policy reminiscent of colonial land policy in terms of dispossessing traditional owners of their land to transfer land ownership to more wealthy, often foreign, investors (Amanor, 2008; Didibhuku & Khosa, 2008; Kanyinga et al., 2008; Lahiff, 2009).

In some African countries, progress has been made to resolving overlapping claims on land. The Ethiopian government has recognized the legitimate claims of traditional users of land and the constructive role that customary land institutions can play in negotiating land access (MoFED, 2006). In South Africa, the land restitution process is close to settling all claims of land dispossession as a result of apartheid (Lahiff, 2009).

South Africa has also pursued land reform through other policy measures such as grants and government assistance for beneficiaries. However, South Africa has been less successful in turning African farmers into engines of rural development. Many new African farmers have to buy land in a collective organization because of apartheid-era restrictions on subdivision. As a result, they have to farm collectively which often fails to produce livelihood or poverty reduction benefits (Lahiff, 2009). Also, new black farmers are inexperienced in agriculture and cannot access agricultural extension services for advice (van den Brink et al., 2009). While the South African example is promising in terms of how to undertake land reform, it also contains lessons that the economic, livelihood, and poverty reduction benefits require ongoing policy attention to realize.

Informal, or customary, land property rights were often viewed as having weaker tenure security than formal property rights such as land titles. However, van den Brink et al. (2006)

argue that informal land rights can have as much security than formal rights. Local communities may have more credible and accepted enforcement mechanisms than some African governments. Indeed, formal titling programs improve land tenure security only if there is credible enforcement by governments. For example, Kenyan governments have ignored formal title ownership to reallocate land to their political supporters (Kanyinga et al., 2008). Furthermore, local communities have an incentive to monitor land use and ownership to ensure local land policy is being followed. As a result, there may exist a mutually reinforcing effect of complementing formal land policy with customary land institutions.

2.3.Land Policy and Climate Change

Recently, a literature on land policy and climate change has emerged. These articles can be split into two groups: articles dealing with adaptation and articles dealing with mitigation.

2.3.1. Adaptation

The land policy and adaptation literature is less developed than the mitigation literature. The key article is by Quan and Dyer (2008). The focus of the article is on how land tenure and land policy affects the incentives to adopt adaptation strategies. Its key finding is that tenure security needs to be improved to encourage adaptation. Furthermore, property rights should also be flexible to allow multiple uses to co-exist on the same land. For example, nomadic pastoralists relies on access to land over a large area to transfer herds to areas that have more forage and pasture (Helland, 2006; Hesse & Cotula, 2006). Nomadic pastoralism is seen as an efficient strategy to climate variability compared to sedentary ranching. However, restricting access will reduce the effectiveness of this strategy and could lead to environmental degradation.

Land policy also needs to take in account population flows caused by climate change. Populations may shift in response to sea level rises or land degradation caused by climate change. This will create demand for land in areas less affected by climate change. If not managed properly, the resulting scarcity of land may lead to conflicts and poverty. Quan and Dyer (2008) argue that governments should plan for shifts in populations by taking an inventory of current settlements, planning where to resettle people and future infrastructure needs.

Quan and Dyer (2008) argue for the acceleration of secure land tenure arrangements as preparation for adapting to climate change. Tenure arrangements should not be limited to freehold rights, but also for access rights to resources to ensure adaptation strategies such as herd mobility and migration is not impeded. To implement an acceleration of secure land tenure arrangements, land administration bodies need to improve their capacity for surveying and registering properties. Quan and Dyer (2008) suggest that low cost measures are available such as granting title on a community basis and devolving land administration to local communities.

2.3.2. Mitigation

What makes agriculture a potentially key player in mitigating climate change is the amount of land controlled by farmers. Farmers can control land through direct ownership, rent, or through use. How agriculture is conducted on the property affects emissions from the farm. Land policy can affect mitigation by defining who has the right to carbon (Knox et al., 2010; Tucker & Gore, 2008). In most countries, the ownership of carbon is not defined[1]. Carbon rights may be implicit such as in Mexico where landowners are entitled to the products of their plants. However, carbon rights are only valuable to the extent that it can be traded for compensation. Otherwise, the carbon rights cannot be sold to realize the financial value.

Even if carbon rights are fully transferable, it may not be desirable to do so (Knox et al., 2010). The value of a carbon right depends on ongoing management of the carbon sink (e.g. trees, land). Transferring the carbon right would eliminate any financial incentive for the owner or user of the carbon sink to manage for maximum sequestration. One solution to this is to design contracts to include penalties for not managing the carbon sink to maximize sequestration (Ha, Strappazzon, Crowe, & Todd, 2004; Knox et al., 2010). However, this requires costly monitoring and enforcement to effectively discourage non-compliance. Another option that does not require as much monitoring is benefits-sharing of the carbon revenue stream between all owners and users of the land to maximize carbon sequestration. This has the attractive property of aligning the incentives of land owners and managers with the buyer of the carbon rights, but it may diminish the financial attractiveness of purchasing the carbon rights if there are many stakeholders sharing the revenue. As a result, a benefit-sharing agreement will grow in complexity as the number of land owners and users increase.

As mentioned before, overlapping rights on the same piece of land is common in Africa. Different users may have different resource rights. For example, one user may be entitled to grow crops on the land but another user has a right to graze on that piece of the land. Under

[1] New Zealand, six states in Australia (New South Wales, South Australia, Queensland, Victoria, Tasmania, and Western Australia), and Alberta province in Canada (Knox et al., 2010).

some laws, the former would have ownership of the carbon rights and is the only one entitled to payment. However, both users have an impact on the carbon sequestration potential of that piece of the land. The primary right-holder (the crop farmer) may have an incentive to deny access to the pastoralist who may depend on that resource to adapt to climate change. Therefore, maintaining flexibility of land tenure is important to prevent perverse outcomes such as evictions, fencing, and denial of access to the resource from secondary right-holders (Knox et al., 2010).

Latent State rights may undermine tenure security. For example, many countries' governments have legal ownership of mineral and hydrocarbon resources below a certain depth. This could reduce the carbon sequestration potential of a project if the State approved resource extraction despite an existing carbon sequestration project. The only way to prevent this is if the carbon buyer could offer more revenue to the government than from mineral or hydrocarbon royalties (Knox et al., 2010).

Other laws can affect the value of a carbon mitigation project. For example, in some African countries, clearing the land of trees is a demonstration of use and is a legitimate claim of ownership (Knox et al., 2010). Poor or selective enforcement of regulations could provide opportunities for land-grabbing by elites. This may be a risk if carbon prices were high.

Land tenure rights are attached to specific pieces of land. However, in many countries land has not been formally registered with their owners, which makes land tenure insecure. Recognition of land rights, formal and informal, are crucial to the viability of a carbon mitigation project and land improvements generally (Mitchell, 2010). However, land administration systems to record rights can be very costly, especially in developing countries. The conventional methods have been a survey of each property ('cadastral mapping') which requires employing skilled surveyors and purchasing surveying equipment. Conventional recording also does not recognize secondary right which makes them inappropriate for Africa.

Mitchell (2010) describes some low cost ways that formal recognition of land rights can be undertaken. Lower cost means of cadastral mapping includes the use of aerial photography, remote sensing, or the use of GPS. This can be verified in the field with the owner and neighbors to confirm the boundaries of the land. Participatory land adjudication can prevent disputes over boundaries and strengthen the credibility of the tenure recognition process. Also, it also allows the strengthening of tenure security through cost-effective means.

3. Method of Analysis

A case study approach will be used in this thesis to analyze the interaction between land policy, African agriculture, food security, and climate change adaptation and mitigation. This is mainly due to a lack of data relating to these interactions. Another key reason is the policy analytical approach of this analysis involves considering economic, political, scientific, historical, and environmental data that cannot be feasibly aggregated into a quantitative model.

The key question that will be asked in this analysis is: how does a given African country's land policy affects a farmer's decision to adopt adaptation or mitigation measures? This analysis will build on economic, political, historical, scientific, and environmental analysis for the rationale of a country's land policy. Understanding the diverse drivers of land policy will provide hints on how to reform land policy.

The specific analysis of how land policy influences a farmers' decision to adapt or mitigate will use an investment framework. This is because adopting adaptation or mitigation measures is similar to investing in new technology and will affect the future value of a farm. The conceptual framework is net present value, where a unit of benefits is worth more today than in the future (Brigham & Ehrhardt, 2008). Conversely, a deferred cost is worth less than a current cost.

Costs and benefits will be listed and assessed in terms of magnitude. Risks of uncertain events such as expropriation, land-grabbing by elites, lack of enforcement, *inter alia* will be considered in addition to climate change. These risks will directly affect the cost/benefit analysis.

The three countries chosen for case study analysis are Ethiopia, Kenya, and South Africa. Ethiopia was chosen because of its unique position of being the only African country that did not experience significant colonization. South Africa was chosen because it is the largest economy on a GDP basis. Kenya was chosen because it decolonized relatively early and has been ruled by the African majority for over 40 years. These countries all have diverse experiences with land policy as we will see in Section 4.

Each country will be evaluated in the following way:

1. Identify how climate change is likely to affect agriculture in that country;
2. Description of land policy institutions and administration;
3. Multi-disciplinary analysis of the evolution and sustainability of land policy;
4. Impact of land policy on economic development and food security;
5. Anticipated impact of land policy on farmers decision to adopt adaptation strategies;
6. Anticipated impact of land policy on farmers decision to mitigate carbon;

7. Opportunities for improvement of land policy in terms of improving development, food security, adaptation, and carbon mitigation benefits.

By using a consistent framework for analysis, this will allow for a limited degree of comparability between the case studies. However, the caveats on comparing within a limited sample still stand and are no more than an indication of differences.

The analysis recognizes not all farmers are the same. For example, a nomadic pastoralist faces different incentives from an irrigated crop farmer. Likewise, a diversity of agro-ecosystems may exist in a country that affects the cost/benefit of adaptation and mitigation.

4. Case Studies

In this section we analyze each of the case studies for the impact of land policy on African agriculture's capacity to provide food security, and incentives to adopt climate change adaptation measures and to engage in mitigation. Table 1 contains key development and agricultural data on Ethiopia, Kenya, and South Africa.

Table 1 Comparison of Key Development and Agricultural Statistics of Case Study Countries

	Year	Ethiopia	Kenya	South Africa
Key Development Statistics				
GDP (2010 US$) (billions)	2008	25.9	30.0	276.5
GNI per capita, Atlas method (current US$)	2008	280	730	5,870
External debt stocks (% of GNI)	2008	11.1	24.4	15.7
Life expectancy at birth, total (years)	2008	55	54	51
Population, total (millions)	2008	80.7	38.8	48.8
Population growth (annual %)	2008	2.6	2.6	1.1
School enrollment, primary (% net)	2008	78.2	81.5	87.5
Surface area (sq. km) (thousands)	2008	1,104.3	580.4	1,219.1
Key Agricultural Statistics				
Cereal yield (kg per hectare)	2008	1,422	1,417	3,807

	Year	Ethiopia	Kenya	South Africa
Food production index (1999-2001 = 100)	**2007**	**135**	**136**	**109**
Arable land (% of land area)	**2007**	**14.0**	**9.1**	**11.9**
Permanent cropland (% of land area)	**2007**	**1.0**	**0.9**	**0.8**

Source: World Bank. (2010). Key Development Data & Statistics. *Data & Statistics* Retrieved December 17, 2010, from http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTIC/0,,contentMDK:20535285~menuPK:64909264~pagePK:64909151~piPK:64909148~theSitePK:6950074,00.html

From the data, it is clear that South Africa has the most advanced economy with the highest GDP and the highest cereal yields. Despite that, it has the lowest age expectancy and has experienced the lowest increase in agricultural production from 1999 to 2007. In contrast, Ethiopia has the lowest GDP and has the highest population of the three case study countries. It has the highest population growth (with Kenya) with the highest age expectancy. Ethiopia also has the highest proportion of arable land of the three case study countries. Kenya has experienced the fastest increase in agricultural production but has the lowest cereal yield. It also has more debt as a proportion of gross national investments than South Africa or Ethiopia.

Clearly, these countries are at different stages of development and we would expect a diversity of land policies. We will first analyze Ethiopia followed by Kenya and South Africa in that order.

4.1.Ethiopia

Ethiopia is heavily dependent on agriculture, with 45% of its GDP from agriculture (World Bank, 2010c). The Ethiopia government recognizes the vulnerability of agriculture to climate change and has prioritized agricultural adaptation projects in its National Adaptation Programme for Action (NAPA) (The Federal Democratic Republic of Ethiopia, Ministry of Water Resources, & National Meteorological Agency, 2007). Ethiopia has recently made significant progress in economic and human development, in order to maintain its development gains and exploit its potential as a relatively water-rich country, protecting Ethiopian agriculture from climate change impacts is of high priority (MoFED, 2006).

4.1.1. Climate Change Impacts

Under the IPCC mid-range projections, Ethiopia is expected to experience an increase of average temperatures of 0.9-1.1°C by 2030 and a small increase in precipitation during the same period (The Federal Democratic Republic of Ethiopia et al., 2007). The impacts of climate change are expected to be greater on Ethiopia than other African countries because of its vulnerability to climate change (The Federal Democratic Republic of Ethiopia et al., 2007; Thornton, van de Steeg, Notenbaert, & Herrero, 2008). The primary cause of Ethiopia's vulnerability to climate change is a high dependence on rain-fed irrigation. This vulnerability is compounded by a lack of adaptive capacity in the form under-developed irrigation infrastructure, high population growth rate, low economic development, inadequate road infrastructure, lack of awareness, *inter alia* (The Federal Democratic Republic of Ethiopia et al., 2007).

The Ethiopian Government is particularly concerned about the impact of more droughts and floods (The Federal Democratic Republic of Ethiopia et al., 2007). Ethiopia has had a history of suffering large human and economic losses as a result of droughts and floods.

4.1.2. Land Policy

In Ethiopia, all the land is owned by the Government on behalf of the Ethiopian people (Deininger, Ali, & Alemu, 2008; Helland, 2006; Mitchell, 2010). This can result in insecure tenure and has implications for farm-level investment decisions. Under the Ethiopian constitution, Ethiopians who want to earn a livelihood from farming is entitled to land (Helland, 2006; MoFED, 2006). However, the implementation of this right is left to regional governments, most of which have not drafted laws to allow Ethiopians to exercise this right (with the exception of Tigray) (Deininger et al., 2008; Helland, 2006). Furthermore, Ethiopian pastoralists have a constitutional right to not to be displaced from their own lands.

Helland (2006) argues that this ambiguity has allowed the Ethiopian government to allocate land to investors despite these constitutional protections. Nomadic pastoralists are particularly vulnerable to their land being re-allocated for other uses. This is because the land that nomadic pastoralists used was viewed as being *res nullius* or empty of human habitation. The Ethiopian government has recognized that such policies were unjustified (MoFED, 2006). The Ethiopian government has committed to improving the lives of pastoralists through its 'Plan for Accelerated and Sustained Development to End Poverty' by improving the quality of natural resource, supporting communal governance, and improving property rights (MoFED, 2006). However, it has yet to fully implement improvements in pastoral land rights.

Crop farmers have stronger property rights but only if they pay their agricultural land tax (Helland, 2006). According to Helland (2006), crop farmers would often take the initiative to pay the taxes if it was not collected. Pastoralists paid an animal tax that was levied on number of animals rather than land. This did not confer protection on land access since there was no connection between the tax paid and land.

Recently, Ethiopia successfully implemented one of the world's largest land registration programs in the world (Deininger et al., 2008). 20 million parcels of land were registered to more than 6 million households. This program awarded non-alienable land use certificates which improved tenure security by providing official documentation of exclusive use rights. Furthermore, this program was implemented with limited external support. Low cost methods were used to register the land. For example, the adjudication of boundaries was devolved to local bodies rather than by a centralized government agency. Such innovations helped reduce the costs of registration to $1 per parcel rather than $20-60 per parcel using conventional methods. The successful implementation of this land registration program demonstrates that Ethiopia has the capacity and experience to improve tenure security for its farmers.

Deininger et al. (2008) found that recipients of the land use certificate experienced greater tenure security. As a result, holders of land use certificates were more likely to invest in farm improvements and land conservation measures than non-holders. Improved tenure security also had an indirect effect of boosting the rental market by encouraging right-holders with excess land to lease out land. Furthermore, it allowed female right-holders the security to seek off-farm work without fearing the appropriation of their land. As a result of this registration, more farm improvement investments were made and land was used more efficiently by people who had the capacity to use more land. Another indirect benefit was allowing rural women to diversify their income through rent and off-farm work which would lead to higher overall income for these households.

Despite this impressive reform, the Ethiopian government is reluctant to provide full, inalienable, land ownership rights (Helland, 2006). Possible reasons are discussed below.

4.1.3. Evolution and Sustainability of Land Policy

The origins of Ethiopia's land tenure system are from the northern and central part of the country (Helland, 2006). The northern part of Ethiopia is where the country was formed by the Ethiopian emperors. The southern part of the country were incorporated into Ethiopia through conquests. There are differing land tenure systems between these two regions. In the north, the basis of land tenure was from community-based land tenure. Right-holders were entitled to use the land, rent it out, and bequeathed the land to descendents but were not allowed to mortgage or sell the land. Tax obligations were attached to land rights.

In the south, land tenure was a product of conquest and the majority of households became sharecropping tenants. Households had no tenure security and were vulnerable to expropriation.

In other parts of the country that were on the fringes of the Ethiopian empire, customary law was used. However, as the potential of irrigation became apparent for converting arid and semi-arid lowland regions into cropping farms, conflict arose over land rights. Eventually, irrigation developers won. This conflict was also repeated with ecotourism development in recent times.

Prior to the 1975 Ethiopian revolution, Ethiopia introduced freehold title to land. The main criterion for land ownership was the payment of land tax to the State.

The 1975 Ethiopian revolution resulted in the nationalization of all rural land. Land was distributed to anyone who had a declared interest in farming. Farmers were prohibited from the sale, lease, transfer, exchange, inheritance of the land as well as the hiring of farm labor. Tenure security was weak due to frequent redistributions to accommodate a growing population.

The current structure of Ethiopian land policy is based on the 1975 land reform. There have been improvements in tenure security embodied by the 1994 constitution and (as mentioned in 4.1.2) which has encouraged investors to establish commercial irrigation cropping and ranching operations. However, the 1994 constitution devolves the responsibility of legislating and enforcing these rights to regional governments. These regional governments have weak administrative and enforcement capacity. The lack of enforcement capacity has resulted in opportunistic land-grabbing by wealthy parties (Helland, 2006). This has had the unfortunate consequence of excluding other users of the resources such as nomadic pastoralists.

Land is a contentious issue in Ethiopia at all levels of society. It has lead to inter-communal conflicts between pastoral communities (Pastoralist Communication Initiative, undated) and inadvertently promotes environmental degradation (Hesse & Cotula, 2006). Weak government enforcement capacity provides opportunities for land-grabbing by the wealthy and well-connected.

Given the negative impacts of Ethiopia’s current land policy, why has the government not abandon the framework of the 1975 land reform and provided freehold title? One possibility is that Ethiopia’s government is pursuing a State-led policy of development along the lines that some of the Asian economies undertook (Chowdhury & Islam, 1993). Such State-led development would confer the primary responsibility for directing investment to the government. The Ethiopian government has used its powers to allocate land to commercial enterprises (Helland, 2006).

However, State-led development that retains insecure tenure property rights may not be conducive to long-term economic development. A key benefit of tenure security is improvements in credit access as a result of the ability to mortgage land. However, Deininger et al. (2008) could not estimate such effects because the land cannot be mortgaged in Ethiopia. Furthermore, many of the Asian economies underwent land reform to improve tenure security. This had the effect of farm consolidation, investment in farm machinery, and releasing rural labor that help build Asia's comparative advantage in labor-intensive products (Binswanger-Mkhize et al., 2009; Chowdhury & Islam, 1993). Therefore, if Ethiopia wants to continue its rapid growth, it would have to improve tenure security for rural people.

4.1.4. Impact of Land Policy on Economic Development and Food Security

Current Ethiopian land policy confers some degree of tenure security but not to a high degree. This could discourage investment in farm improvements, seeds, livestock, or oxen for ploughing. Deininger et al. (2008) presents results that suggest that farms that had soil and water conservation structures produced 9.1% more agricultural output. In their analysis, they found that receiving a land-use certificate would encourage greater farm improvement investments in conservation measures. Therefore, improving tenure security had an indirect effect on encouraging investment and improving tenure security. Given this (albeit limited) evidence, improving tenure security in Ethiopia would have a positive impact on improving food security via encouraging farmers to invest in farm improvements.

As mentioned before, nomadic pastoralists do not have legislated rights to pursue their traditional strategy of herd mobility. This has forced pastoralists to travel further away to find forage and water supplies (Helland, 2006). This can result in greater livestock mortality which would undermine the food security of pastoralists. Furthermore, pastoralists export their livestock to Kenya and the Gulf States, reduction of livestock exports from Ethiopia could affect access to proteins in these markets (UN OCHA Pastoralist Communication Initiative, 2007; UNOCHA-PCI, 2007).

4.1.5. Land Policy and Farm-level Adoption of Adaptation Strategies

Similar reasoning applies to the adoption of adaptation strategies given that improvements in food security from farms would require improving the resilience of production. For example an International Food Policy Research Institute (IFPRI) study of Ethiopian farmers in the Nile Basin estimated that adoption of adaptation strategies would improve farmers' production capacity 10-29% per hectare (Yesuf, Di Falco, Deressa, Ringler, & Kohlin, 2008). Increasing Ethiopian crop farmers' resilience to climate change would require improving tenure security and therefore incentives to invest in farm improvements.

Nomadic pastoralists' strategy of herd mobility is considered by some experts as an optimal response to climate variability and the impacts of climate change (Hesse & Cotula, 2006; UN OCHA Pastoralist Communication Initiative, 2007). However, increased competition for land has reduced access to some resources such as rivers and bush. In the past, pastoral communities were able to negotiate access with other pastoral communities and crop farmers on a reciprocal basis (Helland, 2006). The other pastoral communities would benefit by being able to access more grazing territory, and the crop farmer would benefit from receiving manure from the livestock. Unfortunately, some farmers have excluded nomadic pastoralists by physically obstructing access by fencing their farms. This situation arises out of lack of recognition for pastoralists' customary access rights.

4.1.6. Land Policy and Farm-level Decision to Mitigate Carbon

The lack of tenure security would discourage investment in carbon sequestration unless there were co-benefits and if there was a short payback period. Furthermore, there are no explicit property rights over carbon in Ethiopia (Norton Rose, 2010). Even if a farmer wanted to sequester carbon, it is not clear that the farmer could sell the carbon. As a result, some clarification on carbon property rights would improve incentives to invest in mitigation projects (Knox et al., 2010).

4.1.7. Opportunities for Improvement

Clearly, tenure security is important for sedentary farmers to invest in production-enhancing and adaptation measures. As Yesuf et al. (2008)'s results imply, these could be the same thing. Improving tenure security along the lines of the recent land registration program would help enhance tenure security. However, to generate the full benefits from tenure security the introduction of freehold title should be considered.

Similarly, clarifying carbon property rights would also provide investors, farmers, and carbon buyers with investment certainty over agricultural carbon mitigation projects.

For nomadic pastoralists, improving access rights to forage and water resources will allow them to gain the full food security and adaptation benefits from herd mobility. Access could be improved by devolving local land access issue to community-based land management groups. Ethiopia has shown that it is capable of devolving land registration to local bodies, it is possible that a similar approach could be pursued with improving access for nomadic pastoralists.

To help community-based land management groups improve resource access, legislation should be introduced to stipulate pastoralists' legal rights and responsibilities. One option could be to establish a forum to allow nomadic pastoralists and other land users to negotiate resource access arrangements. The point of legislation should be to improve nomadic pastoralists' bargaining position rather than dictating the form and conduct of the relationship.

4.2.Kenya

Agriculture is a major contributor to Kenya's economy (Government of Kenya, 2010; Kabubo-Mariara & Karanja, 2007; Republic of Kenya, 2008). It contributes around 25% of Kenya's GDP and 82% of Kenya's population is based in rural areas and depends on agriculture. The agricultural sector also absorbs most of Kenya's new labor market entrants (i.e. young people). Furthermore, 70% of Kenya's export earnings are derived from agriculture. As a result, the impact of climate change on agriculture would have a significant impact on Kenya's economic prosperity and social stability.

4.2.1. Climate Change Impacts

There is some evidence that Kenya is already experiencing the impact of climate change (Government of Kenya, 2010). Since the 1960s, Kenya has experienced an increase in temperatures across the country. Furthermore, minimum daily temperatures have increased faster than the increase in maximum daily temperatures which has resulted in lower daily (diurnal) temperature ranges.

Changing rainfall patterns since the 1960s have also been observed (Government of Kenya, 2010). There has been a negative trend of 'long rains' during the March-May season but an extension of the 'short rains' season of October to December. The short rains season has even extended into the historically drier months of January and February. Rainfall intensity (i.e. amount of rain within a 24-hour period) has been decreasing over most of the country. However, rainfall intensity has been increasing for coastal areas during the six-month period of September to February.

These impacts are likely to intensify as climate change progresses. In addition, Kenya can expect increasing sea levels and more frequent droughts in particular.

These observed changes in climatic patterns have already had a tangible effect on Kenyan agriculture and society. For example, the famine cycle in Kenya has declined from 20 years in the 1960s to annual since 2007 (Government of Kenya, 2010). These famine cycles have increased due to more frequent droughts which has increased crop failures and reduced the availability of forage for livestock. These more frequent famine cycles have prompted rural Kenyans to engage in unsustainable land uses and deforestation [2] which increases environmental degradation as well as reduce future agricultural production potential. Climate

[2] Kenya's forest cover has declined from 12% in the 1960s to 1.7% at present (Government of Kenya, 2010).

change is believed to be a major contributor to an observed decline in Kenya's agricultural productivity.

Climate change is also thought to increase the spread of animal diseases in Kenya (Government of Kenya, 2010; Parry et al., 2007). This has implications for Kenya's livestock export industry. In the international trade of livestock products, disease-free status is important for market access. Currently, Kenyan meat exporters are banned from EU markets because of the detection of Rift Valley Fever and foot and mouth disease in Kenya (Government of Kenya, 2010). The increased prevalence of animal diseases could reduce the ability of Kenyan pastoralists to exploit international market opportunities.

The increased frequency of droughts could also cause forced population movements from drought-affected regions to less vulnerable regions (Government of Kenya, 2010). Migration is a common adaptation strategy to changing climate so it is likely that there would be significant population movements if drought frequency increased. As a result, demand for land would increase in less vulnerable areas. However, this increase in demand may exceed the capabilities of existing Kenyan land institutions to manage. For example, existing land markets may not be able to supply sufficient land for migrants, or migrants may not have the resources to buy land. The inadequacy of existing land institutions in managing population movements could lead to inter-communal conflicts.

Finally, the broader economic impact of increased droughts have a serious impact on Kenya's economy (Government of Kenya, 2010). Specifically, frequent crop failures has lead to increased imports of grain staples. Furthermore, export crops and livestock exports are not sufficient to compensate for the increase in exports because of vulnerability to climate change. Given that 60% of Kenya's export earnings are produced by the agricultural sector, a deterioration in export performance could lead to financing and currency problems such as difficulties in managing foreign debt (Republic of Kenya, 2008). These impacts would have wider social and environmental impacts.

4.2.2. Land Policy

Land policy in Kenya is characterized by the retention of colonial-era laws and administration (Kanyinga, 2009; Kanyinga et al., 2008). The basis of Kenya's land laws are from British common law which codifies property rights through title. The President has the power to allocate land. National institutions regulated land affairs. National bodies also have the power to appropriate land using eminent domain.

4.2.3. Evolution and Sustainability of Land Policy

Kenya's land laws did not undergo reform after independence because of disagreement between political parties (Kanyinga, 2009; Kanyinga et al., 2008). The Kikuyu[3]-dominated political party wanted land powers to be managed at the national level whereas the smaller ethnic groups wanted land powers to be devolved to the regional level (Kanyinga, 2009). The difference in attitudes between the Kikuyus and others was that the colonial administration favored the former by allocating some valuable highland farms to prevent conflict. However, such land was actually claimed by other ethnic groups. In the end, the British used the Kikuyus as a buffer against landless Kenyans and to protect white farmers that chose to stay (Kanyinga, 2009).

[3] Kikuyu are the largest ethnic group in Kenya (Kanyinga, 2009; Kanyinga et al., 2008).

Current land laws cannot be reformed without constitutional amendment (Kanyinga et al., 2008). The last attempt to amend the constitution in 2005 was rejected due to perceptions of Kikuyu dominance of the reform process (Kanyinga, 2009). Given the highly divisive nature of land and the constitutional constraints against land law reforms, it would appear the current land policy is unlikely to be reformed given current political divisions.

Nevertheless, escalating violence over land policy issues, especially allocation of land to non-traditional owners and political supporters, could create political momentum for reform. If this occurs, there would be significant land redistribution that could affect security of existing land tenure. The Kenyan Government acknowledges the problems caused by insecure tenure and has developed plans to improve land policy by improving registration, documentation, land use planning and tenure security (Republic of Kenya, 2008). However, it is not clear how these reforms would manage overlapping claims which are at the root of the land problem in Kenya (Kanyinga, 2009; Kanyinga et al., 2008).

4.2.4. Impact of Land Policy on Economic Development and Food Security

As mentioned before, land tenure in Kenya is based on the British concept of property rights. Conceptually, this provides strong legal protection for land tenure holders. Unfortunately, the practice in Kenya is very different.

In Kenya, land-grabbing has been used by Kenyan ‘elites’ to appropriate land from owners with legal title (Kanyinga et al., 2008). After the 2007 election, land-grabbing was conducted by ethnic supporters of the opposition to dispossess Kikuyu land-owners (Kanyinga, 2009). As a result, land-grabbing in Kenya is no longer restricted to members of the elite. Furthermore, national institutions have broad powers to appropriate land or to approve land transactions. Many of these national institutions are vulnerable to influence (Kanyinga, 2009). As a result, every piece of land could be vulnerable to land-grabbing.

Given the vulnerability of private land ownership to land-grabbing, farmers are unlikely to invest in production-maximization projects such as building dams or tiers. This is because the risk of land-grabbing renders land ownership (even with title) insecure (CAPRi, 2010). Land-grabbing reduces investment because it undermines the ability of the land owner to realize the gains of the investment. For example, if a farmer invested in a tier cropping system that takes 5 years to complete, but his land was grabbed in the 2nd year, the farmer has made a costly investment without receiving any benefit from the investment. Therefore, the risk of land-grabbing in Kenya is likely to have a negative impact on economic development and food security by discouraging investment by farmers.

However, some land that has been grabbed has been consolidated into large agricultural production estates. For example, the former Kenyan President Moi has a farm estate of 2500 ha which is significantly larger than the average farm size in Kenya of 2.5 ha (Kanyinga et al., 2008). However, larger farms may not be more efficient per average hectare than smaller farms because they are typically high-input systems and do not maximize the use of the land (van den Brink et al., 2006). According to the Kenyan Government, most land on large farms are idle (Republic of Kenya, 2008). Furthermore, large farms are more export-oriented whereas smaller farms produce for local demand (van den Brink et al., 2006). Therefore, farm consolidation under land-grabbing is unlikely to have promoted food security.

According to the Kenyan Government, 40% of Kenyans do not have access to adequate food (Republic of Kenya, 2008). This is despite increasing food production. Persistent food insecurity is probably due to population growing faster than food production. Lower productivity as a result of climate variability is also a factor (Kabubo-Mariara & Karanja, 2007). Also, frequent droughts have caused crop failures and affected livestock production (Government of Kenya, 2010). This has resulted in increasing food imports. Improving tenure security could encourage Kenyan farmers to improve the efficiency of their farms by investing in farm improvements and equipment.

4.2.5. Land Policy and Farm-level Adoption of Adaptation Strategies

Tenure insecurity is likely to discourage investment by farmers in long-term adaptation strategies. Short-term adaptation strategies may be successful in encouraging widespread adoption. For example, a successful adaptation case in Kenya was the introduction of mangoes as an alternative food crop (Joto Afrika, 2009). Mangoes traditionally take 20 years to establish. However, farmers were taught to graft mango-producing branches to existing trees which reduced establishment time from 20 to 2 years.

However, to improve Kenya's long-term food security given climate change, farmers would need to adopt long-term adaptation and farm improvement measures. This is unlikely to happen unless conflicts over land are defused and land-grabbing is no longer a credible risk.

4.2.6. Land Policy and Farm-level Decision to Mitigate Carbon

The Kenyan Government is interested in participating in carbon markets through the Clean Development Mechanism (CDM) or Reducing Emissions from Deforestation and Degradation plus (REDD+) (Government of Kenya, 2010). It proposes improving the private sectors' capacity to engage with carbon markets such as educating potential beneficiaries on the rules of obtaining certification. The World Bank is supporting the Kenyan Government by investing in the 'Kenya Agricultural Carbon Project' (KACP). The KACP covers 45,000 ha and plans to sequester 60,000 tons of CO_2 equivalent per year (World Bank, 2010b). Most of the farms in the project area are on freehold tenure which suggests legally-strong property rights (ESF Consultants Ltd., 2010).

However, for Kenyan farmers to engage in carbon markets, they would have to make long-term investments such as invest in agro-forestry or change farm practices. Tenure insecurity would discourage long-term investments as described in 4.2.5.

Tenure insecurity is compounded by legal uncertainty over who has the rights to carbon sequestered on a specific piece of land (Knox et al., 2010; Norton Rose, 2010). In Kenya, it is unclear who owns the carbon from soil sequestration. The KACP resolved this problem by designing a benefit-sharing agreement to define how carbon revenue would be shared between the investor, project developer, and farmers (ESF Consultants Ltd., 2010). Therefore, the KACP uses private contract law to govern the ownership and transfer of carbon. However, it is arguable that this is applicable for general situations, because the World Bank is one of the investors in the KACP, its participation would probably deter opportunistic behavior by Kenyan 'elites' (Scott, 2009).

4.2.7. Opportunities for Improvement

Tenure insecurity in Kenya is not caused by inappropriate laws but the lack of enforcement to protect property rights (Kanyinga, 2009; Kanyinga et al., 2008). For example, it is not uncommon for owners with title to have their land appropriated (Kanyinga et al., 2008). After the 2007 election, Kikuyu land owners that had been resettled on other tribes' land were evicted from their land (Kanyinga, 2009). The Njonjo Commission found that in the absence of clear legal and policy frameworks, public officials were able to use their land allocation powers to patronize selected groups (Kanyinga, 2009). Given the frequency of illegal evictions and land-grabbing, it is unlikely that the Kenyan Government's proposal to increase land registration and documentation would actually provide meaningful legal protection against eviction or land-grabbing.

As discussed in 4.2.3, constitutional reform is required to reform land legislation (Kanyinga, 2009; Kanyinga et al., 2008). This is unlikely to occur in the short-term given the violent disagreements between Kenya's political parties on how to reform the constitution and land legislation.

So what can the Kenyan Government do? Kenya could learn from Ethiopia's experiences of improving tenure security through a low-cost verification method that also reduced the potential for conflict at the local level (Deininger et al., 2008; Deininger, Zevenbergen, & Ali, 2006). This was done by involving the claimant and all neighbors in measuring the dimensions of the claimant's land. All neighbors have to be present otherwise the land is not registered. This also avoids the use of expensive surveying equipment and trained personnel. Instead, the claimant and the neighbors have to agree on the dimensions as measurement is taking place. This can help defuse conflict by creating a forum for negotiation, provide opportunities for mutual gain, and build trust between neighbors; if the neighbor also wants to have their property registered, they require the agreement of all their neighbors so cooperation is more productive than conflict. In other words, the Ethiopian model can change the relative payoffs between conflict and cooperation. If agreement cannot be reached, the dispute is resolved by local leaders. This certification process was successful in registering 6 million pieces of land (Deininger et al., 2008).

The Ethiopian model could be applied to Kenya to reduce costs and time of the current certification process (Republic of Kenya, 2008). The increase in tenure security was found to increase investment in farm improvements (Deininger et al., 2008). Therefore, the Ethiopian land certification process could be adapted to improve Kenya's land policy.

4.3.South Africa

South Africa's diversified economy is less reliant on agriculture than in Kenya and Ethiopia. South Africa's agriculture sector generates 5% of South Africa's GDP and 13% of employment (The Government of the Republic of South Africa, 2010). The diversification of South Africa's economy is a product of more advanced economic development.

South African agriculture is still recovering from the legacy of apartheid. This is most apparent in the inequitable distribution of farm land. Approximately 87% of South Africa's commercial farm land (82 million ha or 68% of South Africa's total surface area) is owned by 60,000 white farmers (5% of the white population) (Didibhuku & Khosa, 2008; Lahiff, 2009). The remainder of the commercial farm land is farmed by 13 million Africans in the former homelands (Lahiff, 2009). Therefore, land policy is a significant social issue affecting race relations and poverty in South Africa (Didibhuku & Khosa, 2008).

4.3.1. Climate Change Impacts

South Africa is considered particularly vulnerable to the impacts of climate change because of its lack of water resources (The Government of the Republic of South Africa, 2010). Climate change is expected to cause higher temperatures, particularly in inland areas, and increased frequency of natural disasters.

South Africa's agriculture is particularly vulnerable to the reduction of surface runoff as a result of climate change (Boko et al., 2007). Irrigated agriculture is especially vulnerable to the reduction of surface runoff (Department of Environmental Affairs, 2009).

Agricultural production is also exposed to increases in the range of animal and crop diseases (The Government of the Republic of South Africa, 2010). In semi-arid and arid pastoralist regions, reduction in rainfall will affect the availability of forage for livestock (The Government of the Republic of South Africa, 2010). Increased carbon concentration is also expected to promote the growth of bush encroachment and invasive alien plant species.

Maize is South Africa's main grain crop and the Government has highlighted the impact of climate change on food security (Department of Environmental Affairs, 2009). If climate change results in hotter and drier climate, South Africa's maize production is expected to fall by 10-20%

over the next 50 years. In contrast, South Africa needs to expand maize production by 3% per year to meet growing food demand.

As a result of climate change, South Africa's food security is expected to be reduced by causing a decline in production growth.

4.3.2. Land Policy

South Africa has essentially retained the apartheid-era land policies in terms of favoring large, commercial farms (Didibhuku & Khosa, 2008; Lahiff, 2009; van den Brink et al., 2006; van den Brink et al., 2009). For example, apartheid-era land policies established explicit restrictions on subdivision to ensure white farmers could earn a 'reasonable' income (van den Brink et al., 2006). Furthermore, apartheid-era land policies forcibly relocated African people from their traditional lands to create a large pool of low-cost farm labor (Didibhuku & Khosa, 2008). As mentioned before, most Africans in South Africa live in the former homelands whereas most of the productive farm land are owned by 60,000 white farmers (Didibhuku & Khosa, 2008; Lahiff, 2009).

The post-apartheid Government has attempted to redress this balance through three components: land redistribution, land restitution, and tenure reform (Didibhuku & Khosa, 2008). To date, very little land has been transferred to African farmers. For example, under the Settlement/Land Acquisition Grant (SLAG), 1% of commercial farm land was transferred to African beneficiaries, or 650,000 ha to 60,000 households (Didibhuku & Khosa, 2008). However, transferring land to African farmers was no guarantee of reducing poverty. The South African Government failed to provide enough funding to train beneficiaries to farm their land productively (Lahiff, 2009). As a result, many beneficiaries were not better off after land reform.

In the former homelands (i.e. land for reserved for relocated Africans), land policy is administered by local governmental authorities and traditional leaders (Didibhuku & Khosa, 2008). Under apartheid, the traditional leadership had the power to allocate land but now has to co-exist with democratically-elected local governments. Traditional leaders have used their land allocation powers to preserve the status quo by excluding women from land ownership (Didibhuku & Khosa, 2008). Land tenure in the homelands is generally insecure because traditional leaders are unaccountable for their decisions.

South Africa's experience with land reform has not been encouraging in terms of poverty reduction or reducing racial inequalities. However, it has demonstrated the government's credibility in respecting property rights regardless of race outside of the homelands. This would have important implications for investment and development if land policies could be reformed while respecting incumbent land-owners' property rights.

4.3.3. Evolution and Sustainability of Land Policy

As mentioned in 4.3.2, South Africa's land policy has its origins in the apartheid period. However, the South African legal system is based on British common law which provides for strong protections of property rights and private contracts. The South African Government does have access to expropriation powers but has rarely used them in the post-apartheid period (Didibhuku & Khosa, 2008; Lahiff, 2009). As a result of strong rule of law and credible government commitment to respecting private property rights, South Africa has an active rural land market.

But there are questions on the political and social sustainability of South Africa's land policies (Alden & Anseeuw, 2009). The violent land reforms in Zimbabwe in 2000 won some supporters in South Africa and other African countries with white farmers. Furthermore, land reform has been a key issue in the anti-apartheid movement and South Africa's governing party, the African National Congress (ANC).

However, land has been less urgent as 'middle-class' concerns (e.g. environmental protection) have replaced concerns on inequitable land distributions (Didibhuku & Khosa, 2008). As a result, there is less political support for land reform. Also, the South African Government's macroeconomic policy is based on providing macroeconomic stability to encourage foreign investment (Didibhuku & Khosa, 2008; Lahiff, 2009). An attempt to redistribute land could signal to foreign investors that property rights are under threat and cause a withdrawal of foreign investment. Ultimately, this could undermine South Africa's economic development since the end of apartheid. As a result, the Government may be reluctant to aggressively pursue land reform if it resulted in undermining South Africa's economic development.

In the homelands, the accommodation between elected local governments and traditional leaders may become unsustainable if poverty alleviation becomes a higher priority. Traditional governance does not support economic or social development (Didibhuku & Khosa, 2008). Reforming traditional leadership would be necessary in the long-run to include marginalized groups such as women in development.

4.3.4. Impact of Land Policy on Economic Development and Food Security

South Africa's commercial agriculture sector has become more export-oriented since the end of apartheid (van den Brink et al., 2009). However, this has not resulted in increased employment: employment in commercial agriculture declined from approximately 1.1 million in 1995 to 0.9 million in 2003 (van den Brink et al., 2009). Furthermore, since the end of apartheid, 1 million farm dwellers (or around 200,000 households) have been evicted from commercial farms between 1994 and 2004 (van den Brink et al., 2009). However, the evictions were a continuation of a trend under apartheid rather than because of the end of white minority rule.

The simultaneous growth with lower labor-intensity is consistent with a domestically-focused industry becoming more export-oriented. Given the scale of South African commercial farms, it may have been more financially-viable to substitute capital equipment and new technology for unskilled labor. This would have resulted in higher investment and would have only been possible if commercial farmers (predominantly white) were reasonably confident of receiving a return from their investment – i.e. there was land tenure security.

In contrast, subsistence farms have been growing – 400,000 livelihoods have been added between 1995 and 2003 (van den Brink et al., 2009). This is despite the limited amount of land available to subsistence farmers and low potential for agriculture. However, this indicates the potential that small-scale agriculture could contribute to poverty reduction.

As a result, South Africa's land policy has been successful in preserving the inequitable distribution of farm land. It has contributed to economic development by ensuring investment security for commercial farmers to invest in more capital-intensive operations to compete on international agricultural markets. However, it has not contributed to improving the lives of farm workers or dwellers. Furthermore, it is debatable that South Africa's land policies have contributed to food security. On the one hand, commercial agriculture has become more efficient producers and generated more foreign exchange. On the other hand, the reduced employment of farm workers and eviction of farm dwellers have weaken the ability of rural poor people to provide for their own food security. As a result, it is unclear if South Africa's land policies have strengthened or weakened the country's food security.

4.3.5. Land Policy and Farm-level Adoption of Adaptation Strategies

Commercial farmers and subsistence farmers would face different incentives to adopt adaptation strategies because they would face different levels of tenure security. Commercial farmers have the highest tenure security as discussed in 4.3.4 and so would have the most to gain from adopting adaptation strategies. Subsistence farmers, especially in the homelands, have tenure insecurity and would have less incentive to invest in adaptation strategies. Therefore, subsistence farmers are likely to bear a disproportionate impact from climate change.

Beneficiaries of land reform would be expected to have higher tenure security than subsistence farmers. However, these farmers lack the skills and the resources to operate their farms effectively. This is partly the result of subdivision restrictions; land reform forced untrained farmers to operate farms that were too large for them (Lahiff, 2009). It is also the result of a lack of 'post-settlement' support in terms of farm extension support (Lahiff, 2009). Also, beneficiaries were marginalized from the process of farm planning and procurement of goods and services (van den Brink et al., 2009). For example, beneficiaries could only procure fertilizers and other farm inputs through the Government. As a result of lack of capabilities and disempowerment, 16% of beneficiaries reported that their farms were generating 'sustainable revenue' (Lahiff, 2009). Given the lack of skills, resources, and empowerment, beneficiaries probably would not have an incentive to invest in farm adaptation strategies.

4.3.6. Land Policy and Farm-level Decision to Mitigate Carbon

Much of the discussion from 4.3.5 also applies to farm-level decisions to invest in mitigation projects. Many commercial farms do not use their land as intensively as small farms and so would be able to allocate parts of their operations to carbon mitigation projects (Didibhuku & Khosa, 2008; van den Brink et al., 2006). Furthermore, the productivity benefits from some mitigation strategies would allow commercial farmers to replace chemical fertilizers and therefore, increase their returns (van den Brink et al., 2006). In the event that a market for agricultural carbon credits eventuates, commercial farmers will be able to diversify their income to include carbon revenue (Knox et al., 2010).

Beneficiaries from land reform and subsistence farmers are unlikely to invest in mitigation strategies. Beneficiaries may have sufficient land to adopt such mitigation strategies as agro-forestry but they are unlikely to have the skills or resources to profitably implement them (Lahiff, 2009). Subsistence farmers do not have the tenure security to capture the benefits from investing in mitigation projects. As a result, under South Africa's current land policies, the establishment of a market for agricultural carbon credits is unlikely to benefit South Africa's poorest farmers.

In terms of carbon rights, South Africa has no clear law on carbon rights. This is mainly because South Africa does not have a carbon trading scheme and have not established the legal right to carbon (Tucker & Gore, 2008). However, it is possible to implement a CDM, generate carbon credits, and to trade them to foreign entities. Therefore, establishing the ownership of carbon rights appears to be a matter of private contract law rather than of South African regulation. The main implication of this is that ownership of the carbon is determined through negotiation between the farmer, investor, project developer, and buyer. A contract-based carbon market would suit more business-savvy commercial farmers rather than land reform beneficiaries or subsistence farmers.

4.3.7. Opportunities for Improvement

From the discussion from 4.3.5 and 4.3.6, it is clear that subsistence farmers and beneficiaries from land reform have little incentive to adopt adaptation strategies or implement mitigation projects. There are a number of ways that can improve these farmers' incentives to adapt and mitigate climate change.

First, land reform should be designed to ensure that beneficiaries have the skills, resources, and empowerment to operate farms efficiently. This would involve providing post-settlement support, access to capital, and requiring farmers to lead the farm planning process. It should also remove subdivision restrictions. Furthermore, a land tax should be considered to discourage large commercial farmers holding excess land and to release the land onto the land market or for redistribution. See van den Brink et al. (2006) for more details.

Second, the power of traditional leaders in the homeland should be reduced to ensure there is no competition with democratically-elected local governments. This could be difficult if traditional leaders have high social legitimacy. The power of local traditional leaders can be reduced by the local government issuing land certificates using low-cost methods (Deininger et al., 2008; Mitchell, 2010). This would improve the tenure security of certificate-holders and undermine the traditional leaders' power to allocate land.

5. Policy Implications

In this analysis of Ethiopian, Kenyan, South African land policies it is apparent that land policies must have some impact on farmers' decisions to produce, adapt or mitigate carbon. Land policies influence these decisions by affecting tenure security. In Ethiopia, tenure insecurity arises because land is owned by the Government and there are limitations on how the land can be used. In Kenya, there are laws to protect land ownership, however there are limited means for farmers to enforce their rights should they be usurped. In South Africa, tenure security depends on whether the farmer is commercial, beneficiary of land reform or subsistence; commercial farmers have strong tenure security, beneficiaries have similarly strong, but subsistence farmers have weak tenure security. Therefore, if an African Government wanted to improve incentives for investment in agricultural carbon sequestration projects, it should examine ways of improving tenures security through legal reforms but also by improving the political and social drivers.

African Governments can also use low-cost methods to improve tenure security (Deininger et al., 2008; Mitchell, 2010). However, such certification benefits are appropriate for protecting land ownership but not land *access*. In Kenya and Ethiopia, there are substantial nomadic pastoralist population that move to different areas depending on the seasons. Nomadic pastoralists' movements could affect the viability of an agricultural mitigation project. Restricting access would not be advisable because this could lead to violence and reduce the resilience of pastoralists' communities to cope with climate change (Knox et al., 2010). Instead, African Governments should examine ways to structure land access arrangements to ensure that carbon mitigation projects are not damaged. For example, fencing could be allowed for the specific project area but access to water and communal pastures should not be restricted. The farmer and pastoralists could share costs and benefits from the agricultural mitigation projects to ensure pastoralists have an incentive to manage the impact of their herds appropriately. Governments can codify this requirement to provide protection of these projects. However, expanding benefit-sharing agreements could also diminish the returns for the other parties (Knox et al., 2010).

There are other factors that would affect farmers' decisions to improve food security, adaptation, and mitigation. First, ownership of carbon is undefined in all three countries analyzed in this thesis. Undefined carbon rights would cause investment uncertainty for farmers, investors, project developers, and carbon buyers because they would not know if carbon could be delivered. In South Africa and Kenya, private contract law is used to define benefit-sharing between the farmer, project developer, investor, and buyer. These contracts codify each party's commitments and define rewards and penalties. However, these contracts do not eliminate the legal risk that carbon sequestered may not be legally transferable. Therefore, African Governments should define carbon rights if they want to encourage investment in agricultural carbon mitigation projects.

Secondly, farmers' capabilities are a factor in scaling up improvement in food security through adaptation and mitigation projects. In South Africa, land redistribution was found to be unsuccessful in improving the livelihoods of beneficiaries because they did not have the skills, resources, or were empowered to operate their new farms efficiently. Farmers' capabilities are also an issue in Kenya and Ethiopia, particularly in understanding the links between the co-benefits between mitigation, adaptation, and food security. In many cases, the actual implementation of adaptation/mitigation/food security projects is not complex but may require learning new skills and investing in new equipment or farm improvements. The exception to this would be learning how to benefit from carbon markets; the process for obtaining approval can be a long, frustrating process (Lutken & Michaelowa, 2008). For farmers to invest time and resources in these projects, they have to be convinced that they would benefit from such projects.

In summary, African Governments can significantly improve the investment climate for agricultural mitigation projects that have adaptation and food security co-benefits. In some countries, they may be straight-forward such as improving tenure security using low-cost methods. In many countries, it may involve confronting their colonial legacy and dismantling institutions that benefit a minority of their population. In all cases, African Governments should examine tenure security, land access, carbon rights, and farmers' capabilities before implementing sustainable development policies that rely on large-scale investment in agricultural carbon mitigation.

6. Conclusions

In this thesis I attempt to answer the question, *'what role can land reform play in improving African agriculture's ability to contribute to climate change adaptation, carbon mitigation, and food security?'* This question is designed to explore the feasibility of using international carbon markets as a sustainable development strategy to improve adaptation and food security, in addition to carbon mitigation, in Africa.

I use a multi-disciplinary case study approach to examine this question for the case of Ethiopia, Kenya, and South Africa. I use a 7 criteria to methodically answer this question:

8. Identify how climate change is likely to affect agriculture in that country;
9. Description of land policy institutions and administration;
10. Multi-disciplinary analysis of the evolution and sustainability of land policy;
11. Impact of land policy on economic development and food security;
12. Anticipated impact of land policy on farmers decision to adopt adaptation strategies;
13. Anticipated impact of land policy on farmers decision to mitigate carbon;
14. Opportunities for improvement of land policy in terms of improving development, food security, adaptation, and carbon mitigation benefits.

In all cases I found that land policies could discourage African agriculture to contribute to climate change adaptation, carbon mitigation, and food security. In Ethiopia, tenure security is weak and all land is owned by the government. This reduces the incentive to invest in long-term projects that improve adaptive capacity, agricultural production, and carbon mitigation.

In Kenya, land policies are based on colonial-era policies that protected property rights. However, land-grabbing is common, even property with legal title is vulnerable to expropriation. As a result, there are limited incentives for Kenyan farmers to invest in projects that deliver climate change adaptation, carbon mitigation, and food security co-benefits.

In contrast, South Africa has strong property rights protection, but only if the farm is not in the homelands. In the homelands, traditional leaders decide land policy but are unaccountable to anyone. As a result, South African farmers may benefit from investing in joint adaptation, mitigation, and food security projects. However, because the commercial farm sector is dominated by 60,000 wealthy white farmers, using agricultural mitigation projects to improve adaptation and food security would only benefit a small percentage of South Africa's rural population.

There are several ways that African countries could start to improve the incentives for carbon mitigation projects with adaptation and food security co-benefits. First, improve tenure security and land access. Tenure security is important to encourage long-term investment. Land access is important to allow nomadic pastoralists to flexibly adapt to climate change.

Second, define carbon rights. In all countries examined, no country has defined who owns carbon. This creates investment uncertainty for agricultural carbon mitigation projects because it is unclear if the carbons can be sold and therefore generate a return for investors. Rectifying this situation would substantially improve the investment climate in agricultural mitigation projects.

Third, the capabilities of African farmers should be examined to ensure they have the skills and resources to implement agricultural mitigation projects with adaptation and food security co-benefits. In some cases, these skills may be variations of current farming techniques. However, in all cases, farmers will need to understand how agricultural activities contribute to carbon emissions and mitigation. Furthermore, educating farmers on how they can monetize their activities through international carbon markets is an important step to encouraging farmers to participate in agricultural carbon mitigation projects.

Other policy implications would depend on the specific country circumstances. For example, in South Africa, commercial farm land cannot be sub-divided. Therefore, it would be advisable that policy-makers examine their land policy context to ensure that policy reforms contribute to an improved outcome - not only in terms of improving food security, climate change adaptation, and carbon mitigation – but also in terms of the country's sustainable development.

Further research is required to examine inter-linkages with other human activity that uses land such as forestry, urban development, and mining. But quantitative research would also be useful to estimate the impacts of land policy reform to strengthen the case of using carbon markets as part of a sustainable development strategy to improve Africa's food security and adaptive capacity. Further research is also required to examine how linking African agriculture with international carbon markets could help UNFCCC negotiations reach a post-Kyoto agreement.

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