Impact of Climate Change on Household Poverty in Ethiopia: Application of a Dynamic Micro-Simulation Approach

Zenaye Tekle4 and Belay Simane5

Abstract

While Ethiopia's economy has grown by seven percent annually in recent years, there are concerns that climate change could jeopardize this growth. The economy's dependence on rain-fed agriculture that is sensitive to climate change and variability is one of the reasons why poverty is high in the country. This study used a recursive dynamic CGE micro-simulation approach to analyse the impacts of climate change on poverty in the country and across agro-ecological zones. The effect of climate change on household consumption is negative in 2050 for both rural and urban areas. The households at the drought prone areas are the hardest hit where households' consumption expenditure declines by 30.3 percent. At the national level, total consumption of poor households declines by 21.4 percent while that of the non-poor households declines by 17.0 percent. Accordingly, the impact of climate change raises the national poverty incidence from 29.6 percent in 2010/11 to 45.15 percent in 2050. Climate change also increases the inequality among households. Hence, different adaptation and mitigation measures are vital if the country is to achieve its growth and poverty reduction targets.

Key words: *Ethiopia, Climate Change, CGE Micro-simulation Modeling, Poverty*

Introduction

Over the next 50 years, Ethiopia would experience increasingly erratic weather, with higher rainfall, and a temperature rise of at least 3°C (McSweneey et al., 2010). The mean annual temperature is projected to increase by 1.1 to 3.1°C by the 2060s, and 1.5 to 5.1°C by the 2090s. Ethiopia's low level of economic development combined with its heavy dependence on a climate sensitive

4 Ethiopian Development Research Institute (EDRI), zenayetekle@yahoo.com
5 College of Development Studies, Addis Ababa University (AAU), Addis Ababa, Ethiopia. E-Mail: simaneb@yahoo.com (Corresponding Author)

agricultural sector and its high population growth rate make the country particularly vulnerable to climate change (Simane et al., 2012; Dejene, 2003). Deforestation, accelerated soil erosion, and land degradation are also serious environmental problems that affect the future food security of the country. Therefore, mainstreaming of climate change issues into the national development plans and processes is important to reduce the impacts of climate change on poverty reduction and thereby the development of the country (PANE, 2009).

Across Africa, many studies have investigated the impacts of climate change on agriculture and possible adaption measures using different global models. Using a recursive dynamic general equilibrium framework, Nyeji and Fischer (1993) analysed the impacts of climate change in Egypt and found that there is a general rise in food prices, declines in consumer incomes and a resultant decline in per capita food consumption, deterioration in terms of trade, a surplus agricultural labour led to possible urban and foreign migration. Reid et al., (2007) analysed the effects of climate change in agricultural and fishing sectors using a CGE model of the Namibian economy, and found out that under a worst-case climate change scenario, large-scale shifts in climate zones reduce outputs, and the overall GDP fell by 6 per cent over 20 years from 2027 to 2047. Even under the best-case scenarios generated by the CGE model, subsistence farming will fall sharply. Thus, even under the best-case scenario, a quarter of the population will need to find new livelihoods. Displaced rural populations are likely to move to cities, which could cause incomes for unskilled labour to fall by 12 to 24 per cent in order to absorb the new workers. Income distribution in Namibia is already one of the most uneven in the world and this inequality is likely to increase.

Zhai et al. (2009) simulated the potential long-term impacts of global climate change on agricultural production and trade in the People's Republic of China (PRC) and found that the anticipated decline in agriculture share of GDP, the impact of climate change on the PRC's macro economy will be moderate even though the food processing subsectors are predicted to withstand the worst of losses from the agricultural productivity changes caused by climate change. According to Ahmed et al. (2009a) among the countries with the highest shares of populations entering poverty in the wake of climate extremes in Malawi and Zambia, simulated grains productivity declines of 75% cause the poverty headcount in those countries to increase by about seven percentage points relative to their total populations. Ahmed et al. (2009b) used climate model projections, statistical crop models, and general equilibrium economic simulations to determine how Tanzania's population is vulnerable to impoverishment due to climate change and found that the number of poor in the country could increase by 650,000 people by the year 2031. The largest increase in climate volatility could also put an additional 90,000 people below the poverty line. Thurlow et al. (2009) using a hydro-crop model with a dynamic general equilibrium (DCGE) model concluded that climate variability costs Zambia US$ 4.3 billion over a 10-year period. Overall, climate variability keeps 300,000 people below the national poverty line by 2016.

Hertel et al. (2010) studied the poverty implications of climate-induced crop yield changes by 2030 considering impacts resulting in low, medium, or high productivity and evaluated the resulting changes in global commodity prices, national economic welfare, and the incidence of poverty in 15 developing countries6. The findings indicated that in the low productivity scenario, prices for major staples rise 10-60% by 2030. The poverty impacts of these price changes depend as much on where impoverished households earn their income as on the agricultural impacts themselves, with poverty rates in some non-agricultural household groups rising by 20-50% in parts of Africa and Asia under these price changes, and falling by equal amounts for agriculture-specialized households elsewhere in Asia and Latin America.

In 2011, Kyophilavong and Takamatsu assessed the impact of climate change on poverty in Laos using a static computable general equilibrium model. The study is undertaken for Laos, which has a high share of agriculture sector on GDP and high poverty rates as a case study to assess the impact of climate change on national

6 The 15 developing countries are Bangladesh, Indonesia, Philippines, Thailand, Vietnam, Brazil, Chile, Colombia, Mexico, Peru, Venezuela, Malawi, Mozambique, Uganda and Zambia.

economy and climate change using CGE model. The impact of climate change will reduce GDP by about 3% and equivalent variation will decline by 80 $US million in 2050. Although the result showed that climate change has serious impact on Lao economy in terms of declining GDP, the impact on poverty was negligible which is below 1 percent.

The World Bank (2008) by the development prospects group developed a methodology that provides an economy-wide framework for analysing economic impacts from climate change and potential adaptation policies in Ethiopia. The study used a dynamic single-country prototype Computable General Equilibrium (CGE) model. The model is calibrated to the 2001/02 social accounting and used to assess the potential quantitative impacts of climate change on the economic growth of the country over the next 25 years. The results indicated that as the climate shocks become more negative, the impact is much more serious and results in a decline in average annual real GDP growth rate over a 25-year simulation horizon. In the worst-case scenario, real GDP in the final year would be 46 percent lower than in the base run (World Bank, 2008).

Robinson et al. (2011) also used a dynamic CGE model and studied the economic impacts of climate change and adaptation in Ethiopia with a high dependence on climate sensitive sectors and climate sensitive infrastructure. The study develops a methodology by applying crop and agro-ecology specific analysis. With a system of country-specific hydrology, crop, road and hydropower engineering models, the study simulated the economic impacts of climate change towards 2050 using a multi-sectoral regionalized dynamic computable general equilibrium models. The analysis used high-resolution global circulation models to understand the specific hydrology and crop to identify yield impacts by crop type and agro-ecological zone. The study confirms that climate change would reduce Ethiopia's GDP in 2040s, up to 10 percent with higher negative effects on the poor households. The results suggested that with support from developed countries, suitably scaled adaptation measures could restore aggregate welfare to baseline levels.

Moreover, Gebreegziabher et al. (2011) used a dynamic CGE model in order to grasp the economy-wide effect of climate change induced shocks in agriculture on Ethiopia's economy. This study tried to grasp the impact of climate change on the economic growth and poverty of the country as well as on different zones/areas while incorporating the inter-linkages of livestock farming with crop production. The study found out that over a fifty-year period the projected reduction in agricultural productivity may lead to reductions in average income of 30%, compared to the outcome that would have prevailed in the absence of climate change. The study also stated that in those parts of the moisture sufficient highlands where cereal production currently dominates, overall productivity is projected to increase until approximately 2030 because of climate change, but to decline sharply thereafter. In the drought prone highlands, the situation is somewhat different. Land productivity in crop production is expected to decline because of climate change more or less continuously throughout the period.

The impact of climate change on poverty, however, has not been analysed in detail in Ethiopia where it is a compelling problem. None of the existing studies have analysed poverty at the individual household level with appropriately disaggregated data. In addition, previous studies do not show the disparity of welfare across agro-ecological zones, which is especially important in the context of climate change. Hence, this study engages in a detailed analysis of the impact of climate change on poverty and income distribution in the country in the 2050s. It also captures agro-ecology specific impacts of climate change on household consumption and poverty. The objective of this study is to examine the impacts of climate change on poverty in Ethiopia. Specifically, it aims to identify the changes in consumption and its likely effects on the incidence, depth and severity of poverty in the country and across agro-ecological zones.

This paper builds on the previous literature by providing a comprehensive assessment of economy-wide impact of climate change on poverty in Ethiopia. It simulates scenario of agricultural productivity change induced by climate change up to 2050 using an economy-wide, dynamic computable general equilibrium (DCGE) model.

Climate and Poverty Profile of Ethiopia

Agro- ecological features

Agro-ecological zones (AEZs) in Ethiopia are classified in different ways. The major ones include the traditional agro-ecological zones based on rainfall and elevation variations as well as more finely elaborated agro-ecological zones developed by the Ministry of Agriculture and Rural Development. Three broad agro-ecological zones (rain sufficient areas, drought prone highlands, and pastoralist lowlands) which characterize the landscape in the country are officially recognized in planning documents.

The rain sufficient areas can be further subdivided in to the humid lowlands, the rainfall sufficient cereal-dominant areas, and the rainfall sufficient highland enset-based cropping systems. These AEZs differ in terms of climate, moisture regime and land use (IFPRI, 2011; EDRI, 2009). According to the EDRI social accounting matrix (SAM) of 2005/06, the agro-ecological zones are classified from zone 1 to 5 as the humid lowlands, moisture sufficient cereals based highlands, moisture sufficient enset based highlands, drought prone highlands and pastoralist lowlands, respectively. Around 45 percent of the country consists of a high plateau comprising zones 2 to 4 with mountain ranges divided by the East African Rift Valley. Almost 90 percent of the population resides in these highland regions (1500m above sea level). Within the highlands, zones 2 and 3 generally have sufficient moisture for the cultivation of cereals and enset (a root crop), whereas zone 4 is prone to droughts. Pastoralists mostly populate the arid lowlands in the east of the country (zone 5) (World Bank, 2010).

Most smallholder farmers reside in the moisture reliable cereal-based highlands (i.e. 59 percent of total cultivated area). Farm area in the drought-prone highlands accounts for 26 percent of total area cultivated (EDRI, 2009). With farmers using virtually no irrigation, reliable rainfall is an important condition to achieve good agricultural productivity. However, in the moisture-reliable enset-based highlands (11 percent of total farm area) population pressure has diminished farm size to such an extent that out-migration has become a major pathway out of poverty. Cultivation in the two other areas (humid lowlands and pastoralist area) is relatively less important, accounting for only 3.9% of all cultivated area in Ethiopia (Seyoum et al., 2012).

Deressa and Hassan (2009) analyzed the impact of climate change by classifying the nation in to 11 agro-ecological zones. However, the SAM which is used in this paper classified the country in to 5 agro-ecological zones. Hence, for the analysis in this paper, the 11 agro-ecological zones are aggregated and mapped in to the SAM classification as shown in table 2.1. In addition, in the dynamic model, the humid lowlands are aggregated with the moisture sufficient highland cereals based areas. Hence, the analysis identifies the differential impact of climate change broadly classifying the country in to 4 agro-ecological zones. The average net revenue impact is taken as an elasticity parameter for the simulations based on the mapping.

Table 1: Mapping of agro-ecological zones in Deressa and Hassan (2009) in to the SAM classification

SAM Classification		Deressa and Hassan Classification
Zone 1	Humid Lowlands Moisture Reliable	Hot to warm sub-moist lowlands Hot to warm sub-humid lowlands
Zone 2	Moisture Sufficient Highlands – Cereals Based	Tepid to cool pre-humid mid-highlands Tepid to cool humid midlands Tepid to cool moist mid-highlands Tepid to cool sub-moist highlands Cold to very cold moist Afro-alpine
Zone 3	Moisture Sufficient Highlands – Enset Based	Hot to warm humid lowlands Hot to warm per humid lowlands
Zone 4	Drought-Prone (Highlands)	Tepid to cool sub-moist mid-highlands
Zone 5	Pastoralist (Arid Lowland Plains)	Hot to warm arid lowland plains

1.1.

Trends and Projections of Climate Change

The climate in Ethiopia is already changing. According to the Ethiopian National Meteorology Agency (NMA), the average annual minimum temperature over the country has been increasing by about 0.25°C every 10 years, while average annual maximum temperature has increased by about 0.1°C every decade. The average annual rainfall of the country showed a very high level of variability over the past years even though the trend remained more or less constant (NMA, 2007).

All projections of the future climate indicate substantial increases in the frequency of days and nights that are considered 'hot' in current climate. Mean annual temperature is projected to increase by 1.1 to 3.1°C by the 2060s, and 1.5 to 5.1°C by the 2090s (World Bank, 2011). A forecast by NMA (2007) indicated that temperature will increase in the range of 1.7 – 2.1° C by the year 2050 and 2.7 – 3.4°C by the year 2080 over Ethiopia.

All projections indicate decreases in the frequency of days and nights that are considered cold in the current climate. Models predicting precipitation give controversial results of both increasing and decreasing precipitation. Projections from some models broadly indicate increases in annual rainfall for Ethiopia as a whole. These increases are largely a result of increasing rainfall during the 'short' rainfall season (October-December) in southern Ethiopia. October-December rainfall is projected to increase between 10 and 70% on the average over Ethiopia. Large, proportional increases in October-December rainfall are predicted to occur in the driest, eastern-most parts of Ethiopia (World Bank, 2011).

All models agree that the temperature in Ethiopia will increase in the coming years. Three climate prediction models based on two scenarios from the IPCC Special Report on Emission Scenarios (SRES) predict temperature and rainfall for 2050 and 2100 (Table 3.1). These models are: the Coupled Global Climate Model (CGCM2), the Hadley Centre Coupled Model (HadCM3) and the Parallel Climate Model (PCM) (IPCC, 2001). The two SRES scenarios are the A2 and B2 scenarios7.

Table 2: Climate predictions of SRES models for 2050 and 2100

Model		Temperature(0C)		Precipitation (%)	
		2050	2100	2050	2100
CGM2	A2	3.3	8	-13	-28
	B2	2.9	5.1	-13	-28
HaDCM3	A2	3.8	9.4	9	22
	B2	3.8	6.7	9	22
PCM	A2	2.3	5.5	5	12
	B2	2.3	4	5	12

Source: Strzepek and McClusky (2006).

Poverty and Income Distribution in Ethiopia

Ethiopia is characterized by extreme poverty in terms of both assets and income. Many studies indicate that large proportions of the Ethiopian population live under abject poverty in both urban and rural areas. Based on four household income, consumption and expenditure surveys including the recently released 2010/11 survey, national poverty prevalence declined significantly during 1999/2000–2010/11. Furthermore, the recent interim report of MOFED released in March 2012 has supported a further decline in the poverty incidence. According to the report, the national headcount index has declined to 29.6 percent with both rural and urban areas showing similar downward trends, albeit from different starting points.

7 A2 scenario describes a world in which population growth, per capita economic growth and technological changes are heterogeneous across regions. B2 scenario describes a world in which population increases continuously across the globe at a rate less than A2, intermediate level of economic development that is oriented towards environmental protection and social equity with a focus on local and regional levels (IPCC, 2001).

Table 3: Trends in National and Rural/Urban Poverty

	Poverty indices over time				Change (%)	
	1995/1996	1999/2000	2004/2005	2010/2011	2004/05 over 1999/00	2010/11 over 2004/05
National						
Head count index	0.455	0.442	0.387	0.296	-12.4	-23.5
Poverty gap index	0.129	0.119	0.083	0.078	-30.0	-5.5
Poverty severity index	0.051	0.045	0.027	0.031	-39.8	14.4
Rural						
Head count index	0.475	0.454	0.393	0.304	-13.4	-22.7
Poverty gap index	0.134	0.122	0.085	0.080	-30.8	-5.5
Poverty severity index	0.053	0.046	0.027	0.032	-40.6	17.0
Urban						
Head count index	0.332	0.369	0.351	0.257	-4.70	-26.9
Poverty gap index	0.099	0.101	0.077	0.069	-23.6	-10.1
Poverty severity index	0.041	0.039	0.026	0.027	-33.5	5.1

Source: Ministry of Finance and Economic Development (MOFED, 2012).

On the other hand, as shown in Table 4 inequality has changed relatively little, with a Gini coefficient of 0.29 for 1995/96, 0.28 for 1999/00, 0.30 in 2004/05 and 0.298 in 2010/11 (MOFED, 2012). According to the report of MOFED, the income distribution is even less equitable in both urban and rural areas. Gini coefficient estimates for overall income inequality in Ethiopia were 0.28 in 1999/00, with urban inequality at 0.38 and rural inequality at 0.26. The figures declined to 0.27 and 0.34 for rural and urban area in

1995/96. In 2004/05 although inequality in rural areas remained the same, it rose to 0.44 in urban areas even while the poverty rate declined in urban areas. National inequality also rose to 0.3 from its level of 0.28 in 1999/00. In 2010/11, however, national inequality declined to 0.29 which is attributed to the significant inequality decline in urban areas, where it fell to 0.37 declining by 16% from its level in 2004/05 and the rise in rural inequality to 0.27 in the same year (MOFED, 2012).

Table 4: Trends in the National and Rural/Urban Inequality

Year	Rural	Urban	National
1995/96	0.27	0.34	0.29
1999/00	0.26	0.38	0.28
2004/05	0.26	0.44	0.3
2010/11	0.274	0.371	0.298

Source: Ministry of Finance and Economic Development (MOFED, 2012).

Methodology

Model Specification

Computable general equilibrium (CGE) models are simulations that combine the abstract general equilibrium structure formalized by Arrow and Debreu with realistic economic data to solve numerically for the levels of supply, demand and price that support equilibrium across a specified set of markets (Wing, 2004). CGE models are the best choice if the economic or policy shock to be evaluated is expected to have significant impacts throughout the economy. Moreover, CGE models are the best option if the research question involves analyzing the static/dynamic, direct/ indirect and short/long term effects caused by a shock such as climate change (IDB, 2012).

The standard CGE model explains all of the payments recorded in the SAM. The model therefore follows the SAM disaggregation of factors, activities, commodities, and institutions. It is written as a set of simultaneous equations, many of which are nonlinear. There is no objective function. The equations define the behaviour of the different actors. This behaviour follows simple rules captured by fixed coefficients. For production and consumption decisions, behaviour is captured by nonlinear, first-order optimality conditions. That is, production and consumption decisions are driven by the maximization of profits and utility, respectively. The equations also include a set of constraints that are satisfied by the system but not considered by any individual actor. These constraints cover markets (for factors and commodities) and macroeconomic aggregates (balances for savings investment, the government, and the current account of the rest of the world) (Lofgren *et al*., 2002).

The model used in this study is a recursive dynamic extension of the standard CGE model created by the International Food Policy Research Institute (IFPRI). This kind of dynamic model is based on the assumption that the behaviour of economic agents (private and public) is characterized by adaptive expectations: economic agents make their decisions based on experiences and current conditions, with no role for forward-looking expectations about the future (Lofgren, Harris, and Robinson, 2001). In each period, the capital stock is updated with the total amount of new investment and depreciation. New capital is distributed among sectors based on each sector's initial share of aggregate capital income. Total labour supply is updated by the population growth rate, i.e. as population grows, the labour supply increases at the same rate.

Data Sources

The core dataset capturing the economic structure of the Ethiopian economy comes from the 2005/06 social accounting matrix (SAM) developed by the Ethiopian Development Research Institute (EDRI). The SAM disaggregates the economy into five agro-ecological zones and builds on a detailed regional disaggregation of household groups. As the current structure of the Ethiopian economy is different from 2005/06 on which the existing SAM is based, the SAM was updated to the present with 2009/10 data. The dynamic CGE model is used to simulate the growth of the Ethiopian economy based on actual economic developments from 2005/06–2009/10. The projected 2009/10 SAM and GDP were then converted to current prices. Actual value added shares of activities and actual aggregate demand components of 2009/10 (from national accounts) were then used to adjust value added by sector in the projected 2009/10 SAM.

The SAM is disaggregated into 113 activities (with 77 agricultural activities by agro-ecological zones, AEZs), 64 commodities, 16 factors (by AEZs except capital), and 13 institutions including 12 households. The SAM also has measures of taxes, saving-investment, inventory, and rest of the world accounts to show the interaction of different economic agents.

The Simulation

The CGE model uses the outputs from a Ricardian model study by Deressa and Hassan (2009) on the impact of climate change on agriculture to calibrate a hypothetical general equilibrium in 2050. Total factor productivity (TFP) (alphava) is used for the simulations. Total Factor Productivity (TFP) is the portion of output not explained by the amount of inputs used in production. Productivity impacts in crop agriculture enter the model in the form of zone-specific annual shocks to the TFP parameters of the agricultural production functions. Hence, the shift parameter for CES activity production function (alphava) is used for the simulations as shown in the following aggregate value added production function. The equation states that, for each activity, the quantity of value-added is a CES function of disaggregated factor quantities (Lofgren *et al*., 2002).

$$QVA_a = \alpha_a^{va} . \left(\sum_{f \varepsilon F} \delta_{fa}^{Va} . QF_{fa}^{-\rho_a^{va}} \right)^{\frac{1}{\rho_a^{va}}}$$

Where,

$$\begin{bmatrix} quantity\ aggregate \\ value\ added \end{bmatrix} = CES \begin{bmatrix} factor \\ inputs \end{bmatrix}$$

$f \varepsilon F (= F')$ = a set of factors,

α_a^{va} = efficiency parameter in the CES value-added function,

$\delta_{f\alpha}^{v\alpha}$ = CES value-added function share parameter for factor f in activity a,

$QF_{f\alpha}$ = quantity demanded of factor f from activity a,

$\rho_{\alpha}^{v\alpha}$ = CES value-added function exponent

For the analysis in this paper, we used the prediction of Deressa and Hassan (2009) net crop revenue per hectare of the PCM model. The PCM model is chosen for the analysis since most climate change model projections for Ethiopia report an increase in precipitation level. The PCM model predicts an increase in precipitation level by 5 % and a rise in temperature by 2.3 degree centigrade.

The Micro-simulation Model

The micro-simulation exercise is an attempt to link the macro model to the household model in a sequential fashion. The change in climate change induced productivity in the DCGE model in the scenarios produces new sets of consumption level. The change in per capita household consumption from the macro-model is then used to update the final consumption of the households. To achieve this purpose, the Central Statistical Agency (CSA)'s 2010/11 Household Income Consumption and Expenditure (HICE) survey is used. From the total households in the HICE, 17332 are urban households and 10320 are rural households. The sets of variables introduced into the household model produce poverty and inequality indices.

After making simulation exercises on the impact of climate change on household consumption for both rural and urban households, the Foster-Greer-Thorbecke (FGT) poverty indices, which measure the incidence, depth and severity of poverty, are estimated. Besides, a measure of inequality, Gini coefficient is estimated. The per capita household consumption expenditure is converted to consumption per adult by using the adult equivalent conversion factor. Households were classified into poor and non-poor households both for urban and rural areas by using the consumption per adult per year using the 2010/11 indices where 30.4 percent of the rural and 25.7 percent of the urban households were categorized as poor and the rest as non-poor households as calculated by MOFED.

The poverty line is set to match the observed national poverty headcount ratio reported by MOFED and this in turn dictated the poverty level of utility in the initial equilibrium. The poverty line was set at 4,810 birr for the urban households and for that of the rural households, it was set to be birr 3,145. For the analysis in this study, the change in the level of consumption in the rural and urban areas is taken as a rate for the new consumption level of rural and urban households.

The well-known Foster, Greer and Thorbecke (FGT) measures are used for poverty analysis and can be summarized as follows. By far the most widely used measure is the headcount index, which simply measures the proportion of the population that is counted as poor, often denoted by P0. It is popular because it is easy to understand and measure. However, it does not indicate how poor the poor are. The poverty gap index (P1) measures the extent to which individuals fall below the poverty line (the poverty gaps) as a proportion of the poverty line. The sum of these poverty gaps gives the minimum cost of eliminating poverty, if transfers were perfectly targeted. The measure does not reflect changes in inequality among the poor. In addition to the poverty incidence and poverty gaps, the FGT measures the squared poverty gap ("poverty severity") index (P2) which averages the squares of the poverty gaps relative to the poverty line. Inequality will be measured by the most widely used measure of inequality, the Gini coefficient.

$$P_{\alpha} = \frac{1}{N} \sum_{i=1}^{H} \left(\frac{z - y_i}{z}\right)^{\alpha}$$

Where

N = the total population,

H = the number of persons who are poor, and

z = the poverty line,

y_i = income (actual) of the poor (or other standard of living indicator),

$\alpha \geq 0$ is a "poverty aversion" parameter

When α = 0 = P0 is the Headcount Poverty Rate

α = 1 = P1 is the Poverty Gap Index

α = 2 = P2 is the Poverty Severity Index

$$Gini = \frac{1}{\mu N(N-1)} \sum_{i>j} \sum_{j} \left| x_i - x_j \right|$$

Where, x is income
N is population

Results and Discussion

The Impact of Climate Change on Production

The simulated impact of climate change on the production of the five major cereals (teff, wheat, maize, sorghum and barley) is presented in Table 5. These crops are the core of Ethiopia's agriculture and food economy, accounting for about three-quarters of total area cultivated and 29 percent of agricultural GDP in 2005/06 (starting year of the simulation) (Seyoum *et al.*, 2012). This suggests that the effect of climate change on these crops has a major implication on the economy of the country. Hence, as can be seen from Table 6., without any planned adaptation, total teff production could fall between 7.8 percent in the 2020s to 34 percent in the 2050s, while maize and sorghum production could fall between 8 percent in the 2020s to 30 percent in the 2050s. Similarly, barley production could decline between 10 percent in the 2020s to 38 percent in the 2050s while wheat production could fall as much as 22 percent in the 2020s to 75 percent in the 2050s. The fall in the production of wheat is the highest compared to the other four cereals indicating the vulnerability of the crop to the impact of climate change. The decline in the production of wheat and maize is in line with the study of Nelson *et al.* (2009) that projects large losses in production of wheat (34 percent) and maize 10 percent for Sub-Saharan Africa. Calzadilla *et al*. (2009) also project a loss of wheat production by 24 percent because of climate change for Sub-Saharan Africa.

Table 5: The impact of climate change on total production of major cereal crops in billion birr

Crops	Simulations	2020	2030	2040	2050
Teff	Base	454	935.3	1790	3002.5
	Climate Change	418.4	766.6	1314.5	1981

	Change (%)	-7.8	-18	-26.6	-34
Barley	Base	323.7	739.8	1468	2454.8
	Climate Change	289.9	579.7	1024.4	1516.8
	Change (%)	-10.4	-21.6	-30.2	-38.2
Wheat	Base	751.6	1704.5	3072.3	4685.6
	Climate Change	582.4	977	1242.2	1164.8
	Change (%)	-22.5	-42.7	-59.6	-75.1
Maize	Base	686.5	1241.3	2096.6	3191.9
	Climate Change	640.6	1053.7	1624.8	2257.2
	Change (%)	-6.7	-15.1	-22.5	-29.3
Sorghum	Base	591.9	1260.5	2452.7	4236.8
	Climate Change	539.9	1033.9	1839.7	2908.9
	Change (%)	-8.8	-18	-25	-31.3

Source: Own Survey, 2012

The Impact of Climate Change on Household Consumption

Climate change has a negative effect on the consumption of households in most of the agro-ecological zones. The results indicated that consumption of households follows the pattern of change in income. Households adjust their consumption in response to the rise in prices. The impact is not uniform across the different agro-ecological zones. The households in moisture sufficient cereal-based highlands will not be affected in the 2020s; but would cut 14.6 percent of their consumption due to climate change in the 2050s. The households in the moisture sufficient enset based areas would reduce their consumption by 23 percent while households at the drought prone areas will be the hardest hit where households could cut 30.3 percent of their consumption due to climate change in 2050. The pastoralist households would experience a rise in consumption until the 2040s but would reduce their consumption by 3.4 percent in the 2050s. This might be due to the assumption of the PCM model which projects an increase in precipitation and hence would get improved production in the future. In rural non-farming and urban areas, climate change in 2050 brings a loss of household consumption between 14 to 15 percent. The decline in consumption is very high in the drought prone areas followed by non-farming and urban poor households. The impacts in the drought prone areas are greater due to reductions in agricultural production from climate change.

For the non-farming rural and urban poor households, the reduction in consumption is attributed to price increases since they are buyers of food products.

Table 6: Impact of climate change on consumption of households in different agro-ecological zones (billion birr)

Agro-ecological Zones		2020	2030	2040	2050
Moisture sufficient highland-cereals	Base	266.4	471.1	703	879.6
	Climate Change	268.4	451.5	640.3	751.2
	Change (%)	0.8%	-4.2%	-8.9%	-14.6%
Moisture sufficient enset-based highlands	Base	111.2	202.3	310.9	390.7
	Climate Change	105.2	176.4	253.5	300.9
	Change (%)	-5.4%	-12.8%	-18.5%	-23.0%
Drought-prone	Base	115.2	209.2	314.8	390.7
	Climate Change	103.1	165.8	230.3	272.5
	Change (%)	-10.5%	-20.7%	-26.8%	-30.3%
Pastoralist	Base	47.4	92.9	146.3	182.7
	Climate Change	49.1	95	147.6	176.3
	Change (%)	3.6%	2.3%	0.9%	-3.5%
Non-farming	Base	90.6	162.8	250.1	314.4
	Climate Change	88.4	151	222.4	267.4
	Change (%)	-2.4%	-7.2%	-11.1%	-14.9%

Large Urban	Base	58.4	104	159	198.2
	Climate Change	57.1	97.1	142.3	169.5
	Change (%)	-2.2%	-6.6%	-10.5%	-14.5%

Source: Own Survey, 2012

As shown in Table 7, total household consumption declines due to climate change. The consumption of poor households would decline by 21.4 percent while that of the non-poor households would decline by 17 percent. Similar to the findings of Robinson *et al.* (2011), the impact of climate change on the consumption of the rural poor households is greater than non-poor households. In addition, the impact of climate change is higher for rural households compared to that of the urban households.

Table 7: The impact of climate change on total household consumption in billion birr

Household Consumption	Total		Rural		Urban	
	Poor	Non-Poor	Poor	Non-Poor	Poor	Non-Poor
Base	404.9	1951.4	379.6	1778.5	25.3	172.9
Climate Change	318.1	1619.7	297	1471.3	21.1	148.4
Change (%)	-21.4	-17.0	-21.8	-17.3	-16.6	-14.2

Source: Own Survey, 2012

Poverty and Inequality Changes

Using the results of our micro-simulations we can calculate the effects of climate change on poverty incidence, depth and severity. The results show that climate change would increase the poverty headcount ratio, which measures the share of the population below the poverty line to the total population, to 31.43 in the 2020s to 45.15 percent in the 2050s from its level of 29.6 percent in the baseline. The trend in this measure of the incidence of poverty is increasing as shown in Figure 1. This is unlike the study of Kyophilavong and Takamatsu (2011), which found negligible changes (less than 1%) in poverty and inequality in Laos from predicted climate changes.

Figure 1: The Impact of Climate Change on National Poverty Incidence

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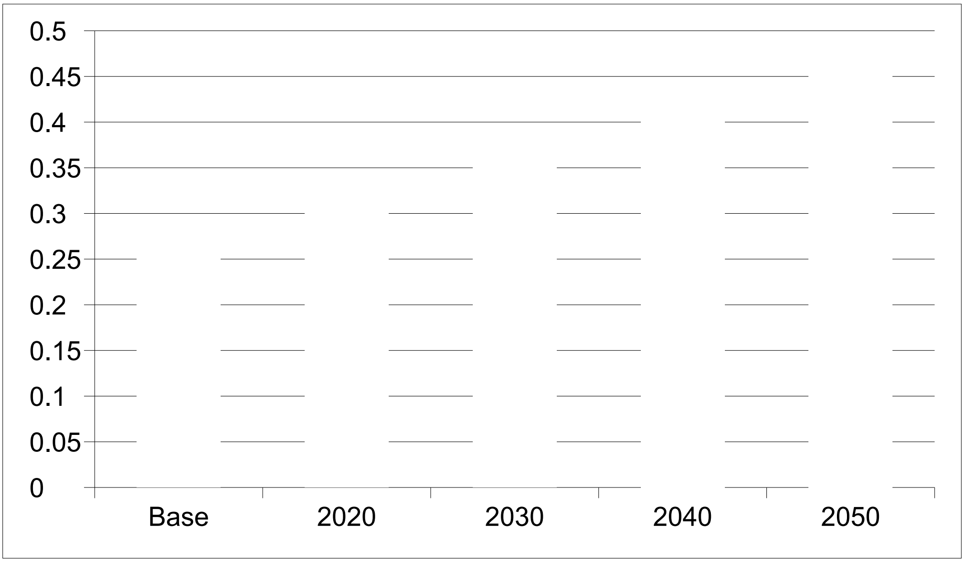
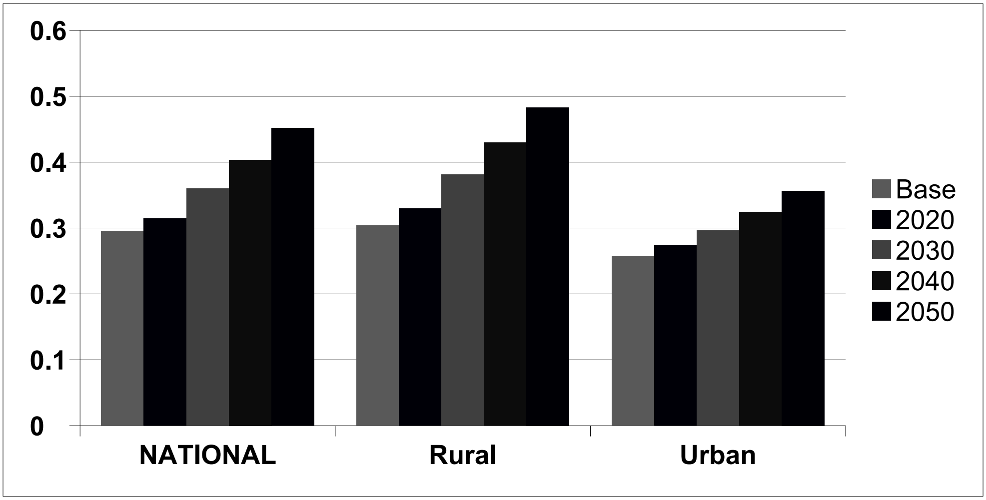


Source: Own Survey, 2012

Based on our simulations, the rural headcount index also would rise from its level of 30.4 percent in the baseline to 32.94 percent in the 2020s to 48.29 percent in the 2050s, putting nearly half of the rural population of Ethiopia below the poverty line. The rural poverty incidence increases through times. On the other hand, the poverty incidence of urban households would rise only slightly from its level of 25.7 percent in 2010/11 to 27.33 percent in the 2020s and to 35.64 percent in the 2050s. As shown in Figure 2, the impact of climate change on rural poverty incidence is much greater than that of the urban households. This is largely due to the fact that rural households livelihood is primarily dependent on climate sensitive agriculture and their low adaptive capacity.

Figure 2: The Impact of Climate Change on Rural and Urban Poverty Incidence



Source: Own Survey, 2012

According to our simulations, the indices of the national gap of poverty that can be considered as the cost of eliminating poverty relative to poverty line would reach 8.8 percent in the 2020s and 14.09 percent in 2050s from its level of 7.8 percent in the base year. The increase in the national poverty gap is attributed to the rise in the rural and urban poverty headcount index.

In a similar manner as for poverty incidence, the rural poverty gap index rises to 9.2 percent and 15.09 percent in 2020s and 2050s from its base level of 8 percent increasing the gap of the rural poor population further down from the poverty line. Similarly, the poverty gap index of the urban households also increases to 7.74 percent in 2020s to 11.02 percent in 2050s from its level of 6.9 percent in the base year. Initially, the poverty gap index of the rural households was higher than urban households and become significantly greater because of climate change. Higher poverty gap index of the rural areas indicated that rural households need more resources to get out of poverty. The implication is that, due to climate change, more people in rural areas need higher amount of perfectly targeted safety-net program compared to the urban households to lift them out of poverty.

The severity of poverty (squared poverty gap), which takes into account the distance separating the poor from the poverty line and the inequality among the poor, would also increase through time and would reach 6.16 percent in 2050 increasing from its level of 3.1 percent in the baseline scenario. The rural poverty severity index would increase to 6.61 percent in 2050 from its level of 3.2 percent in the baseline. The urban poverty severity index would also rise to 4.76 percent in 2050 from its level of 2.7 percent in 2010/11.

The magnitude of increase for all the poverty indices is higher for the rural households than urban households. The finding indicates, not surprisingly, that declining cropland productivity caused by climate change would increase poverty more in rural areas than in urban areas as shown in Table 8.

Table 8: Impact of climate change on poverty incidence, depth and severity

	Levels	Base	2020	2030	2040	2050
Poverty incidence	National	29.60%	31.43%	35.97%	40.33%	45.15%
	Rural	30.40%	32.94%	38.14%	42.97%	48.29%
	Urban	25.70%	27.33%	29.63%	32.44%	35.64%
Poverty gap	National	7.80%	8.80%	10.52%	12.20%	14.09%
	Rural	8.00%	9.20%	11.15%	13.00%	15.09%
	Urban	6.90%	7.74%	8.70%	9.79%	11.03%
Poverty severity	National	3.10%	3.57%	4.38%	5.20%	6.16%
	Rural	3.20%	3.73%	4.65%	5.55%	6.61%

	Urban	2.70%	3.14%	3.60%	4.14%	4.76%

Source: Own Survey, 2012

Using our simulation results we calculate Gini coefficients of household consumption as a measure of economic inequality. In our base year, inequality as indicated by the Gini coefficient is higher among the urban households than the rural households: the Gini coefficient was 37.1 percent for urban households while it was 27.4 percent among rural households. This implies that the average distance rich to poor in the income distribution among the urban households is higher. In our climate change scenarios the estimated inequality at the national level rose to 32.37 percent in the 2020s to 33.15 percent in the 2050s from its level of 29.8 percent in the base year. Inequality among rural households would rise from the level of 27.4 percent at the baseline to 31.08 percent in the 2020s and 31.98 percent in 2050s. The urban inequality in 2020 would rise to 39.08 percent. The level of inequality increases in 2050 and would reach 39.45 percent from its level of 37.1 percent in the baseline. Hence, the rise in the national inequality level is attributed to the rise in both the rural and urban inequality due to the climate change scenario. While this is in line with the study by Reid *et al*. (2007) which concluded that climate change could exacerbate the already uneven distribution of income in Namibia, it contrasts with the work of Kyophilavong and Takamatsu (2011), which found the effect of climate change on inequality to be very small (below one percent) in Laos.

To sum up, all poverty indicators showed that poverty will be exacerbated due to climate change in 2050. Poverty will be worsened in both rural and urban areas. However, the magnitude of increment of the poverty indices is higher for the rural households than urban households. Inequality also increased in both rural and urban areas due to climate change.

Table 9: Impact of climate change on income inequality

Year	National	Rural
Base	0.298	0.274
2020	0.324	0.310
2030	0.327	0.314
2040	0.330	0.317
2050	0.332	0.319

Source: Own Survey, 2012

Conclusion

This study examined the impact of climate change on poverty through its effect on crop production. The analysis used a recursive dynamic CGE micro-simulation approach to analyse the poverty impacts of climate change in the country and across agro-ecological zones and applied forecasted net land productivity impacts of a Ricardian model study for Ethiopia using the PCM model.

The results confirm that climate change negatively affects production and consumption in 2050 throughout Ethiopia. However, the impacts are not uniform across the different agro-ecological zones. The households in the drought prone areas are the hardest hit where household consumption expenditure declines by 30.3 percent. In urban and rural non-farming areas, climate change in 2050 brings a fall in consumption of households between 14-15 percent. An exception is in the areas of the pastoralist households where there is an increase in income and consumption of households up to the 2040s. At the national level, total consumption of poor households declines by 21.4 percent while the consumption of non-poor households declines by 17.0 percent. The results further indicated that climate change will increase the incidence, depth and severity of poverty negatively affecting the Ethiopian government's target of poverty reduction.

According to the results of the analysis, poverty and inequality will be exacerbated by the effect of climate change in 2050. The impact of climate change raises the national poverty incidence from 29.6 percent in 2010/11 to 45.15 percent in 2050. Poverty will be worsened at both rural and urban areas causing the total number of poor people in the country to rise significantly. Climate change also increases the inequality among households from its level of 29.8 percent in the base year to 33.2 percent in 2050.

In summary, the results show high levels of vulnerability for Ethiopian households, both urban and rural, to changes in the global climate. The simulations presented here show a dependence of both rural and urban peoples in Ethiopia on climate sensitive production processes, in particular agriculture. The magnitude of increment of the poverty indices is higher for the rural households than urban households. Hence, different adaptation and mitigation measures especially in rural areas and in agricultural production are vital if the country is to achieve its growth and poverty reduction targets. Further research programs that analyse identify and disseminate climate resilient agricultural innovations would have potentially large benefits for both rural and urban Ethiopian households.

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