zef
Center for
Development Research
University of Bonn

BiomassWeb

Working Paper 181

Ermias Engida Legesse, Amit Srivastava, Arnim Kuhn and Thomas Gaiser

Household income implications of improved fertilizer accessibility and lower use inefficiency: Long-term scenarios for Ethiopia

ISSN 1864-6638 **Bonn, July 2019**

ZEF Working Paper Series, ISSN 1864-6638
Center for Development Research, University of Bonn
Editors: Christian Borgemeister, Joachim von Braun, Manfred Denich, Till Stellmacher and Eva Youkhana

Authors' addresses

Ermias Engida Legesse
Institute of Food and Resource Economics, University of Bonn
Nussallee 21
53115 Bonn, Germany
Tel. +49 228 73-2326
Email: ermias.engida@ilr.uni-bonn.de

Dr. Amit Srivastava
Institute of Crop Science and Resource Conservation, University of Bonn
Katzenburgweg 5
53115 Bonn, Germany;
E-mail: amit.srivastava@uni-bonn.de

Dr. Arnim Kuhn
Institute of Food and Resource Economics, University of Bonn
Nussallee 21
53115 Bonn, Germany
E-mail: arnim.kuhn@ilr.uni-bonn.de

Dr. Thomas Gaiser
Institute of Crop Science and Resource Conservation, University of Bonn
Katzenburgweg 5
53115 Bonn, Germany
E-mail: tgaiser@uni-bonn.de

Please quote as: Engida, E., A. Srivastava, A. Kuhn and T. Gaiser, 2019. Household income implications of improved fertilizer accessibility and lower use inefficiency: Long-term scenarios for Ethiopia. ZEF Working Paper 181. Bonn.

Photograph on cover page: Asrat Gella, 2018.

Household income implications of improved fertilizer accessibility and lower use inefficiency: Long-term scenarios for Ethiopia

Ermias Engida Legesse, Amit Srivastava, Arnim Kuhn and Thomas Gaiser

Abstract

High population growth rates in Ethiopia are likely to aggravate farmland scarcity, as the agrarian share of the population stays persistently high, but also create increasing demand for food and non-food biomass. Based on this expectation, this study investigates welfare implications of interventions that improve access and knowhow to modern farming inputs in order to improve crop biomass productivity. Using a dynamic meso-economic modeling framework for Ethiopia, ex-ante scenarios that simulate a) decreased costs of fertilizer use for all crops and b) elevated efficiency of fertilizer application for wheat and maize are run for a period of 20 years. These interventions together lead to yield increases of 4 percent for wheat and 12.5 for maize on average across simulation years as compared to the base run. The increased fertilizer application is also found to be profitable for the average farmer despite the price reductions for wheat and maize due to increased market supply. As a result of price and income effects of the interventions, all household types exhibit welfare gains. Non-farming households, being net consumers, enjoy lower costs of living due to lower commodity prices. Rural farming households enjoy even higher welfare gains as non-farming households because they exhibit higher consumption shares of the two food commodities in question, and because their farming profits increase.

Keywords: CGE; fertilizer-yield-response; productivity; welfare; Ethiopia

1 Agricultural Development in Ethiopia

1.1 Characterization of the country's crop biomass sector

Ethiopia is located at the Horn of Africa and covers 1.13 million square kilometers. The country comprises a high central plateau, the 'Highlands' ranging from 1500 to 2500 meters above sea level and surrounded by lowlands on all sides. The highlands cover around 43 percent of the total area. Since the climatic conditions in the highlands are more suitable for humans and domesticated animals, it contains nearly 85 percent of the country's population, 95 percent of the cultivated land and 80 percent of cattle (World Bank 2004). The highlands are already densely populated, and rapid population growth is bound to cause increasing scarcity of farmland in the coming decades. For instance, an average smallholder farmer cultivates cereals on 0.82 hectares of land in 2015/16, down from 0.94 hectares in 2004/05 (CSA 2016). By contrast, the half of the country area covered by lowlands is still largely underutilized due to the prevalence of human and animal diseases such as malaria. This part of the country contains millions of hectares of potentially arable land which receives sufficient precipitation for rain-fed crop production and has also a high potential for irrigated farming.

Agriculture is still the dominant sector of the Ethiopian economy. While its GDP share declined in recent years, its importance to the economy is still significant, as it still contributes around 40 percent of the GDP and employs 77 percent of the workforce. Moreover, agricultural employment grew at an average annual rate of 2.5 percent during the period from 2005 to 2013 (Bachewe et al. 2015; Martins 2015). Besides, the sector contributed 80.8 percent of the total commodity exports during 2004/05 – 2013/14 (Bachewe et al. 2015; National Bank of Ethiopia (NBE) 2014).

The heterogeneity in topography, climatic conditions, and soil types enable the country to grow a wide variety of crops, consisting of different cereals, pulses, oilseeds, vegetables, root crops, fruit crops and perennial crops like khat (*Catha edulis*), coffee (*Coffea arabica*), sugar cane (*Saccharum officinarum*) and enset (false banana, *Ensete ventricosum*). According to CSA agricultural survey data (2016), smallholder farmers[1] cultivate more than 14 million hectares of Ethiopian land covered with these crops and produce more than 34 million metric tons of output. Cereal crops cover the biggest share with 71 percent of the total cropland and 68 percent of total crop output (Figure 1). Among the eight major cereal crops cultivated in Ethiopia, teff (*Eragrostis tef*), maize (*Zea mays*), sorghum (*Sorghum bicolor*), and wheat (*Triticum aestivum*) are the big four both in area coverage (85.2 percent) and total cereal output (87.2 percent). The remaining crop types contribute a relatively small share both to total area and production.

---

[1] The Central Statistical Agency (CSA) classifies Ethiopian farms with holdings less than 25.2 ha land as smallholder farms. Smallholder farmers dominate the agricultural land use in Ethiopia, managing 94 percent of total cultivated land in 2013/14 (Bachewe et al. 2015).

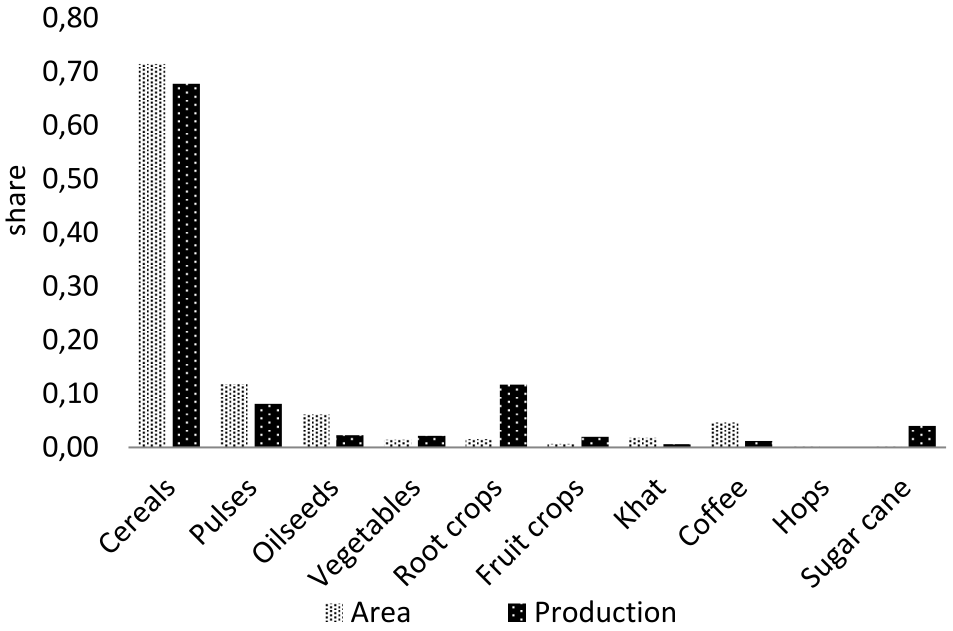

Figure 1: Crop varieties in Ethiopia, area and production share (2015/16)
Source: Own computation based on 2015/16 AgSS[2] data (CSA 2016).

1.2 Productivity and agronomic practices in the crop sub-sector

Total crop production significantly increases at a rate faster than the area expansion from 2004/05 to 2015/16 (Figure 2). This implies that yields have grown consistently more than area over this decade. Referring to AgSS data, yield improvement appears to be explaining most of the success in the crop sub-sector - production more than doubles (124 percent) during this period whereas the area covered expands by just 27.3 percent. Though yields exhibited an impressive growth, obtained yield levels are still relatively low in comparison to attainable yields. For instance, in 2004 Ethiopian maize yields were less than a quarter of those in Egypt and a fifth of those in the USA. By 2013, the gap narrowed, although still considerable, with Ethiopian maize yields reaching 44 percent of Egypt's and a third of USA's yield levels (Bachewe et al. 2015).

---

[2] Agriculture sample survey data from the CSA (Central Statistics Agency) of Ethiopia

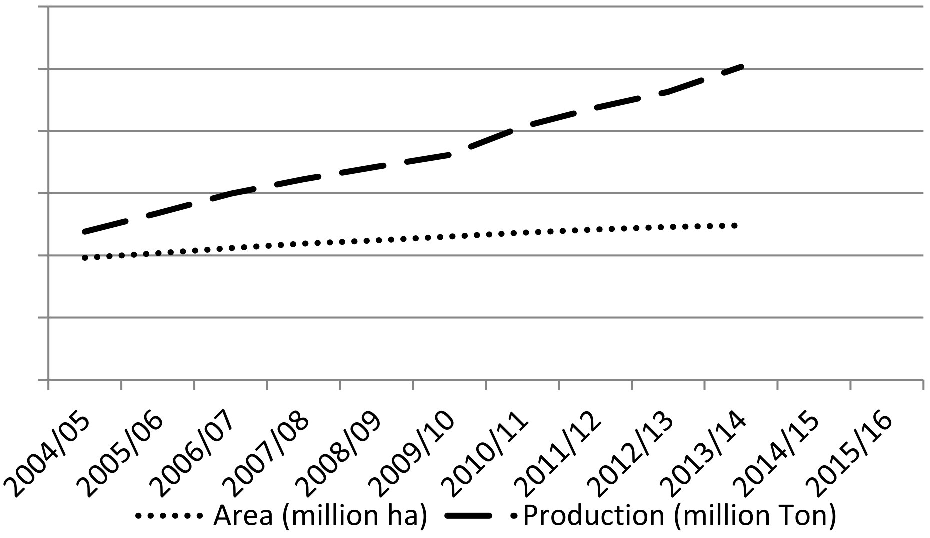

Figure 2: Trend in production and area growth on Ethiopia's crop sub-sector (2004/5-2015/16)
Source: Own computation based on AgSS data 2004/5 – 2015/16 (CSA 2005-2016).

A Solow decomposition of the crop output growth in Ethiopia was done by Bachewe et al. (2015). The result reveals the importance of increased input use, including labor, as well as productivity growth. Specifically, labor accounted for 31 percent followed by the expansion in the cultivated area (13 percent), increased application of chemical fertilizer (8 percent), improved seeds (11 percent), returns to scale (8 percent) and rural roads (3 percent). The unexplained residual, or total factor productivity growth, reached 22 percent. Average annual Total Factor Productivity (TFP) growth was 2.3 percent. The result shows that contribution of modern inputs to output growth is significant, but absolute levels of application are still considered low.

Ethiopia's agriculture is characterized by a low input, low value, subsistence-oriented, rain-fed crop sub-sector. It is dependent on a highly erratic rainfall regime and vulnerable to frequent weather fluctuations and drought episodes that often lead to harvest failures. In addition, the shortage of arable land in the highlands where the population is concentrated leads to severe and protracted environmental degradation that is further exacerbated by critically low levels of human and physical infrastructure (World Bank 2004). Based on data from the 2015/16 AgSS (CSA 2016), only 55.7 percent of the entire cropland cultivated by smallholder farmers is treated with some type of fertilizer including natural fertilizer like manure. Cereal crops like teff, maize and wheat enjoy relatively higher fertilizer application, being 76, 73 and 84.4 percent of their land, respectively; whereas application on sorghum plots was even lower with 26 percent in 2015/16. Moreover, the share of cropland cultivated with improved seeds is still not higher than 8 percent, with the only exception of maize and wheat which got more attention from local breeding institutions. The Ethiopian Institute of Agricultural Research (EIAR) has developed and made available 87 improved varieties for wheat and 45 for maize since 1970 (ATA-MoA 2014). However, Zeng et al. (2013) estimate that only 39 percent of the maize area in Ethiopia was planted with improved varieties in 2010, and this figure has shown no significant change up until 2015 when it reached 41.8 percent (CSA 2016). Improved seed application was almost inexistent for teff and sorghum (2.1 and 0.2 percent) in 2015. Only 23.6 percent of cropland received pesticide treatment. The latter is significantly higher for cereals, where 55 and 48 percent of wheat and teff area received pesticide applications in 2015/16, whereas that of maize and sorghum was 9 and 12 percent. In addition, 30 percent of cropland was covered under the extension package[3] while that is 38 percent for cereals particularly. Maize and wheat are the two major cereal crops that have got the maximum extension service from 'development agents' in the country, with 54 and 50 percent of the area covered respectively. Teff and sorghum got lower attention than maize and wheat – 38 and 15 percent of their respective area are covered under the extension package. Irrigation is the other modern farm management practice which is practically non-existent in Ethiopia's smallholder farming – irrigation coverage is 1.2 percent for all crops in general and 0.7 percent for cereals in particular which confirms the sector's complete dependence on rainfall. Summing up, the crop sub-sector in Ethiopia, with special emphasis on the major cereal crops, is still traditional with a low level of application of modern inputs and practices.

As discussed above, expansion in cultivated area is one of the driving forces for the increase in crop output. However, the land expansion only happens as a result of the rapid expansion of the farming population. Individual farm plot holdings are diminishing in size. As a result of the rapid population growth, the already scarce supply of farmland resources is constantly tightening; and farmsteads and plot allocation have become more and more fragmented in the course of time. For instance, if we look at grain crops[4] as reported in the CSA national representative dataset (2004/05-2015/16), cultivated land increased by 27.3 percent over the decade, 2004/05 – 2015/16, while the number of smallholders increased by 45.8 percent, indicating a smaller average farm size over time – the average land holding size declined by 12.7 percent over this period (Figure 3).

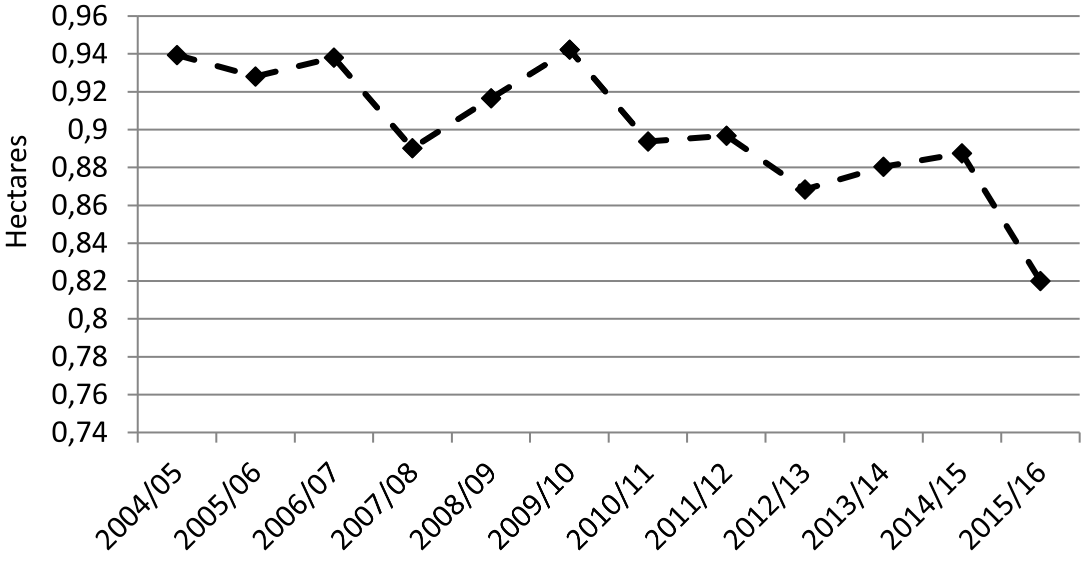

Figure 3: Change in farm size (2004/05-2015/16; area per farm)
Source: Own computation based on data from AgSS 2004/5 – 2015/16 (CSA 2005-2016).

With declining farm size, it becomes increasingly difficult to practice traditional soil-fertility restoring techniques (e.g. fallowing and crop rotation) and maintain the households' livelihood from the land. As noted by Boserup (1965) and others, rising population density typically causes a transition from fallow-based systems to permanent cultivation. As a result, more than 60 percent of Ethiopian soils are nutrient-depleted (IFAD 2012). While the land resources are depleted and short in quantitative

---

[3] The agricultural extension package in Ethiopia referred to as Participatory Demonstration and Extension Training System (PADETS) focuses on farmers' demonstration plots, and is based on the provision of advisory services, seed, fertilizer, and credit.

[4] Grain crop is defined as the combination of cereals, pulses, and oilseeds.

supply, the country's population is increasing rapidly, thus creating a huge demand for food. In order not to slide back into the position of a food net importer, the productivity of the scarce resources would have to be swiftly enhanced by using modern practices. For instance, farmers would have to add supplementary nutrients using increased quantities of organic and chemical fertilizers to maintain increased yields under these conditions (Demeke et al. 1998). Increasing adoption of modern inputs remains one of the best hopes towards higher agricultural production in countries like Ethiopia.

1.3 Use and access to modern inputs

Currently, the use of fertilizer is increasing all over Ethiopia. According to the CSA, the area of fertilized land has doubled during the last 13 years. In line with this, the amount of fertilizer used all over the country has increased more than threefold during the same period which indicates that the application rate has also been increased, although slowly. The application rate on average increased from 66 kilograms per hectare in 2003/04 to 104 kilograms per hectare in 2015/16, considering fertilized cropland only (see Figure 4).

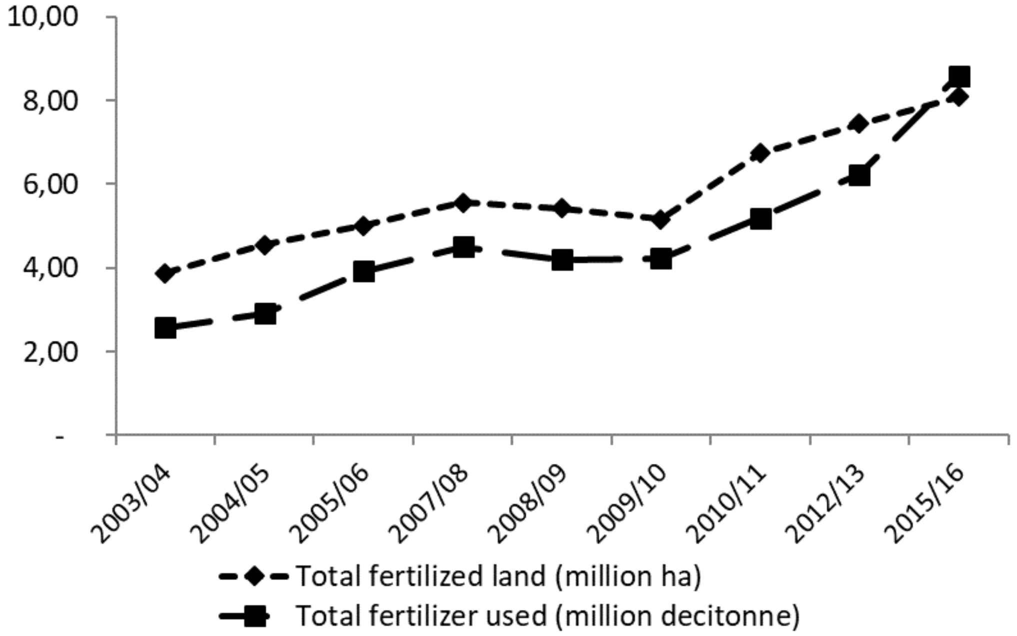

Figure 4: Trend in fertilizer application (2003/04-2015/16)
Source: Own computation based on data from AgSS 2003/4-2015/16 (CSA 2004-2016).

Not only the application rate but also the share of fertilized cropland increased throughout the same period. In 2003/4 fertilizer was applied to only 40 percent of Ethiopia's cropland. However, this has changed and reached 55 percent in the very recent past, 2015/16 (see Figure 5). Despite the fact that the application rate gradually increased, fertilizer use intensity is still at a low level (look at figure A1 in the Annex for the dynamics in the fertilizer application rate for the five major cereal crops). If applied to the entire cultivated cropland in 2015/16, the mentioned 104 kilograms per hectare application rate on fertilized land would almost halve to 59 kilograms per hectare. Calculations based on the World Bank's Ethiopian socioeconomic survey 2015/16 shows that 56 percent of the respondent households never used chemical fertilizer on their farming plots in any instance (see Table A1 under Annex A). Although the use of fertilizer has increased in Ethiopia in recent years, this is evidence that most farmers are not adequately compensating for the loss of soil nutrients caused by more intensive cultivation (Demeke et al. 1998).

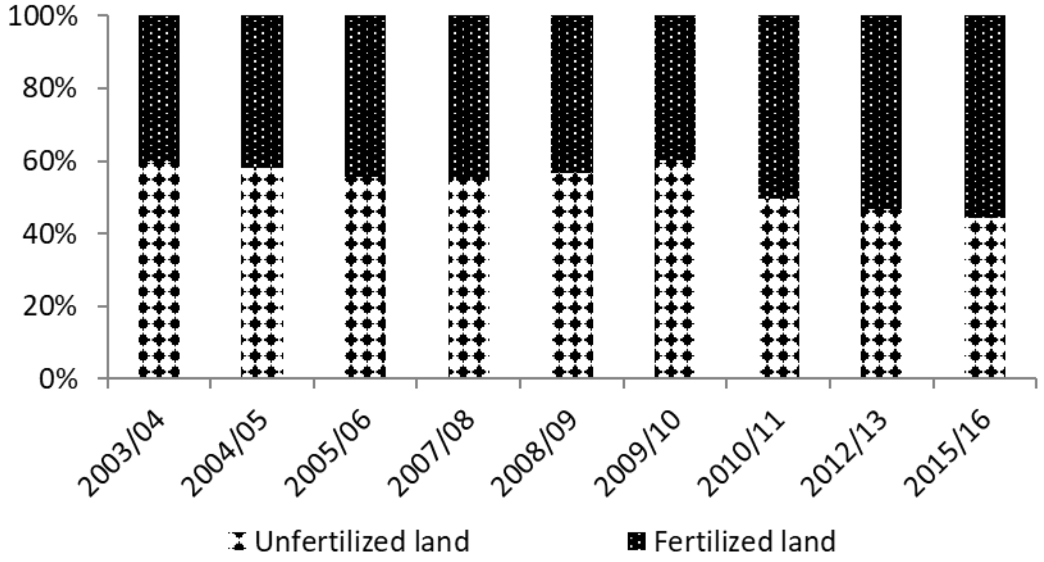

Figure 5: Share of fertilized land (2003/04-2015/16)
Source: Own computation based on data from AgSS (2004-2016).

Several arguments are brought forward in the economics literature about possible reasons for the low fertilizer use in developing countries like Ethiopia. Rashid et al. (2013), and Zerfu and Larson (2010) argue that fertilizers are more expensive in Africa as compared to other developing regions, for instance Asia. This is because ocean freight costs in Asia are lower due to economies of scale, and domestic transport costs are much higher in Africa than in Asian countries mainly due to weak infrastructure and a non-conducive policy environment. These together with institutional problems lead to relatively high input costs and the absence or late arrival of supplies. These discourage the use of chemical fertilizers and contribute to the inefficient use of inputs as well.

Technical use inefficiency is the other big problem that reduces the response of the fertilizer applied. Inefficiency in fertilizer application could emanate from the late arrival of inputs and from knowledge gaps and information hurdles. Yu and Nin Pratt (2014), Beshir et al. (2012), and Admassie and Ayele (2004) argue that farmers face a high knowledge cost related to the adoption of new technologies. Lack of education and past experience in modern input use can effectively increase the adoption barrier and hence significantly slow down the diffusion of a new technology. The authors also indicate that extension services can help cut the adoption cost. Thus, more contact of farmers with extension agents or improved availability of any other efficient dissemination mechanism would reduce inefficiency in technology adoption, especially for technologies that are new to and little understood by the farmer.

1.4 The fertilizer subsector in Ethiopia

Fertilizer markets in Ethiopia had been controlled by the government through its input marketing agency. As in many countries, it was inefficient; it needed large direct subsidies and incurred large administrative costs. As a result, in 1992 the government decided to end its monopoly as part of the overall market liberalization policy. However, four years later new companies owned by the regional governments started to flourish and monopolize the fertilizer market. According to Demeke et al. (1998) these holding companies highly benefit from indirect support from the government. Because of this and the fact that the fertilizer market in Ethiopia is thin and opportunity costs of private sector capital in this market can be high, private sector participation in fertilizer import and distribution business in Ethiopia was discouraged. This contributes to the inefficiency in the fertilizer market in the country. The public input distribution delivered inputs, which are of low-quality and arrived too late. Spielman et al. (2010), for instance, quote a study which finds that half of the surveyed Ethiopian smallholders reported that their fertilizer arrived after planting, and 25 percent complained of the poor quality of the fertilizer they received. Late arrival and unavailability are still the major problems.

In the new millennium, the government adopted a strategy to develop an input marketing system with strong participation of farmers' organizations. The initiative was welcomed because it was also one of the policy prescriptions emerging from the development partners for addressing the problems of thin markets and product aggregation problems. This was an aggressive strategy, and the cooperatives' market share grew rapidly, reaching almost 75 percent of the total fertilizer use in 2007/2008 (World Bank 2009). This rapid growth was promoted by providing subsidized credits to the cooperative unions to import and distribute fertilizer.

Currently, the government is initiating the commencement of domestic fertilizer production. The Ministry of Agriculture (MoA) and the Agricultural Transformation Agency (ATA), together with four cooperative unions located in four regions are constructing four fertilizer blending factories. The construction of the blending factories was initiated by the first ever soil fertility study and digital soil fertility mapping project done in 162 'Weredas' (districts) in 2013/14 fiscal year. This study reveals that the soil in the country needs additional nutrients other than nitrogen and phosphorus. The Ministry and ATA found out that sulfur, potassium, boron, and zinc are deficient in many areas which indicates that one compound fertilizer NPS and five blended fertilizers namely NPSB, NPKSB, NPSZnB, NPKSZnB, and NPSZn are needed to address the key nutrient deficiencies in the tested soils according to ATA's 2013/14 report (ATA-MoA 2014).

Not only from the supply side but also from the demand side there have been different strategies and programs in place for the last several years to promote fertilizer application in Ethiopia:

1. Sasakawa/Global 2000 programs: SG-2000 programs in the 1990s supported half-hectare demonstration plots, typically in productive areas, where farmers were supplied with credit, inputs, and extension advice. These programs were successful in raising yields, but the challenge has been to sustain adoption by farmers after they "graduate" from the programs and to spread adoption to less-favored areas, because of input and output market constraints that reduce access to inputs, reduce profitability, or increase risks. These programs were implemented in a number of countries during the 1990s, including Ethiopia, Mozambique, Uganda, and Ghana.
2. Ethiopian government initiated a 100 percent credit guarantee scheme on farmers' fertilizer purchases in 1994. A study in 2010 has reported that about 90 percent of fertilizer was delivered on credit at below-market interest or even at zero interest. Subsequently, based on data from CSA agriculture sample surveys, the total fertilizer use has increased from 250,000 tons in 1995 to 400,000 tons in 2008 and to around 900,000 tons in 2015. The credit scheme in Ethiopia, however, raises some concerns, as many other top-down credit schemes in developing countries do. First, the input distribution tied to credit may limit the emergence of private sector retailers, as pointed out by Jayne et al. (2003).

This study aims at quantifying the supply and income effects of increased fertilizer use as a result of reduced costs (observed and unobserved) and increased application efficiency. To enable the analysis of a broad range of effects, a dynamic Computable General Equilibrium (CGE) model for Ethiopia is used. The model is subject to specific modifications that allow illustrating the effect of increased fertilizer use on crop yields. The basic model as well as specific extensions are explained in the next section.

2 The model

The model used is the IFPRI Computable General Equilibrium (CGE) model for Ethiopia. A CGE model covers all economic sectors of a country or region and ensures macro-economic consistency. Owing to the structure of the Ethiopian economy, the CGE model has a focus on agriculture and food production, and thus, for instance, the main crop cultivars such as maize, teff or wheat are explicitly represented as production activities and commodities. Moreover, the model is recursive-dynamic which means that it can be used for multi-annual projections that are driven by trends in economic drivers such as population or technical productivity. Crucially, land is explicitly modeled as a production factor that is owned by households. Thus, there is a starting point for introducing sector-specific land productivities that are driven by input use such as fertilizer. Finally, the model's agricultural supply is partitioned into four agro-ecological zones (AEZs)[5], the output of which is pooled nationally.

The model assumes that producers maximize profits subject to costs governed by the specific production function employed. A multi-stage production function is used. First, factors of production are made to combine using a constant elasticity of substitution. The optimal amount of factors is ruled based on their relative prices. The value-added composite is then combined with fixed share intermediates using a Leontief specification. Profit maximization drives producers to sell these products in domestic or foreign markets based on the potential returns. The domestically marketed domestic output is an imperfect substitute for both internationally traded domestic output and imported goods.

In the model, representative household groups are sole owners of factors of production (labor, land, livestock, and capital) and it is their primary source of income. They maximize their income by allocating factors of production across activities. Supply and demand for these factors have to equilibrate based on closure rules which affect returns to factors and thus incomes of households owning the factors. In addition to factor returns, households get a smaller portion of their income from government transfers and remittances from abroad. Their demand for goods and services, on the other hand, is represented by a linear expenditure system (LES). The model assumes households maximize utility subject to budget constraint and save a fixed share of their income. Households are also subjected to direct taxation at a fixed rate. The total revenue collected from this and other types of taxes (import tariff and sales tax) represents government income. Transfer from the rest of the world in terms of aid and borrowing augments this revenue. Assuming real government consumption held constant, government budget adjusts to price changes. Thus, positive or negative government savings bridge any mismatch between the revenues and expenditures.

The external balance of Ethiopia with the rest of the world is maintained using a flexible foreign saving and fixed exchange rate regime. Whenever the demand for foreign currency exceeds the supply, it is assumed to be covered by increased foreign saving and it decreases whenever the opposite happens. This current account closure is believed to better represent the current managed floating exchange rate regime in the country.

The savings pool collects money from domestic (households and government) and foreign sources and finances the economy's investment demand. In every period of the model run, the capital stock continues updating with the total amount of new investment and depreciation.

2.1 Data

The Social Accounting Matrix (SAM) which this model is calibrated on was first developed by the Ethiopian Development Research Institute (EDRI) for a 2005/06 snapshot of the Ethiopian economy

---

[5] AEZ1-'Humidity-sufficient cereal based highlands'; AEZ2-'humidity-sufficient, enset-based highlands'; AEZ3-'drought-prone'; AEZ4- 'pastoralist'.

and later updated for 2009/10 by Engida et al. (2011). The SAM has 23 agricultural activities which are further disaggregated by the four AEZs. Besides, there are 36 other activities of which 25 are industrial and the rest 11 are service sector. Every activity produces and serves the economy with its respective commodity. In the SAM there are different factors of production; labor – disaggregated by skill level and location (into the AEZs), land and livestock – disaggregated by the AEZs, and capital. The SAM contains 14 different types of institutions from which 12 are representative households which are disaggregated by their location and income class (i.e. poor and non-poor), and a government and rest of the world (RoW). A direct and two different indirect (sales and import tariff) tax types are considered. Besides, there is a saving-investment account.

2.2 Endogenizing crop productivity

2.2.1 Simplified yield response function

The impact of increasing rates of typically used mineral fertilizer on rain water use efficiency (WUE) and radiation use efficiency (RUE) of maize grain yield and stover biomass productivity was estimated across the agro-ecological zones (AEZs) of Ethiopia using the crop model LINTUL5 embedded into a general modeling framework. LINTUL5 is a bio-physical model that simulates plant growth, biomass, and yield as a function of climate, soil properties, and crop management using experimentally derived algorithms. The applied version LINTUL5 simulates potential crop growth (limited by solar radiation only) under well-watered conditions, ample nutrient supply and the absence of pests, diseases, and weeds. To simulate a continuous cropping system, the model was embedded into a general modeling framework, SIMPLACE (Scientific Impact Assessment and Modelling Platform for Advanced Crop and Ecosystem Management) (Gaiser et al. 2013). The SIMPLACE<LINTUL5-SLIM-SoilCN solution of the modeling platform was used in this study. SLIM is a conceptual soil water balance model subdividing the soil in a variable number of layers, substituting the two-layer approach in LINTUL5 (Addiscott and Whitmore 1991). In this modeling framework, water, nutrients (NPK), temperature, and radiation stresses restrict the daily accumulation of biomass, root growth, and yield.

Spatial resolution was at the 1 km grid cell level, where cropland and soil data are available. A long maturing cycle maize variety (namely BH660) was used in the simulations in AEZs 1 and 2 where the length of crop growing season is more than 160 days, elsewhere a medium maturing cycle variety (namely BH540) was used in the simulations. The simulated yield from all the simulation units within each administrative zone was averaged to obtain a representative value for a specific year for comparing them with the observed yield.

Two sets of parameters for the hybrid maize varieties, BH660 and BH540, were calibrated against experimental data (yield and phenology) under rain-fed conditions collected from Melko (Jimma Agricultural Centre) for the year 2008 to 2012. Fertilizer application rates used in the experiments were 23 kg ha-1 of urea and 217 kg ha-1 DAP (Di-Ammonium Phosphate) at planting and 150 kg ha-1 urea after 35 days of planting. According to Jaleta et al. (2013), both BH660 and BH540 are the most popular and widely grown maize varieties in the country. The maize crop parameter dataset (provided with the LINTUL5 model and Srivastava et al. 2017), was used as a starting point to establish a new parameter set for these maize varieties.[6]

Results show a strong effect of the application rate of mineral fertilizer on maize yield and stover biomass across the AEZs. The national average maize grain yield under different application rates of the mentioned mix of fertilizers (DAP and urea in a 1:0.9 - ratio) is illustrated by Figure 6. The data points allow for a quadratic approximation which is differentiable with respect to fertilizer use and can

---

[6] Further details on the soil types, crop varieties and the crop modeling effort in general can be found in Srivastava et al. (2019).

thus be used to derive economically optimal fertilizer use rates under alternative input and output price constellations. This yields a fertilizer yield response function for maize.

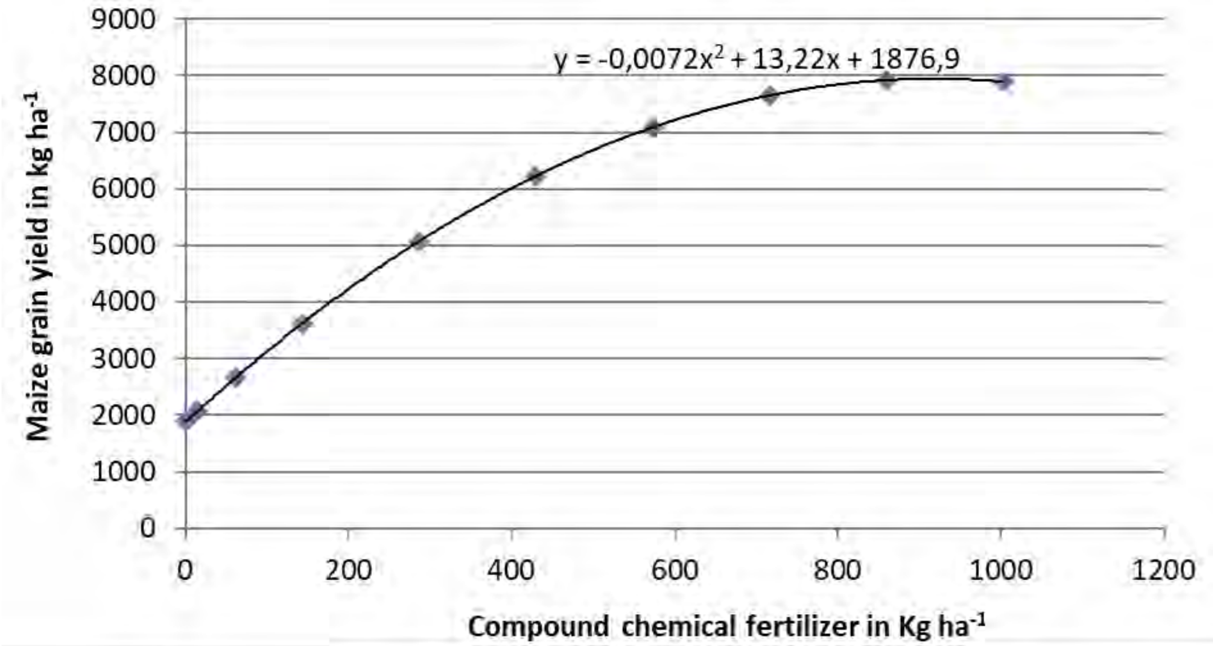

Figure 6: LINTUL5-simulated maize yields, and quadratic approximation function (Ethiopian national average results) at different use levels of mixed chemical fertilizer

Source: Author's computation based on results from the crop model.

The following Table 1 displays parameters and results of the quadratic approximation function that is integrated into the CGE model.

Table 1: LINTUL5-simulated maize yields, and quadratic approximation function (Ethiopian national average results) at different use levels of mixed fertilizer, and coefficients of the quadratic approximation function

Constant (*fertconst*)	1876.9		
Linear coefficient (*fertlin*)	13.22		
Quadratic coefficient (*fertq*)	-0.0072		
DAP-Urea mixed fertilizer application in kg/ha	Simulated yield in kg/ha from LINTUL5	Quadratic approximation of LINTUL5-simulated yields	Deviation
1	1914.24	1890.09	-24.15
62	2687.11	2670.12	-16.99
143	3565.92	3623.61	57.69
287	5024.44	5074.57	50.13
430	6299.13	6229.78	-69.35
573	7153.87	7089.23	-64.64
717	7634.57	7652.93	18.36
860	7848.98	7920.88	71.90
1003	7949.89	7893.07	-56.82

Source: Authors' computation based on results from the crop model.

The results show that the maximum yield level to be obtained in Ethiopia is far above the current maize yield, which is due to low fertilizer use. At given price levels for fertilizer and maize, the profit function that can be obtained from the yield response function has its optimal fertilizer use level per hectare far above the observed levels. The reason might be unobserved costs in fertilizer use in Ethiopia. Thus, to use this yield function in an economic model, the first order condition (FOC) of the profit function has to be calibrated to current use levels, which is explained in section 2.2.2.

In order not to only have maize as a crop where flexible fertilizer use is linked to productivity, other crops were considered as well. Teff, wheat, barley (*Hordeum vulgare*), and sorghum were our first choice. However, because of lack of recent information on the crops' responsiveness to fertilizer, we are bound to add only wheat for the current run. We obtained the required data from the "wheat profitability calculator for Ethiopia" prepared by HarvestChoice, IFPRI, and CIMMYT. Based on grid cell-level estimates of wheat yields, and response to the nutrient application, together with grid cell-specific estimates of chemical fertilizer and wheat prices, this spreadsheet model assesses the profitability of fertilizer application for all administrative regions in Ethiopia (HarvestChoice 2012). Three levels of fertilizer application (0%, 50%, and 100% of recommended fertilizer rates) and their respective yield levels are calculated and provided for each grid cell. The parameters needed for the wheat yield response function are then estimated based on data from these model results. The fertilizer-yield response function that we estimated for wheat in Ethiopia is displayed in Figure 7.

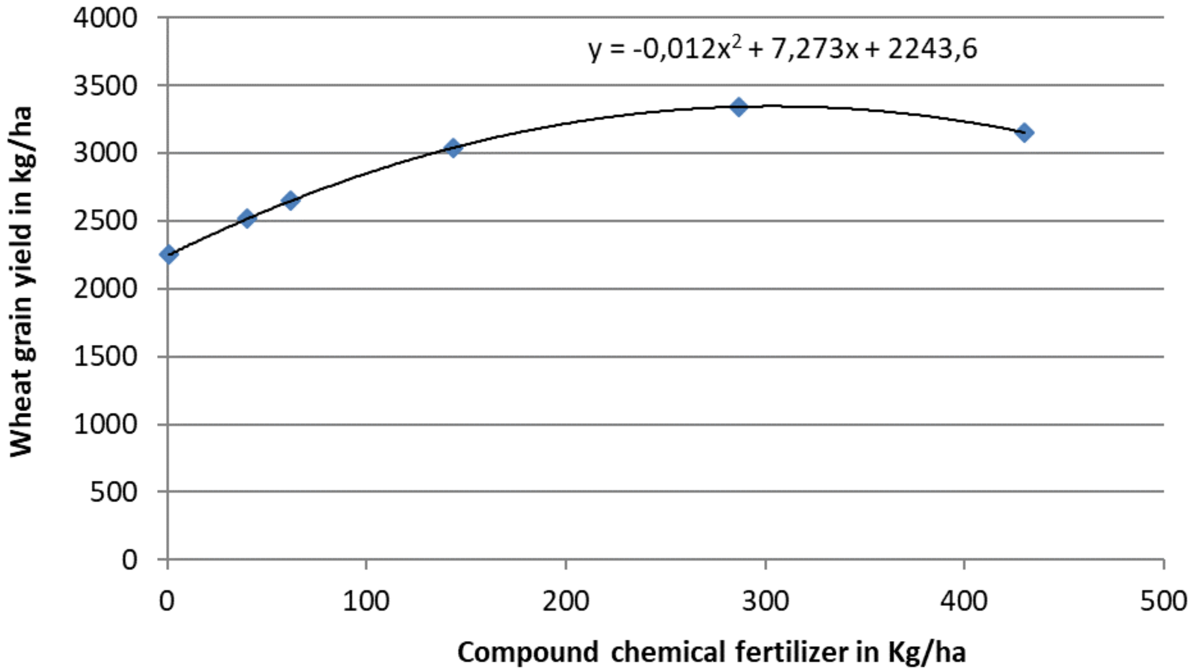

Figure 7: Different use levels of mixed chemical fertilizer and wheat yield based on the quadratic yield response function for wheat

Source: Authors' computation based on HarvestChoice dataset (HarvestChoice 2012).

Based on this dataset, application of around 300 kg of chemical fertilizer could give the farmer the highest possible wheat yield which is about 3.4 tons per hectare. This means that the yield response observed for wheat is far below that of maize. There could be many reasons for this, but application of non-improved seed varieties and/or a relative unsuitability of the country's soils and climate for wheat production (as compared to maize) might explain the difference.

The bio-physical economic model currently covers only two but highly significant crops. According to CSA report for 2015/16, maize and wheat nationally contribute 38 and 49 percent of cereal area and production respectively (CSA 2016).

2.2.2 Integrating yield response into the CGE model

The principal approach to incorporate a fertilizer yield response function to the CGE model is to create a 'fertilizer module', i.e. a set of equations that a) calculate yields, b) identify optimal fertilizer use levels per hectare based on a profit function approach, and c) finally ensure that changes in nominal quantities and prices obtained in this module are translated into equivalent changes in quantities and prices in the CGE model. Moreover, minor changes to a very limited number of equations of the original CGE model have to be made.

First, the yield ($Qyperha_{a,c}$)[7] is defined as a function of fertilizer per hectare by a quadratic model:

$$Qyperha_{a,c} = fertq_{a,c} \cdot Qabsfert_{a,c}^2 + fertlin_{a,c} \cdot Qabsfert_{a,c} + fertconst_{a,c}$$

The parameters of the above quadratic function ($fertq_{a,c}$, $fertlin_{a,c}$, *and* $fertconst_{a,c}$) are shown in Figure 6 and 7 above. Now it has to be ensured that changes in output (QA_a) per unit of land use in the CGE model compared to its base value are equal to changes of simulated ($Qyperha_{a,c}$) to its yields per hectare ($Qyperha0_{a,c}$) at the base:

$$\frac{QA_a}{QF_{'land',a}} = \frac{QA0_a}{QF0_{'land',a}} \cdot \frac{Qyperha_{a,c}}{Qyperha0_{a,c}}$$

The next step is defining a fertilizer demand function that expresses marginal revenues and costs of fertilizer use.

Adding prices for the two crops (maize and wheat) and fertilizer ($Poutput_{a,c}$ and $Pfert_c$), the profit per can be expressed as:

$$\pi_{a,c} = Poutput_c \cdot Qyperha_{a,c} - Pfert_c \cdot Qabsfert_{a,c}$$

As yield per hectare ($Qyperha_{a,c}$) is a function of fertilizer input per hectare ($Qabsfert_{a,c}$), profit per hectare can be re-written as:

$$\begin{aligned}\pi_{a,c} = {} & Poutput_c \cdot \left(fertq_{a,c} \cdot Qabsfert_{a,c}^2 + fertlin_{a,c} \cdot Qabsfert_{a,c} + fertconst_{a,c} \right) \\ & - Pfert_c \cdot Qabsfert_{a,c}\end{aligned}$$

$$\begin{aligned}\pi_{a,c} = {} & Poutput_c \cdot fertq_{a,c} \cdot Qabsfert_{a,c}^2 \\ & + Poutput_c \cdot fertlin_{a,c} \cdot Qabsfert_{a,c} \\ & + Poutput_c \cdot fertconst_{a,c} \\ & - Pfert_c \cdot Qabsfert_{a,c}\end{aligned}$$

Differentiating this for the decision variable $Qabsfert_{a,c}$ and solving for the fertilizer price ($Pfert_c$) yields:

$$Pfert_c = Poutput_c \cdot \left(2\, fertq_{a,c} \cdot Qabsfert_{a,c} + fertlin_{a,c} \right)$$

The problem is now that if we apply recent average prices of fertilizer, maize and wheat in this equation, we would get a way higher fertilizer application rate as observed for Ethiopia. That means

---

[7] Set *c* stands for commodities, set *a* for activities producing these commodities, and set *f* for production factors used by activities.

that there must be unobserved cost elements of fertilizer that were not accounted for, and which we have to add to *Pfert* in order to arrive at observed fertilizer application rates. This fixed calibration factor is thus calculated as the difference between marginal fertilizer price and marginal profitability of fertilizer application:

$$Fertcalib_{a,c} = Poutput_{c} \cdot \left(2\,fertq_{a,c} \cdot Qabsfert_{a,c} + fertlin_{a,c}\right) - Pfert_{c}$$

Fertcalib can be interpreted as an indicator for unobserved costs in fertilizer marketing and use, and could thus be varied in policy simulations or medium-term scenarios of better marketing and use efficiency. The complete fertilizer demand function is now:

$$Pfert_{c} + fertcalib_{a,c} = Poutput_{c} \cdot \left(2\,fertq_{a,c} \cdot Qabsfert_{a,c} + fertlin_{a,c}\right)$$

We have created a new equation with the first order condition (FOC) above, and we have created two new variables contained in it, the absolute prices for the crop outputs ($Poutput_{a,c}$) and fertilizer ($Pfert_{c}$) that have to be defined in related equations. In these, changes in absolute prices are determined by changes in relative prices in the CGE part of the model where markets determine price changes for the crops and fertilizer:

$$\frac{Poutput_{a,c}}{Poutput0_{a,c}} = \frac{PQ_{c}}{PQ0_{c}} \text{ for c, a = crop commodities/activities with fertilizer-yield function}$$

$$\frac{Pfert_{a,c}}{Pfert0_{a,c}} = \frac{PQ_{c}}{PQ0_{c}} \text{ for c = fertilizer, a = cropping activity with variable fertilizer use}$$

The next step is to enable the CGE model to change its fertilizer input use in accordance with the fertilizer module. By default, single intermediate inputs in the CGE model are a fixed share ($ica_{c,a}$) of total intermediate inputs per activity, i.e. a Leontief demand function.

$$QINTA_{a} = \sum_{c} QINT_{c,a} \cdot ica_{c,a}$$

For variable fertilizer use, this restrictive function has to be relaxed and also altered to better reflect crop production processes. First, the $ica_{c,a}$ input-output coefficients for fertilizer input use are made variable for crops with yield functions, while leaving the other inputs' shares of these crops fixed. Generally, input use in such crops is no longer related to the total quantity of inputs ($QINTA_{a}$ in the CGE model), but rather to land use, which is the standard way to describe a production technology in agronomy, meaning that

$$QINT_{c,a} = ica_{c,a} \cdot QF_{f,a}$$

for c = fertilizer, a = crops with a fertilizer-yield function, and f = land.

For these same cropping activities, total input use is not a fixed proportion of output any more,[8] but simply the sum of all inputs used.

$$QINTA_{a} = \sum_{c} QINT_{c,a}$$

QINTA then enters the equation defining total output as a function of factor use (value added) and input use. With a subset of $ica_{c,a}$ being variable, changes of fertilizer use per unit of land use in the physical fertilizer module can now be translated into input use per unit of land in the CGE model:

---

[8] With total input as a fixed proportion of output, non-fertilizer input use would have to decrease when fertilizer input is increased, which is agronomically implausible.

$$\frac{ica_{c,a}}{ica0_{c,a}} = \frac{Qabsfert_{a,c}}{Qabsfert0_{a,c}} \quad \text{for c = 'fertilizer' and a = 'activities with fertilizer-yield function'}$$

The last necessary step is to relax the fixed ‘yield parameter’ $fprd_{f,a}$ that is part of the CGE model equation defining value-added creation through factor use. This parameter serves as an equivalent to the yield per hectare from the fertilizer module and therefore has to be made variable for those activity-commodity pairs for which fertilizer yield response function is available. Counterfactual changes in $fprd_{f,a}$ are then equivalent to changes in crop yields from the yield response functions.

3 Simulation scenarios

Three different scenarios are simulated that run for a period of 20 years from 2011 to 2030: a baseline scenario for reference, and two counterfactual scenarios that simulate decreased costs of fertilizer use and elevated efficiency of application.

Scenario level 1: Baseline scenario (BASE) is the scenario in which relevant trends of the recent past in Ethiopian economy are applied.

The baseline scenario is as a benchmark which aims at continuing recent trends in model drivers over the simulation period. All factors of production except capital are made to face endogenous demand from the different activities and have fixed (or exogenous) supply which is the sum total of the demands from activities. The balance between the two is secured by the economy-wide wage rate. This makes them mobile across the activities. Based on several years' agriculture sample survey (AgSS) data, land[9] supply is exogenously made to increase at a decreasing rate as shown in Figure 8. Moreover, based on 2 rounds of labor force survey data from the CSA (1999 and 2014), the supply of agricultural labor (including unskilled labor) is made to increase by 3.19 percent annually while we apply a higher growth rate (6.14 percent) for non-agricultural labor (skilled and semi-skilled). Factor capital, on the other hand, is assumed to be fully employed and activity specific. Demands from activities are fixed while the supply is endogenous. Activity-specific wage rates are made flexible to balance the demand and supply for factor capital. Demand for capital in every activity is set to grow with the amount of investment in the economy. According to the structure of the model, the newly formed capital (i.e. investment) is distributed among activities in the SAM based on their initial capital share and this augments the capital accumulation in every activity.

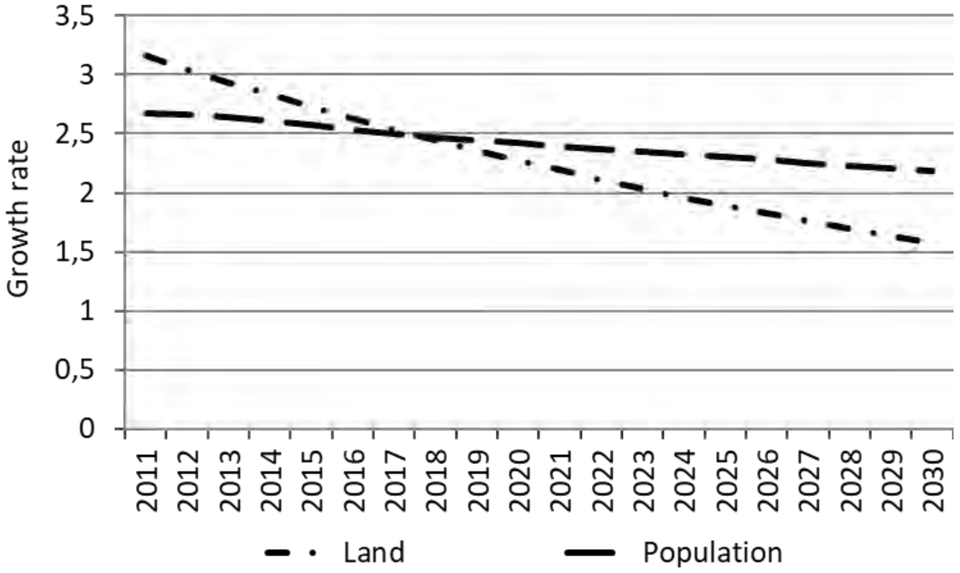

Figure 8: Land and population growth trends (2011-2030)
Source: Authors' calculation based on data from FAO (2017), and CSA (1999, 2014).

The other growth drivers in the model are population growth and Total Factor Productivity (TFP). The overall population in the country is made to increase at a decreasing rate for the next 20 years. Using 18 years data (2000-2017) from FAO data portal (2017) we calculated and applied the growth trajectory shown in Figure 8 to the model households. The other essential element of the economic growth is TFP growth in all activities. The growth rates applied in the model are calculated in a way to

---

[9] According to the SAM, factor land is used by crop cultivation activities only.

enable the economy to continue growing with the average growth rate reported for the last decade. In fact, actual sectoral shares are also considered. Thus, on average 3.3, 4.3 and 2.6 percent annual TFP growth rates are applied to agriculture, industry, and service sector activities respectively.

Scenario level 2: Better access to inputs and alternative pace of technological progress

In this scenario there are two simulations: one (F_ACCESS1) which experiments a decline in transaction (including transportation) cost, while the other (F_ACCESS2), on top of this, considers improved fertilizer accessibility and reduced use inefficiency through a reduction in unobserved cost that hinders Ethiopian farmers to optimize fertilizer use. The two simulations are similar to the BASE except for these additional interventions.

As briefly explained at the end of section 1.3, infrastructural and institutional predicaments in the country have led to high transaction costs. Referring to the study by Rashid et al. (2013) on Ethiopia, in fertilizer value chain transaction cost constitutes 15.3 percent of the landed cost (cost of the good plus freight only) at the port of Djibouti, and 13.2 percent of the farm gate price, respectively. Since the farm gate price is calculated only up to the input distribution center, an additional 5 percent transportation cost is added which is an assumption about the total cost from the distribution center to the farm gate. Studies on the most remote areas in Ethiopia estimate this cost to be as high as 50 – 80 percent of the transportation cost to the distribution center (Minten et al. 2013). All these calculations come up with a 'transaction and transportation' cost of 21.06 percent of the total fertilizer sales value. This is maintained in the SAM and it is made to decrease by 5 percent every year for both simulations in the second scenario (Table 2). This is in an assumption of a minimum effort by the government to improve the infrastructural and institutional barriers in fertilizer provision which is the public sector's role towards better input accessibility for the advancement of the agriculture sector.

Moreover, as shown in Table 2, a 1 percent reduction in the unobserved cost is applied every year in F_ACCESS2 simulation on top of the transaction cost intervention. As explained above in section 2.2, the profit function obtained from the physical yield function postulates an optimal fertilizer use level per hectare far above the observed (actual) levels. We termed this positive profit, at suboptimal levels of fertilizer use, as unobserved transaction costs (the parameter *fertcalib* in the CGE model). There are different reasons for this far sub-optimal use: Input inaccessibility (additional reasons to those counted in transaction cost) and use inefficiency are the major. As explained at the end of section 1.3, technical use inefficiency in fertilizer application could emanate from late arrival of inputs and from knowledge gaps and information hurdles. Long and inefficient input procurement bureaucracy is one of the major factors for missing input markets or late supply of inputs. Actually, there are also different factors from the demand side like financial constraints, lack of information (or knowhow) and risk aversion behavior of the farmer. These factors also explain input inaccessibility as a reason for unobserved cost.

This scenario tries to capture impacts of public effort towards improving input accessibility and reducing unobserved costs, for instance through improved access to credit for inputs, facilitating more frequent contact with extension agents or any other knowledge dissemination mechanisms that can improve farmers access to and understanding of modern inputs and their use efficiency.

Referring to Table 2, the initial unobserved cost in maize production is almost threefold higher than in wheat. Thus, a percent reduction applied in F_ACCESS2 effectively means a threefold reduction in unobserved cost in maize than in wheat. Besides, the coefficients estimated for the fertilizer-yield response functions are also bigger in maize than in wheat. These show that interventions are stronger and would get a bigger response in maize than wheat.

With these simulations, this paper aims to broadly investigate welfare and food security implications of improved fertilizer accessibility and usage in Ethiopia. Specifically, it focuses on direct and indirect effects of productivity implications of improved access to and use efficiency of modern inputs.

Table 2: Experimental parameters and their respective shocks in the simulations

Experimental parameters	**Applied on**	**INITIAL**	**Annual change**		
			BASE	**F_ACCESS1**	**F_ACCESS2**
Transaction + Transportation cost (percentage of the total value sales)	Fertilizer commodity	21,06	-	- 5%	- 5%
Unobserved transaction cost (birr per hectare)	Wheat activity	15,4	-	-	- 1%
	Maize activity	41,7			

Source: Authors' calculation.

The above mentioned interventions to improve the agriculture sector in Ethiopia need significant investment, especially from the government side. Even though we do not have the intention to do a thorough analysis on the cost-benefit comparison at the national level in this paper, it is worthwhile to mention quotes on the required public expenditure in order to undertake such interventions and attain the intended progress in the agriculture sector. Moreover, we also calculate the extent to which the possible benefits could cover the intended expenditure. According to the estimation in the Comprehensive Africa Agriculture Development Programme (CAADP) framework, an allocation of at least 10% of public expenditure to the agriculture sector is needed for the overall rural and agricultural development envisioned in Africa (NEPAD 2003). Specifically if we take agricultural extension services in Ethiopia, it has traditionally been financed and provided almost entirely by the public sector. Thus, these programs represent a significant public investment, roughly estimated to be 2 percent of total annual government expenditure (Spielman et al. 2012).

4 Empirical results

4.1 Supply (production) effects and economic growth

Let us start the analysis with model results on food supply as the counterfactual scenarios are designed to improve productivity in maize and wheat production. The interventions increase the use of fertilizer due to decreased costs (both observed and unobserved). As a result, the experimental simulations show a positive response in yields and total output. As shown in Table 3, a five percent annual reduction in transaction costs for fertilizer acquisition (i.e. F_ACCESS1) motivates the average wheat and maize farmer in Ethiopia to apply higher amounts of fertilizer. In the BASE run, wheat and maize farmers use 50 and 68.6 kg of chemical fertilizer per hectare each year on average. Now, as a result of the intervention, their average annual application would rise to 56.8 and 70.8 kg respectively (i.e. additional of 6.8 and 2.2 kg). The improved soil fertility, as a result, gives an additional yield of about 39.8 and 27 kg of wheat and maize per hectare on average each year and raised the annual per hectare yield in the BASE run (i.e. 2.58 and 2.74 tons) to 2.62 and 2.77 tons, respectively.

On the other hand, if the public sector managed to reduce unobserved costs in fertilizer use by 1 percent every year (i.e. F_ACCESS2), then the farmers on average would annually apply 67.4 and 98.3 kg of chemical fertilizer per hectare which is additional of 17.4 and 29.8 kg on wheat and maize respectively. In turn, this brings about higher yield level; 2.68 and 3.08 tons, which is higher than the BASE by 98.6 and 342.3 kg of wheat and maize per hectare respectively.

Based on these results and data from 2009/10 AgSS, on a total area of 1.7[10] million hectares of wheat land, the country would be capable of producing 4.4 and 4.5 million tons of wheat annually as a result of the two interventions, F_ACCESS1 and F_ACCESS2 respectively. These interventions increase the country's annual wheat production capacity by 67,000 and 166,000 tons (i.e. 1.5 and 3.8 percent) from the BASE respectively. This necessitates the use of around 95,600 and 113,400 tons of chemical fertilizer annually which is higher as compared to the BASE. Similarly, the 1.8 million hectares of total maize acreage would annually give us 4.9 and 5.5 million tons in the two simulations respectively as a result of the application of 125,600 and 174,300 tons of chemical fertilizer. Thus, these interventions enable the country to raise its total annual maize production by 47,800 and 606,600 tons (i.e. 1 and 12.5 percent respectively) as compared to the BASE.

If we scale down the analysis to holder level, an average Ethiopian wheat farmer, producing 929.5 kg of wheat per annum on a 0.361 ha plot would increase his production to 944 kg as a result of F_ACCESS1 which enables him to apply 20.5 kg of chemical fertilizer; 2.45 kg (13.5 percent) greater than what he used to apply. Similarly, an average maize farmer's annual production on a 0.248 ha plot increases by 1 percent, from 679 kg to 685.5 kg with the same intervention. This requires the application of 17.6 kg of chemical fertilizer annually, which is 0.6 kg (i.e. 3.4 percent) higher than in the BASE. However, if we consider F_ACCESS2, the same farm plots would give about 965 kg and 764 kg of wheat and maize to the farmer based on the application of 24.3 and 24.4 kg of chemical fertilizer, respectively. As can be generalized from the results, wheat and maize farmers are benefitting from both interventions in terms of output. However, maize farmers benefit significantly higher from F_ACCESS2 relative to wheat farmers due to stronger intervention (as explained in section 3).

---

[10] Total acreage figures used in this paragraph are subjected to relative changes based on model results.

Table 3: Average annual chemical fertilizer use and output level

			BASE		**F_ACCESS1**		**F_ACCESS2**	
			Chemical fertilizer	**Output**	**Chemical fertilizer**	**Output**	**Chemical fertilizer**	**Output**
Wheat	kg	per ha	**50.0**	**2,576.3**	**56.8 (13.5%)**	**2,616.1 (1.5%)**	**67.4 (34.8%)**	**2,674.9 (3.8%)**
	Holder level (kg)	per plot**	18.04	929.52	20.48	943.87	24.31	965.10
		diff*			2.45	14.36	6.27	35.58
	Aggregate level (Tons)	total***	84,155.1	4,337.316.7	95,582.3	4,404.300.3	113,428.4	4,503.352.8
		diff*			11,427.2	66,983.6	29,273.3	166,036.1
Maize	kg	per ha	**68.6**	**2.738.2**	**70.8 (3.4%)**	**2,765.2 (0.99%)**	**98.3 (43.4%)**	**3,080.5 (12.5%)**
	Holder level (kg)	per plot**	17.00	678.86	17.56	685.55	24.38	763.72
		diff*			0.57	6.69	7.38	84.86
	Aggregate level (Tons)	total***	121,501.9	4,852.826.3	125,550.6	4,900.628.3	174,289.2	5,459.469.8
		diff*			4,048.7	47,802.0	52,787.3	606,643.5

*diff=annual average difference from the BASE.

** plot size (country average) is 0.361 and 0.248 ha for wheat and maize respectively.

***total wheat and maize acreages in Ethiopia are 1.68 and 1.77 million hectares.

Note: Percentage changes are provided in parentheses.

Source: Authors' calculation from the model results.

Looking at the dynamics, yield in wheat and maize increases at an increasing rate throughout the period. Even though this trend holds for all the simulations, both experimental simulations, especially decreasing the observed and unobserved transaction costs (i.e. F_ACCESS2) bring significantly stronger effect on yield rate for both crops. As seen in Figure 9, the differential is increasing for both crops. The cumulated effects of the introduced shocks in both simulations make both activities produce consecutively higher amounts of output on a given plot. Wheat yield grows by about 40 kg on average per annum while maize yield increases by around 27 kg on average because of increased fertilizer use as a result of decreased acquisition cost. Whereas decreasing fertilizer inaccessibility and use inefficiency simultaneously bring the highest productivity gain in both crops: yield increases on average by about 1 and 3.5 quintals for wheat and maize respectively. The dynamics in both fertilizer application and yield show that reducing the unobserved transaction cost for modern input use is highly critical and makes the effort to improve input accessibility even more effective.

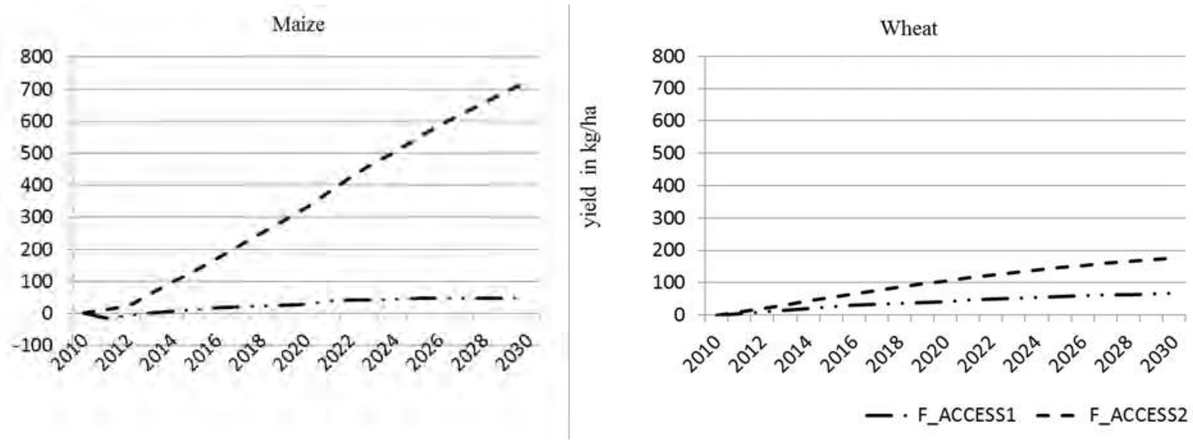

Figure 9: Dynamics in yield for wheat and maize (2010-2030) (deviations between BASE and experimental simulation trajectories)

Source: Authors' computation based on model results.

Due to frequent droughts (especially in the drought-prone areas of east and south-east parts of the country) and rising food prices, the government of Ethiopia relies on wheat imports for relief and market stabilization. Thus, according to FAOSTAT[11], Ethiopia's wheat imports increased more than three-fold in the last twenty-five years. For instance, from 2008-2013 the country imported an average of about half a billion USD worth of wheat each year, putting a burden on Ethiopia's foreign currency reserve. The additional output obtained as a result of the simulated interventions could contribute to easing this deficit by boosting domestic production of staple grains. Our experimental simulations, as compared to BASE, result in a maximum of 1.25 million USD saving every year from wheat import cuts. Moreover, the country also enjoys a maximum of around 350,000 USD additional earnings every year from maize exports.

Even though the new interventions have significant yield and output effects on wheat and maize, they have limited effects on macroeconomic aggregates, like aggregate value added (GDP), income for an average household, and total consumption. Aggregate value addition in the economy is increasing at an increasing rate for all the cases. Figure 10 shows the dynamics in additional GDP obtained as a result of the counter factual interventions (comparison with the BASE). The difference is not significant, especially for F_ACCESS1 because of two reasons; first, the major beneficiaries from both interventions are two activities; maize and wheat that holds only 6 percent of the national GDP and second, the other activities that also benefit from the first intervention – annual reduction in fertilizer transaction cost – follow a fixed share Leontief aggregation function for intermediate demand with 0.028 average share for fertilizer. This shows that fertilizer application is at a very low rate in these activities and efforts to increase fertilizer application have low return to output in these activities.

---

[11] http://www.fao.org/faostat/en/#data/TP

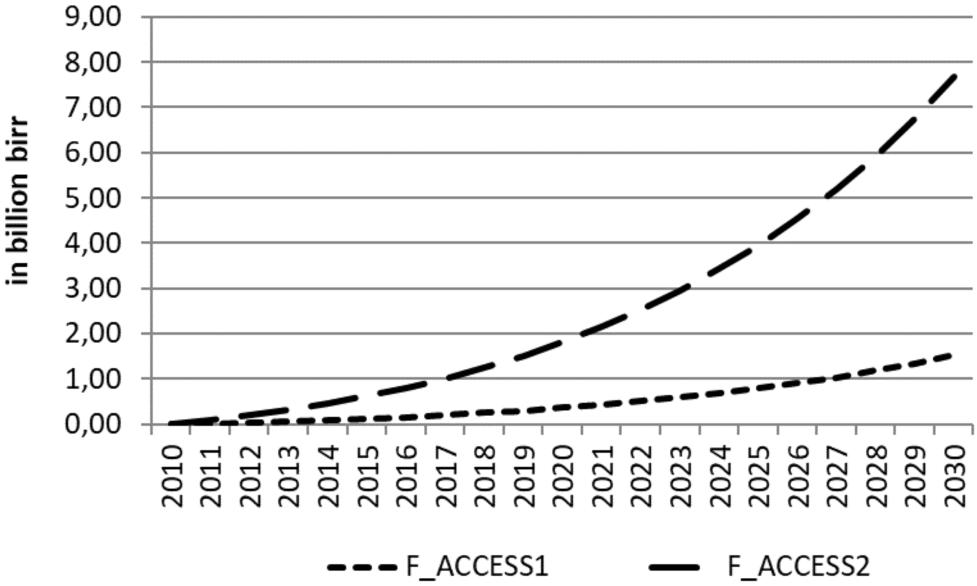

Figure 10: Dynamics in the aggregate value addition (2010-2030), comparison with the BASE (in billion birr)

Source: Authors‘ computation based on model results.

4.2 Effects on producers' income

All the simulations bring about a positive and increasing income change for both farming and non-farming households. However, compared to the BASE scenario, the additional productivity gain resulting from the two experimental simulations leads to a small impact on income for both household types. As highlighted above, the shocks involved in the two experimental simulations are not strong enough to produce a significantly higher rise in income than the BASE scenario for an average household. If we look at the households by their income classification, poor farmers get relatively higher returns. F_ACCESS1 and F_ACCESS2 enable poor farmers to get annually 0.02 and 0.01 percentage points higher income respectively as compared to the BASE; whereas the non-poor households receive incomes of only 0.008 and 0.005 percentage points higher. The slightly lower benefit from F_ACCESS2 despite government's additional effort might be explained by the slight decline in land rental rate.

However, income from growing wheat and maize contribute a negligible share of the aggregate household income in the economy, and even for the average farming household. Looking at the aggregate effect does not show us the impact on the specific households. Thus, simulation effect on wheat and maize farmers' profitability in particular needs to be discussed.

It is possible to calculate income effects through profitability of the additional fertilizer applied. A commonly used measure of profitability is the value-cost ratio (VCR). Here it is applied to the model results (i.e. additional chemical fertilizer used per holder and the additional output obtained as a result (both in kg)[12] to calculate the profitability of additional fertilizer used per holder's plot relative to BASE. This ratio is the value of the additional production due to application of the additional fertilizer to the total cost of the additional fertilizer applied. The additional output from an average wheat or maize plot that received the additional fertilizer is X. P is the price of wheat or maize output (farm gate price). Price of fertilizer is P_f, and Q_f is the additional amount of fertilizer applied to that particular plot, then the VCR is given as follows:

---

[12] Additional fertilizer used and additional output obtained are calculated for each experimental simulation as the amount used or produced in comparison with that in the BASE run.

$$VCR = \frac{P * X}{P^f * Q^f}$$

Looking at the results from Table 4, the VCR levels mean that each kg of additional fertilizer applied to wheat and maize plots is found to be profitable to the holder. As can be understood from the formula, a VCR of 1 is the threshold to profitability. However, it is commonly argued that a VCR of at least 2 is needed for fertilizer to be profitable in Africa. A high threshold level is recommended for Africa just to compensate for the higher probability of adverse conditions that greatly influence profitability, as for instance infestations and weather risks.

An average wheat farmer in Ethiopia with a 0.36 ha plot obtains an additional of 33.2 and 79.3 birr of profit from applying an additional of 2.45 and 6.27 kg of chemical fertilizer in F_ACCESS1 and F_ACCESS2, respectively. Similarly, an average maize farmer gets 20.9 – 261.6 birr of profit from his quarter a hectare plot as a result of the application of additional 0.6 – 7.4 kg of chemical fertilizer in the two simulations. As discussed above, the VCR levels from Table 4 show that each birr spent to purchase additional fertilizer for maize production is very profitable. For wheat production, although it is not completely profitable, we could also say it is profitable since the VCR level is pretty much closer to the threshold for Africa (especially in the first intervention) which is double the ratio elsewhere. These results indicate that improved fertilizer accessibility and reduced use inefficiency could make a significant difference regarding fertilizer application and profitability. Thus, as compared to BASE, wheat and maize farmers are better off in terms of profitability. This positive effect could be higher with higher fertilizer application.

Table 4: VCR calculations for additional fertilizer application on average wheat and maize plots in Ethiopia

	F_ACCESS1		**F_ACCESS2**	
Fertilizer price birr per kg	13.90		13.90	
Wheat price birr per kg	4.68		4.68	
Maize price birr per kg	4.31		4.29	
	Wheat	Maize	Wheat	Maize
Additional chemical fertilizer used per holder (kg)	2.45	0.57	6.27	7.38
Additional Output (kg)	14.36	6.69	35.58	84.86
Additional spending for fertilizer (birr)	34.03	7.87	87.18	102.62
Additional birr obtained from sales	67.19	28.80	166.46	364.19
Additional Profit in birr	33.16	20.93	79.29	261.57
VCR	1.97	3.66	1.91	3.55

Source: Authors' calculation based on model results and 2009/10 data from FAOSTAT[13].

Note: All the acreage and price figures basically used in this calculation are subject to changes from the model results.

In an attempt to look at the welfare gains and losses to market participants from changes in market conditions as a result of the interventions, aggregate value addition is calculated for each intervention. If we take the last intervention (for the sake of straight forward calculation of its budgetary cost), maize and wheat farmers (only) receive improved access to extension service and consequently enjoy better information and knowhow about modern inputs which is denoted by a 1-percent annual reduction in unobserved cost in these activities only. As a result, this intervention would come up with total welfare gain of about 6 billion birr in the country in 2030 which grows from 73.5 million birr in 2011 with a 28 percent average annual growth rate. As seen in Figure 12, the welfare gain significantly increases throughout the period. Comparing this with the current (and projected) total public expenditure on

---

[13] www.fao.org/faostat/en/#data

extension service[14], the additional welfare gain would on average be as high as 12.4 percent of it. Here one should not forget that the welfare gain is obtained from an intervention on two crops only while the expenditure is for the overall extension service in the country.

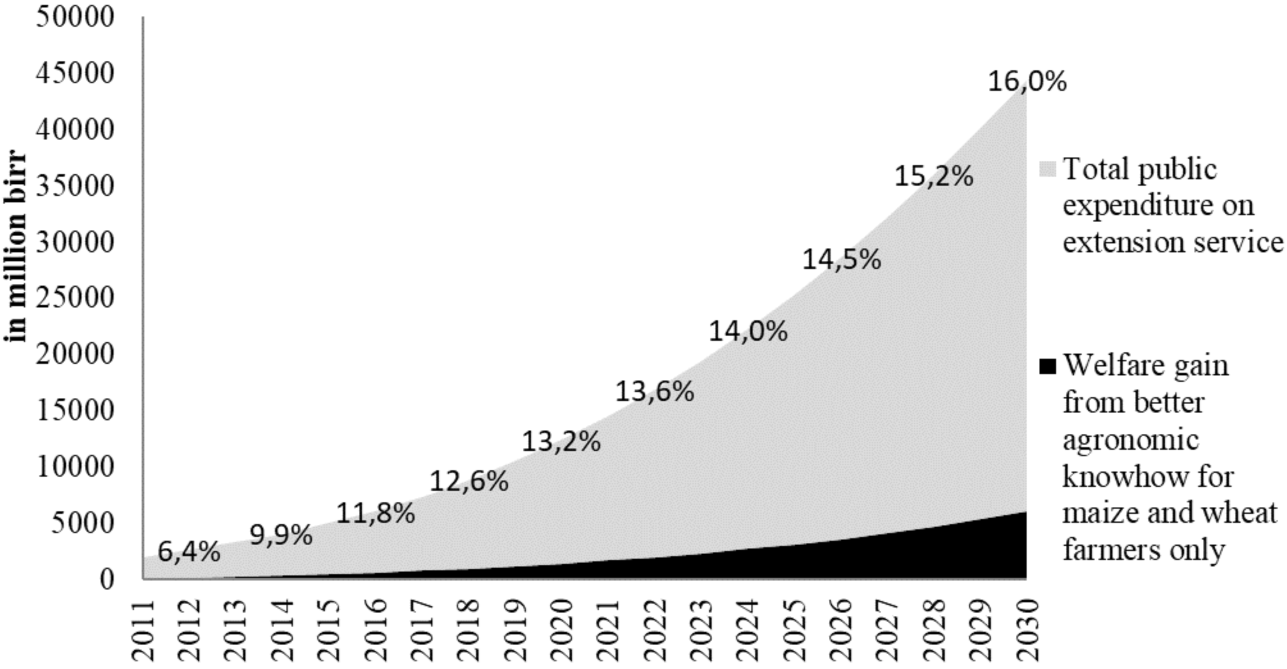

Figure 12: Trajectories for public expenditure on extension service and the expected welfare gain

Source: Authors‘ calculation based on model resulst and data from NBE (2017).

4.3 Effects on household consumption

When discussing changes in household welfare as a result of productivity interventions, a distinction between net producers and net consumers of maize and wheat has to be made. Subsequent price drops have adverse effects on net producers, whereas they are blessings to net consumers. A broader perspective is needed to deal with this issue, as households have diverse sources of income and lower crop prices could still have positive effects on the producer households' consumption expenditure. Slight income changes and price reductions are obtained from the model results. Wheat and maize prices annually decrease at a maximum of 0.08 and 0.5 percentage points relative to the BASE in F_ACCESS1 and F_ACCESS2 respectively. Thus, households that consume a higher portion of these commodities, such as rural farming households which consume 35 percent of their total consumption from crop commodities, exhibit higher welfare improvements as a result of cheaper consumption than households that consume less of these commodities (in our case, non-farming households where total consumption from these commodities represents less than 15 percent of the household budget on average). Farming households enjoy higher consumption increases in the experimental simulations for most of the simulation period than non-farming households. Looking at the trajectories in Figure 13, it is clear that changes in household consumption are caused by the price changes rather than income changes. The bigger price decrease under F_ACCESS2 enables farming households to enjoy a higher welfare gain than net consumers. Though it is relatively lower, the welfare of the non-farming households also improves as a result of reduced cost of living. Based on income classification, poor

---

[14] 3.65 billion birr on average between 2009/10 and 2016/17 based on data from National Bank of Ethiopia (NBE 2017) and estimation from Spielman et. al. (2012).

farming households enjoy a higher improvement in consumption as a result of relatively higher additional income and price reductions.

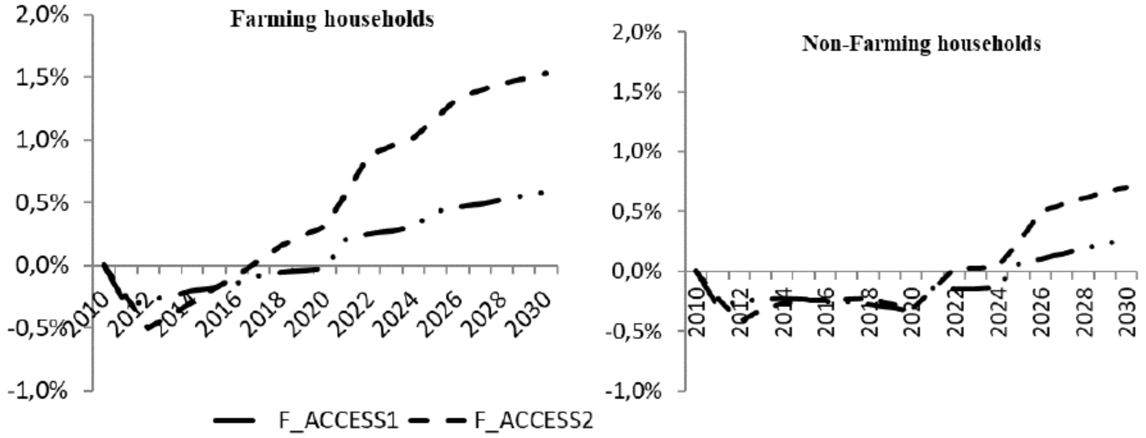

Figure 13: Dynamics in simulation results on households' consumption (2010-2030)
(percentage deviations between BASE and simulation trajectories)
Source: Authors' computation based on model results.

5 Summary and conclusion

Similar to the current trend in most Sub-Saharan African countries, population growth in combination with increasing income will further increase demand for food in Ethiopia. While the country has managed to increase per-capita food production by more than 50 percent since the year 2000, cropland scarcity is bound to be a serious challenge for future supply growth. Average farm sizes are decreasing, while soils are being depleted as they are not sufficiently replenished with the nutrients that the soils are deficient with.

This study investigates scenarios of improved access and knowhow to modern farming inputs in order to improve crop biomass productivity. We try to quantify the economy-wide implications of such productivity improvements with a major emphasis on resulting household welfare. A recursive-dynamic IFPRI CGE model for Ethiopia is run for 20 years based on the 2009/10 Ethiopian Social Accounting Matrix (SAM). In order to capture the appropriate yield response to fertilizer application into the CGE model, we make land productivity to be determined by a yield response function that we estimated based on results from an agronomic model for maize and data from HarvestChoice for wheat.

In comparison with current trends, model results show positive effects in the two experimental simulation scenarios: (1) a five percent annual reduction in fertilizer transaction costs to make fertilizer more accessible, and (2) provision of input credit and extension services on top of the first in order to improve farmers' access and knowhow to modern inputs which is assumed to imply a one percent annual reduction in unobserved transaction costs of fertilizer use. The simulations are applied only on wheat and maize. In both cases, the interventions come up with a significant increase in yields and total output both at the aggregate and the household level. More interestingly, when the value-cost ratio (VCR) is calculated - as a measure of profitability - for average wheat and maize farmers (with 0.36 and 0.25 hectares of average holdings respectively), results suggest that the increased fertilizer application is profitable for farmers in the case of both maize and wheat though it is not completely profitable in the case of wheat. If the entirety of households in the economy is considered, effects of the new interventions are found to be rather insignificant. This is because income from wheat and maize activities contributes a minimal share of an average Ethiopian household's income, even of farming households. Despite small income effects, the interventions enable all households to enjoy higher consumption as a result of price reductions, especially of wheat and maize. This improvement in consumption is relatively higher for the farming households with high consumption shares for agricultural commodities as compared to their non-farming counterparts.

In both yield and profitability results from the 2nd simulation we noted that the effects in maize production are much stronger than in wheat. There are two reasons for this: the calculated unobserved cost component in maize production is almost three times higher than in wheat, so when a 1% reduction is applied, this means that the reduction in unobserved costs in maize is effectively three times larger than that in wheat. The other reason might be due to the coefficients estimated for the fertilizer-yield response functions. The coefficients estimated suggest a higher yield response of maize to fertilizer than for wheat (see Figure 6 and 7).

As the model results show, at the current level of application, additional fertilizer use and improved knowhow would be profitable and have significantly positive welfare effects for producers. Moreover, the aggregate welfare effect indicates that these interventions have a positive impact on the economy in general. For instance, the total welfare gain obtained from improved access to extension services is equivalent to 12.4 percent of the current annual public expenditure on extension service. We can put this into perspective that can help us see how economically viable the intended intervention is. The welfare gain from an intervention only on wheat and maize crops could sufficiently justify an increase of 12.4 percent of the current public expenditure on farm extension services, assuming that this would facilitate a one percent reduction in unobserved cost.

Thus, in order to reap these potential benefits, reductions in transaction costs of fertilizer acquisition could be achieved in different ways. Improving the rural road network would reduce the cost markup from harbor to farm. Additionally, reducing bureaucratic obstacles in fertilizer procurement could avoid belated input application. Finally, improved accessibility to agriculture extension agents and creating possible alternative income sources, especially off-farm, would significantly ease adoption barriers and cut the high knowledge costs related to the adoption of new technologies. The comparison between the two counterfactual simulations shows that better information and knowhow regarding modern input use is highly critical and makes the effort to improve input accessibility even more effective.

Most of the time, farmers complain about the negative relation between accessibility of extension agents and distance from the main road (or the administrative center). Thus the government has to work hard on increasing the number of extension agents, improving their capacity and supervision to ensure full coverage.

References

Addiscott, T.M. and Whitmore, A.P. (1991). Simulation of solute leaching in soils of differing permeabilities. SoilUse and Management, Vol. 7, Issue 2, pp. 94-102, 1991. https://doi.org/10.1111/j.1475-2743.1991.tb00856.x.

Admassie, A. and Ayele, G. (2004). Adoption of improved technology in Ethiopia. Addis Ababa, Ethiopia: Ethiopia Development Research Institute. Pmid:16895031.

ATA-MoA (2014). Seed System Development Strategy. Agricultural Transformation Agency – Ministry of Agriculture. Accessed January 19, 2015. http://www.ata.gov.et/wp-content/uploads/20130415_Overall-seed-systemstrategy_vFINALDRAFT_Offical-Release_final.pdf.

Bachewe, N.F., Berhane, G., Minten, B., and Taffesse, A. S. (2015). Agricultural growth in Ethiopia (2004-2014): evidence and drivers. Ethiopia Strategy Support Program (ESSP II) Working Paper 81, International Food Policy Research Institute, Addis Ababa, Ethiopia.

Beshir, H., Emana, B., Kassa, B. and Haji, J. (2012). Determinants of chemical fertilizer technology adoption in North eastern highlands of Ethiopia: the double hurdle approach. J. Res. Econ. Int. Finan. 1(2):39-49.

Boserup, E. (1965). The Conditions of Agricultural Growth. London: Allen and Unwin. http://www.peakoilindia.org/wp-content/uploads/2013/10/Boserupian-Theory.pdf.

Central Statistical Authority (CSA) (1999). Statistical Report on the 1999 National Labor Force Survey. March 1999. Addis Ababa.

Central Statistical Authority (CSA) (2004). Agricultural Sample Survey 2003/2004 (1996 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistics Authority (CSA) (2005). Agriculture Sample Survey 2004/05 (1997 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistics Agency (CSA) (2006). Agriculture Sample Survey 2005/06 (1998 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistics Agency (CSA) (2007). Agriculture Sample Survey 2006/07 (1999 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistics Agency (CSA) (2008). Agriculture Sample Survey 2007/08 (2000 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistics Agency (CSA) (2009). Agriculture Sample Survey 2008/09 (2001 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistics Agency (CSA) (2010). Agriculture Sample Survey 2009/10 (2002 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistics Agency (CSA) (2011). Agriculture Sample Survey 2010/11 (2003 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistics Agency (CSA) (2012). Agriculture Sample Survey 2011/12 (2004 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistics Agency (CSA) (2013). Agriculture Sample Survey 2012/13 (2005 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistics Agency (CSA) (2014). Agriculture Sample Survey 2013/14 (2006 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistics Agency (CSA) (2015). Agriculture Sample Survey 2014/15 (2007 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistics Agency (CSA) (2016). Agriculture Sample Survey 2015/16 (2008 E.C.). Statistical Bulletin, Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Addis Ababa, Ethiopia.

Central Statistical Authority (CSA) (2014). Analytical Report on the 2013 National Labor Force Survey. June 2014. Addis Ababa

CSA and World Bank (2013). Ethiopian Rural Socioeconomic Survey. Survey report. http://siteresources.worldbank.org/INTLSMS/Resources/3358986-1233781970982/5800988-1367841456879/9170025-1367841502220/ERSS_Survey_Report.pdf.

Spielman, D.J., Kelemework D.M., and Alemu D. (2012). Seed, Fertilizer, and Agricultural Extension in Ethiopia. Food and Agriculture in Ethiopia. International Food Policy Research Institute.

Demeke, M., V. Kelly, T.S. Jayne, A. Said, J. C. Le Valee, and H. Chen (1998). Agricultural Market Performance and Determinants of Fertilizer Use in Ethiopia. Grain Market Research Project Working Paper No. 10. Addis Ababa: Ministry of Economic Development and Cooperation, Government of Ethiopia.

Engida, E., Tamru, S. , Tsehaye, E., Dario, D., Paul, D., and Sherman, R. (2011). Ethiopia's Growth and Transformation Plan: A Computable General Equilibrium Analysis of Alternative Financing Options. ESSP II Working Paper 30. Addis Ababa, Ethiopia. Ethiopia Strategy Support Program II

FAO (Food and Agricultural Organization of the United Nations). (2017). FAOSTAT. Rome: FAO. http://www.fao.org/faostat/en/#country/238.

Gaiser, T., Perkons, U., Küpper, P.M., Kautz, T., Uteau-Puschmann, D., Ewert, F., Enders, A. and Krauss, G. (2013). Modeling biopore effects on root growth and biomass production on soils with pronounced sub-soil clay accumulation. Ecological Modelling, Vol. 256, pp. 6–15, 2013. doi:10.1016/j.ecolmodel.2013.02.016.

HarvestChoice (2012). "Profitability Calculator." International Food Policy Research Institute, Washington, DC., and University of Minnesota, St. Paul, MN. Available online at http://harvestchoice.org/node/4172.

Jaleta, M., Kassie, M. and Shiferaw, B. (2013). Tradeoffs in crop residue utilization in mixed crop–livestock systems and implications for conservation agriculture. Agricultural Systems, Vol. 121, pp. 96–105, 2013.

Jayne, T.S., Govereh, J., Wanzala, M. and Demeke, M. (2003). Fertilizer Market Development: A Comparative Analysis of Ethiopia, Kenya, and Zambia. Food Policy 28: 293–316.

Martins, P. (2014). Structural Change in Ethiopia: An Employment Perspective. World Bank, Policy Research Working Paper, WPS 6749. Washington, DC. Available online: http://documents.worldbank.org/curated/en/465501468031484282/Structural-change-in-Ethiopia-an-employment-perspective.

Minten, B., Koru, B. and Stifel, D. (2013). The Last Mile(s) in Modern Input Distribution: Pricing, Profitability, and Adoption. Agricultural Economics, Vol. 44, Issue 6, pp. 629-646, 2013. https://doi.org/10.1111/agec.12078.

National Bank of Ethiopia (NBE) (2014). Annual report 2013-2014. Addis Ababa.

NBE (2017). National Bank of Ethiopia 2016/17 Annual Report. Addis Ababa, Ethiopia.

http://www.nbe.gov.et/pdf/annualbulletin/NBE%20Annual%20report%202016-2017/NBE%20Annual%20Report%202016-2017.pdf.

NEPAD (2003). Comprehensive Africa Agriculture Development Programme. July 2003 ISBN 0-620-30700-5.

Rashid, S., Tefera, N., Minot, N. and Ayele, G. (2013). Fertilizer in Ethiopia: An assessment of policies, value chains, and profitability. IFPRI Discussion Paper 01304.

Srivastava, A.K., Mboh, C.M., Gaiser, T., Zhao, G. and Ewert, F. (2017). Climate change impact under alternate realizations of climate scenarios on maize yield and biomass in Ghana. Agricultural Systems, Vol. 159, pp. 157-174, 2018. https://doi.org/10.1016/j.agsy.2017.03.011.

Srivastava, A., Gaiser, T., Ewert, F., Mboh, C. M., Engida, E. and Kuhn A. (2019). Effect of Mineral Fertilizer on Rain Water and Radiation use Efficiencies for Maize Yield and Stover Biomass Productivity in Ethiopia. Agricultural Systems, Vol. 168, pp. 88-100, 2019. DOI: 10.1016/j.agsy.2018.10.010.

World Bank (2004). Ethiopia: Economic Memorandum. Background report: Four Ethiopias, A regional characterization; Assessing Ethiopia's growth potential and development obstacles. Poverty reduction and economic management 2. Country department for Ethiopia. Africa region. http://siteresources.worldbank.org/INTETHIOPIA/Resources/PREM/FourEthiopiasrev6.7.5.May24.pdf.

World Bank (2009). Fertilizer Supports Project Implementation Completion Report (ICR): Background, Project Outcomes and Lessons Learned. Draft. Addis Ababa.

Yu B. and Nin Pratt, A. (2014). Fertilizer adoptioan in Ethiopia cereal production. Journal of Development and Agricultural Economics. Vol. 6(7), pp. 318-337, July, 2014.

Zeng, D., Alwang, J., Norton, G.W., Shiferaw, B. and Jaleta, M. (2013). Ex-post impacts of improved maize varieties on poverty in rural Ethiopia: diffusion and impact of improved varieties in Africa (DIIVA), Rome, CGIAR Standing Panel on Impact Assessment (SPIA).

Zerfu, D. and Larson, D.F. (2010). Incomplete Markets and Fertilizer Use Evidence from Ethiopia. The World Bank. Development Research Group. Agriculture and Rural Development Team. March 2010.

Annex

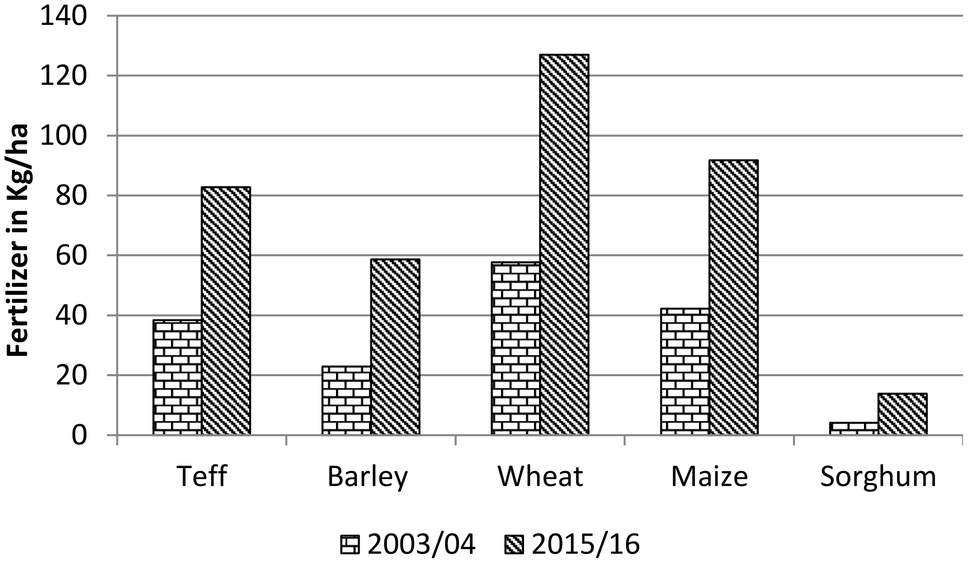

Figure A1: Dynamics in fertilizer application rate during the last decade
Data source: CSA Agriculture sample surveys, 2003/04 and 2015/16 (CSA 2004, 2016).

Table A1: Major fertilizer suppliers to the farmer

Who are your major suppliers of fertilizer?	Percent
Government Organization	14.26
Private Organization	0.91
Merchants	3.79
Cooperatives	23.37
Other (Specify)	1.64
Never used fertilizer	56.03
Total	100

Data source: World Bank Ethiopian socioeconomic survey (ESS) 2015/16.

ZEF Working Paper Series, ISSN 1864-6638
Center for Development Research, University of Bonn
Editors: Christian Borgemeister, Joachim von Braun, Manfred Denich, Till Stellmacher and Eva Youkhana

1. Evers, Hans-Dieter and Solvay Gerke (2005). Closing the Digital Divide: Southeast Asia's Path Towards a Knowledge Society.
2. Bhuiyan, Shajahan and Hans-Dieter Evers (2005). Social Capital and Sustainable Development: Theories and Concepts.
3. Schetter, Conrad (2005). Ethnicity and the Political Reconstruction of Afghanistan.
4. Kassahun, Samson (2005). Social Capital and Community Efficacy. In Poor Localities of Addis Ababa Ethiopia.
5. Fuest, Veronika (2005). Policies, Practices and Outcomes of Demand-oriented Community Water Supply in Ghana: The National Community Water and Sanitation Programme 1994 – 2004.
6. Menkhoff, Thomas and Hans-Dieter Evers (2005). Strategic Groups in a Knowledge Society: Knowledge Elites as Drivers of Biotechnology Development in Singapore.
7. Mollinga, Peter P. (2005). The Water Resources Policy Process in India: Centralisation, Polarisation and New Demands on Governance.
8. Evers, Hans-Dieter (2005). Wissen ist Macht: Experten als Strategische Gruppe.
8.a Evers, Hans-Dieter and Solvay Gerke (2005). Knowledge is Power: Experts as Strategic Group.
9. Fuest, Veronika (2005). Partnerschaft, Patronage oder Paternalismus? Eine empirische Analyse der Praxis universitärer Forschungskooperation mit Entwicklungsländern.
10. Laube, Wolfram (2005). Promise and Perils of Water Reform: Perspectives from Northern Ghana.
11. Mollinga, Peter P. (2004). Sleeping with the Enemy: Dichotomies and Polarisation in Indian Policy Debates on the Environmental and Social Effects of Irrigation.
12. Wall, Caleb (2006). Knowledge for Development: Local and External Knowledge in Development Research.
13. Laube, Wolfram and Eva Youkhana (2006). Cultural, Socio-Economic and Political Con-straints for Virtual Water Trade: Perspectives from the Volta Basin, West Africa.
14. Hornidge, Anna-Katharina (2006). Singapore: The Knowledge-Hub in the Straits of Malacca.
15. Evers, Hans-Dieter and Caleb Wall (2006). Knowledge Loss: Managing Local Knowledge in Rural Uzbekistan.
16. Youkhana, Eva; Lautze, J. and B. Barry (2006). Changing Interfaces in Volta Basin Water Management: Customary, National and Transboundary.
17. Evers, Hans-Dieter and Solvay Gerke (2006). The Strategic Importance of the Straits of Malacca for World Trade and Regional Development.
18. Hornidge, Anna-Katharina (2006). Defining Knowledge in Germany and Singapore: Do the Country-Specific Definitions of Knowledge Converge?
19. Mollinga, Peter M. (2007). Water Policy – Water Politics: Social Engineering and Strategic Action in Water Sector Reform.
20. Evers, Hans-Dieter and Anna-Katharina Hornidge (2007). Knowledge Hubs Along the Straits of Malacca.
21. Sultana, Nayeem (2007). Trans-National Identities, Modes of Networking and Integration in a Multi-Cultural Society. A Study of Migrant Bangladeshis in Peninsular Malaysia.
22. Yalcin, Resul and Peter M. Mollinga (2007). Institutional Transformation in Uzbekistan's Agricultural and Water Resources Administration: The Creation of a New Bureaucracy.
23. Menkhoff, T.; Loh, P. H. M.; Chua, S. B.; Evers, H.-D. and Chay Yue Wah (2007). Riau Vegetables for Singapore Consumers: A Collaborative Knowledge-Transfer Project Across the Straits of Malacca.
24. Evers, Hans-Dieter and Solvay Gerke (2007). Social and Cultural Dimensions of Market Expansion.
25. Obeng, G. Y.; Evers, H.-D.; Akuffo, F. O., Braimah, I. and A. Brew-Hammond (2007). Solar PV Rural Electrification and Energy-Poverty Assessment in Ghana: A Principal Component Analysis.

26. Eguavoen, Irit; E. Youkhana (2008). Small Towns Face Big Challenge. The Management of Piped Systems after the Water Sector Reform in Ghana.

27. Evers, Hans-Dieter (2008). Knowledge Hubs and Knowledge Clusters: Designing a Knowledge Architecture for Development

28. Ampomah, Ben Y.; Adjei, B. and E. Youkhana (2008). The Transboundary Water Resources Management Regime of the Volta Basin.

29. Saravanan.V.S.; McDonald, Geoffrey T. and Peter P. Mollinga (2008). Critical Review of Integrated Water Resources Management: Moving Beyond Polarised Discourse.

30. Laube, Wolfram; Awo, Martha and Benjamin Schraven (2008). Erratic Rains and Erratic Markets: Environmental change, economic globalisation and the expansion of shallow groundwater irrigation in West Africa.

31. Mollinga, Peter P. (2008). For a Political Sociology of Water Resources Management.

32. Hauck, Jennifer; Youkhana, Eva (2008). Histories of water and fisheries management in Northern Ghana.

33. Mollinga, Peter P. (2008). The Rational Organisation of Dissent. Boundary concepts, boundary objects and boundary settings in the interdisciplinary study of natural resources management.

34. Evers, Hans-Dieter; Gerke, Solvay (2009). Strategic Group Analysis.

35. Evers, Hans-Dieter; Benedikter, Simon (2009). Strategic Group Formation in the Mekong Delta - The Development of a Modern Hydraulic Society.

36. Obeng, George Yaw; Evers, Hans-Dieter (2009). Solar PV Rural Electrification and Energy-Poverty: A Review and Conceptual Framework With Reference to Ghana.

37. Scholtes, Fabian (2009). Analysing and explaining power in a capability perspective.

38. Eguavoen, Irit (2009). The Acquisition of Water Storage Facilities in the Abay River Basin, Ethiopia.

39. Hornidge, Anna-Katharina; Mehmood Ul Hassan; Mollinga, Peter P. (2009). ‘Follow the Innovation’ – A joint experimentation and learning approach to transdisciplinary innovation research.

40. Scholtes, Fabian (2009). How does moral knowledge matter in development practice, and how can it be researched?

41. Laube, Wolfram (2009). Creative Bureaucracy: Balancing power in irrigation administration in northern Ghana.

42. Laube, Wolfram (2009). Changing the Course of History? Implementing water reforms in Ghana and South Africa.

43. Scholtes, Fabian (2009). Status quo and prospects of smallholders in the Brazilian sugarcane and ethanol sector: Lessons for development and poverty reduction.

44. Evers, Hans-Dieter; Genschick, Sven; Schraven, Benjamin (2009). Constructing Epistemic Landscapes: Methods of GIS-Based Mapping.

45. Saravanan V.S. (2009). Integration of Policies in Framing Water Management Problem: Analysing Policy Processes using a Bayesian Network.

46. Saravanan V.S. (2009). Dancing to the Tune of Democracy: Agents Negotiating Power to Decentralise Water Management.

47. Huu, Pham Cong; Rhlers, Eckart; Saravanan, V. Subramanian (2009). Dyke System Planing: Theory and Practice in Can Tho City, Vietnam.

48. Evers, Hans-Dieter; Bauer, Tatjana (2009). Emerging Epistemic Landscapes: Knowledge Clusters in Ho Chi Minh City and the Mekong Delta.

49. Reis, Nadine; Mollinga, Peter P. (2009). Microcredit for Rural Water Supply and Sanitation in the Mekong Delta. Policy implementation between the needs for clean water and ‘beautiful latrines’.

50. Gerke, Solvay; Ehlert, Judith (2009). Local Knowledge as Strategic Resource: Fishery in the Seasonal Floodplains of the Mekong Delta, Vietnam

51. Schraven, Benjamin; Eguavoen, Irit; Manske, Günther (2009). Doctoral degrees for capacity development: Results from a survey among African BiGS-DR alumni.

52. Nguyen, Loan (2010). Legal Framework of the Water Sector in Vietnam.

53. Nguyen, Loan (2010). Problems of Law Enforcement in Vietnam. The Case of Wastewater Management in Can Tho City.

54. Oberkircher, Lisa et al. (2010). Rethinking Water Management in Khorezm, Uzbekistan. Concepts and Recommendations.

55. Waibel, Gabi (2010). State Management in Transition: Understanding Water Resources Management in Vietnam.

56. Saravanan V.S.; Mollinga, Peter P. (2010). Water Pollution and Human Health. Transdisciplinary Research on Risk Governance in a Complex Society.

57. Vormoor, Klaus (2010). Water Engineering, Agricultural Development and Socio-Economic Trends in the Mekong Delta, Vietnam.

58. Hornidge, Anna-Katharina; Kurfürst, Sandra (2010). Envisioning the Future, Conceptualising Public Space. Hanoi and Singapore Negotiating Spaces for Negotiation.

59. Mollinga, Peter P. (2010). Transdisciplinary Method for Water Pollution and Human Health Research.

60. Youkhana, Eva (2010). Gender and the development of handicraft production in rural Yucatán/Mexico.

61. Naz, Farhat; Saravanan V. Subramanian (2010). Water Management across Space and Time in India.

62. Evers, Hans-Dieter; Nordin, Ramli, Nienkemoer, Pamela (2010). Knowledge Cluster Formation in Peninsular Malaysia: The Emergence of an Epistemic Landscape.

63. Mehmood Ul Hassan; Hornidge, Anna-Katharina (2010). 'Follow the Innovation' – The second year of a joint experimentation and learning approach to transdisciplinary research in Uzbekistan.

64. Mollinga, Peter P. (2010). Boundary concepts for interdisciplinary analysis of irrigation water management in South Asia.

65. Noelle-Karimi, Christine (2006). Village Institutions in the Perception of National and International Actors in Afghanistan. (**Amu Darya Project Working Paper No. 1**)

66. Kuzmits, Bernd (2006). Cross-bordering Water Management in Central Asia. (**Amu Darya Project Working Paper No. 2**)

67. Schetter, Conrad; Glassner, Rainer; Karokhail, Masood (2006). Understanding Local Violence. Security Arrangements in Kandahar, Kunduz and Paktia. (**Amu Darya Project Working Paper No. 3**)

68. Shah, Usman (2007). Livelihoods in the Asqalan and Sufi-Qarayateem Canal Irrigation Systems in the Kunduz River Basin. (**Amu Darya Project Working Paper No. 4**)

69. ter Steege, Bernie (2007). Infrastructure and Water Distribution in the Asqalan and Sufi-Qarayateem Canal Irrigation Systems in the Kunduz River Basin. (**Amu Darya Project Working Paper No. 5**)

70. Mielke, Katja (2007). On The Concept of 'Village' in Northeastern Afghanistan. Explorations from Kunduz Province. (**Amu Darya Project Working Paper No. 6**)

71. Mielke, Katja; Glassner, Rainer; Schetter, Conrad; Yarash, Nasratullah (2007). Local Governance in Warsaj and Farkhar Districts. (**Amu Darya Project Working Paper No. 7**)

72. Meininghaus, Esther (2007). Legal Pluralism in Afghanistan. (**Amu Darya Project Working Paper No. 8**)

73. Yarash, Nasratullah; Smith, Paul; Mielke, Katja (2010). The fuel economy of mountain villages in Ishkamish and Burka (Northeast Afghanistan). Rural subsistence and urban marketing patterns. (**Amu Darya Project Working Paper No. 9**)

74. Oberkircher, Lisa (2011). 'Stay – We Will Serve You Plov!'. Puzzles and pitfalls of water research in rural Uzbekistan.

75. Shtaltovna, Anastasiya; Hornidge, Anna-Katharina; Mollinga, Peter P. (2011). The Reinvention of Agricultural Service Organisations in Uzbekistan – a Machine-Tractor Park in the Khorezm Region.

76. Stellmacher, Till; Grote, Ulrike (2011). Forest Coffee Certification in Ethiopia: Economic Boon or Ecological Bane?

77. Gatzweiler, Franz W.; Baumüller, Heike; Ladenburger, Christine; von Braun, Joachim (2011). Marginality. Addressing the roots causes of extreme poverty.

78. Mielke, Katja; Schetter, Conrad; Wilde, Andreas (2011). Dimensions of Social Order: Empirical Fact, Analytical Framework and Boundary Concept.

79. Yarash, Nasratullah; Mielke, Katja (2011). The Social Order of the Bazaar: Socio-economic embedding of Retail and Trade in Kunduz and Imam Sahib

80. Baumüller, Heike; Ladenburger, Christine; von Braun, Joachim (2011). Innovative business approaches for the reduction of extreme poverty and marginality?

81. Ziai, Aram (2011). Some reflections on the concept of 'development'.

82. Saravanan V.S., Mollinga, Peter P. (2011). The Environment and Human Health - An Agenda for Research.

83. Eguavoen, Irit; Tesfai, Weyni (2011). Rebuilding livelihoods after dam-induced relocation in Koga, Blue Nile basin, Ethiopia.

84. Eguavoen, I., Sisay Demeku Derib et al. (2011). Digging, damming or diverting? Small-scale irrigation in the Blue Nile basin, Ethiopia.

85. Genschick, Sven (2011). Pangasius at risk - Governance in farming and processing, and the role of different capital.

86. Quy-Hanh Nguyen, Hans-Dieter Evers (2011). Farmers as knowledge brokers: Analysing three cases from Vietnam's Mekong Delta.

87. Poos, Wolf Henrik (2011). The local governance of social security in rural Surkhondarya, Uzbekistan. Post-Soviet community, state and social order.

88. Graw, Valerie; Ladenburger, Christine (2012). Mapping Marginality Hotspots. Geographical Targeting for Poverty Reduction.

89. Gerke, Solvay; Evers, Hans-Dieter (2012). Looking East, looking West: Penang as a Knowledge Hub.

90. Turaeva, Rano (2012). Innovation policies in Uzbekistan: Path taken by ZEFa project on innovations in the sphere of agriculture.

91. Gleisberg-Gerber, Katrin (2012). Livelihoods and land management in the Ioba Province in south-western Burkina Faso.

92. Hiemenz, Ulrich (2012). The Politics of the Fight Against Food Price Volatility – Where do we stand and where are we heading?

93. Baumüller, Heike (2012). Facilitating agricultural technology adoption among the poor: The role of service delivery through mobile phones.

94. Akpabio, Emmanuel M.; Saravanan V.S. (2012). Water Supply and Sanitation Practices in Nigeria: Applying Local Ecological Knowledge to Understand Complexity.

95. Evers, Hans-Dieter; Nordin, Ramli (2012). The Symbolic Universe of Cyberjaya, Malaysia.

96. Akpabio, Emmanuel M. (2012). Water Supply and Sanitation Services Sector in Nigeria: The Policy Trend and Practice Constraints.

97. Boboyorov, Hafiz (2012). Masters and Networks of Knowledge Production and Transfer in the Cotton Sector of Southern Tajikistan.

98. Van Assche, Kristof; Hornidge, Anna-Katharina (2012). Knowledge in rural transitions - formal and informal underpinnings of land governance in Khorezm.

99. Eguavoen, Irit (2012). Blessing and destruction. Climate change and trajectories of blame in Northern Ghana.

100. Callo-Concha, Daniel; Gaiser, Thomas and Ewert, Frank (2012). Farming and cropping systems in the West African Sudanian Savanna. WASCAL research area: Northern Ghana, Southwest Burkina Faso and Northern Benin.

101. Sow, Papa (2012). Uncertainties and conflicting environmental adaptation strategies in the region of the Pink Lake, Senegal.

102. Tan, Siwei (2012). Reconsidering the Vietnamese development vision of "industrialisation and modernisation by 2020".

103. Ziai, Aram (2012). Postcolonial perspectives on 'development'.

104. Kelboro, Girma; Stellmacher, Till (2012). Contesting the National Park theorem? Governance and land use in Nech Sar National Park, Ethiopia.

105. Kotsila, Panagiota (2012). "Health is gold": Institutional structures and the realities of health access in the Mekong Delta, Vietnam.

106. Mandler, Andreas (2013). Knowledge and Governance Arrangements in Agricultural Production: Negotiating Access to Arable Land in Zarafshan Valley, Tajikistan.

107. Tsegai, Daniel; McBain, Florence; Tischbein, Bernhard (2013). Water, sanitation and hygiene: the missing link with agriculture.

108. Pangaribowo, Evita Hanie; Gerber, Nicolas; Torero, Maximo (2013). Food and Nutrition Security Indicators: A Review.

109. von Braun, Joachim; Gerber, Nicolas; Mirzabaev, Alisher; Nkonya Ephraim (2013). The Economics of Land Degradation.

110. Stellmacher, Till (2013). Local forest governance in Ethiopia: Between legal pluralism and livelihood realities.

111. Evers, Hans-Dieter; Purwaningrum, Farah (2013). Japanese Automobile Conglomerates in Indonesia: Knowledge Transfer within an Industrial Cluster in the Jakarta Metropolitan Area.

112. Waibel, Gabi; Benedikter, Simon (2013). The formation water user groups in a nexus of central directives and local administration in the Mekong Delta, Vietnam.

113. Ayaribilla Akudugu, Jonas; Laube, Wolfram (2013). Implementing Local Economic Development in Ghana: Multiple Actors and Rationalities.

114. Malek, Mohammad Abdul; Hossain, Md. Amzad; Saha, Ratnajit; Gatzweiler, Franz W. (2013). Mapping marginality hotspots and agricultural potentials in Bangladesh.

115. Siriwardane, Rapti; Winands, Sarah (2013). Between hope and hype: Traditional knowledge(s) held by marginal communities.

116. Nguyen, Thi Phuong Loan (2013). The Legal Framework of Vietnam's Water Sector: Update 2013.

117. Shtaltovna, Anastasiya (2013). Knowledge gaps and rural development in Tajikistan. Agricultural advisory services as a panacea?

118. Van Assche, Kristof; Hornidge, Anna-Katharina; Shtaltovna, Anastasiya; Boboyorov, Hafiz (2013). Epistemic cultures, knowledge cultures and the transition of agricultural expertise. Rural development in Tajikistan, Uzbekistan and Georgia.

119. Schädler, Manuel; Gatzweiler, Franz W. (2013). Institutional Environments for Enabling Agricultural Technology Innovations: The role of Land Rights in Ethiopia, Ghana, India and Bangladesh.

120. Eguavoen, Irit; Schulz, Karsten; de Wit, Sara; Weisser, Florian; Müller-Mahn, Detlef (2013). Political dimensions of climate change adaptation. Conceptual reflections and African examples.

121. Feuer, Hart Nadav; Hornidge, Anna-Katharina; Schetter, Conrad (2013). Rebuilding Knowledge. Opportunities and risks for higher education in post-conflict regions.

122. Dörendahl, Esther I. (2013). Boundary work and water resources. Towards improved management and research practice?

123. Baumüller, Heike (2013). Mobile Technology Trends and their Potential for Agricultural Development

124. Saravanan, V.S. (2013). "Blame it on the community, immunize the state and the international agencies." An assessment of water supply and sanitation programs in India.

125. Ariff, Syamimi; Evers, Hans-Dieter; Ndah, Anthony Banyouko; Purwaningrum, Farah (2014). Governing Knowledge for Development: Knowledge Clusters in Brunei Darussalam and Malaysia.

126. Bao, Chao; Jia, Lili (2014). Residential fresh water demand in China. A panel data analysis.

127. Siriwardane, Rapti (2014). War, Migration and Modernity: The Micro-politics of the Hijab in Northeastern Sri Lanka.

128. Kirui, Oliver Kiptoo; Mirzabaev, Alisher (2014). Economics of Land Degradation in Eastern Africa.

129. Evers, Hans-Dieter (2014). Governing Maritime Space: The South China Sea as a Mediterranean Cultural Area.

130. Saravanan, V. S.; Mavalankar, D.; Kulkarni, S.; Nussbaum, S.; Weigelt, M. (2014). Metabolized-water breeding diseases in urban India: Socio-spatiality of water problems and health burden in Ahmedabad.

131. Zulfiqar, Ali; Mujeri, Mustafa K.; Badrun Nessa, Ahmed (2014). Extreme Poverty and Marginality in Bangladesh: Review of Extreme Poverty Focused Innovative Programmes.

132. Schwachula, Anna; Vila Seoane, Maximiliano; Hornidge, Anna-Katharina (2014). Science, technology and innovation in the context of development. An overview of concepts and corresponding policies recommended by international organizations.

133. Callo-Concha, Daniel (2014). Approaches to managing disturbance and change: Resilience, vulnerability and adaptability.

134. Mc Bain, Florence (2014). Health insurance and health environment: India's subsidized health insurance in a context of limited water and sanitation services.

135. Mirzabaev, Alisher; Guta, Dawit; Goedecke, Jann; Gaur, Varun; Börner, Jan; Virchow, Detlef; Denich, Manfred; von Braun, Joachim (2014). Bioenergy, Food Security and Poverty Reduction: Mitigating tradeoffs and promoting synergies along the Water-Energy-Food Security Nexus.

136. Iskandar, Deden Dinar; Gatzweiler, Franz (2014). An optimization model for technology adoption of marginalized smallholders: Theoretical support for matching technological and institutional innovations.

137. Bühler, Dorothee; Grote, Ulrike; Hartje, Rebecca; Ker, Bopha; Lam, Do Truong; Nguyen, Loc Duc; Nguyen, Trung Thanh; Tong, Kimsun (2015). Rural Livelihood Strategies in Cambodia: Evidence from a household survey in Stung Treng.

138. Amankwah, Kwadwo; Shtaltovna, Anastasiya; Kelboro, Girma; Hornidge, Anna-Katharina (2015). A Critical Review of the Follow-the-Innovation Approach: Stakeholder collaboration and agricultural innovation development.

139. Wiesmann, Doris; Biesalski, Hans Konrad; von Grebmer, Klaus; Bernstein, Jill (2015). Methodological review and revision of the Global Hunger Index.

140. Eguavoen, Irit; Wahren, Julia (2015). Climate change adaptation in Burkina Faso: aid dependency and obstacles to political participation. Adaptation au changement climatique au Burkina Faso: la dépendance à l'aide et les obstacles à la participation politique.

141. Youkhana, Eva. Postponed to 2016 (147).

142. Von Braun, Joachim; Kalkuhl, Matthias (2015). International Science and Policy Interaction for Improved Food and Nutrition Security: toward an International Panel on Food and Nutrition (IPFN).

143. Mohr, Anna; Beuchelt, Tina; Schneider, Rafaël; Virchow, Detlef (2015). A rights-based food security principle for biomass sustainability standards and certification systems.

144. Husmann, Christine; von Braun, Joachim; Badiane, Ousmane; Akinbamijo, Yemi; Fatunbi, Oluwole Abiodun; Virchow, Detlef (2015). Tapping Potentials of Innovation for Food Security and Sustainable Agricultural Growth: An Africa-Wide Perspective.

145. Laube, Wolfram (2015). Changing Aspirations, Cultural Models of Success, and Social Mobility in Northern Ghana.

146. Narayanan, Sudha; Gerber, Nicolas (2016). Social Safety Nets for Food and Nutritional Security in India.

147. Youkhana, Eva (2016). Migrants' religious spaces and the power of Christian Saints – the Latin American Virgin of Cisne in Spain.

148. Grote, Ulrike; Neubacher, Frank (2016). Rural Crime in Developing Countries: Theoretical Framework, Empirical Findings, Research Needs.

149. Sharma, Rasadhika; Nguyen, Thanh Tung; Grote, Ulrike; Nguyen, Trung Thanh. Changing Livelihoods in Rural Cambodia: Evidence from panel household data in Stung Treng.

150. Kavegue, Afi; Eguavoen, Irit (2016). The experience and impact of urban floods and pollution in Ebo Town, Greater Banjul Area, in The Gambia.

151. Mbaye, Linguère Mously; Zimmermann, Klaus F. (2016). Natural Disasters and Human Mobility.

152. Gulati, Ashok; Manchanda, Stuti; Kacker, Rakesh (2016). Harvesting Solar Power in India.

153. Laube, Wolfram; Awo, Martha; Derbile, Emmanuel (2017). Smallholder Integration into the Global Shea Nut Commodity Chain in Northern Ghana. Promoting poverty reduction or continuing exploitation?

154. Attemene, Pauline; Eguavoen, Irit (2017). Effects of sustainability communication on environments and rural livelihoods.

155. Von Braun, Joachim; Kofol, Chiara (2017). Expanding Youth Employment in the Arab Region and Africa.

156. Beuchelt, Tina 2017. Buying green and social from abroad: Are biomass-focused voluntary sustainability standards useful for European public procurement?

157. Bekchanov, Maksud (2017). Potentials of Waste and Wastewater Resources Recovery and Re-use (RRR) Options for Improving Water, Energy and Nutrition Security.

158. Leta, Gerba; Kelboro, Girma; Stellmacher, Till; Hornidge, Anna-Katharina (2017). The agricultural extension system in Ethiopia: operational setup, challenges and opportunities.

159. Ganguly, Kavery; Gulati, Ashok; von Braun, Joachim (2017). Innovations spearheading the next transformations in India's agriculture.

160. Gebreselassie, Samuel; Haile Mekbib G.; Kalkuhl, Matthias (2017). The Wheat Sector in Ethiopia: Current Status and Key Challenges for Future Value Chain Development

161. Jemal, Omarsherif Mohammed, Callo-Concha, Daniel (2017). Potential of Agroforestry for Food and Nutrition Security of Small-scale Farming Households.

162. Berga, Helen; Ringler, Claudia; Bryan, Elizabeth; El Didi, Hagar; Elnasikh Sara (2017). Addressing Transboundary Cooperation in the Eastern Nile through the Water-Energy-Food Nexus. Insights from an E-survey and Key Informant Interviews.

163. Bekchanov, Maksud (2017). Enabling Environment for Waste and Wastewater Recycling and Reuse Options in South Asia: the case of Sri Lanka.

164. Kirui, Oliver Kiptoo; Kozicka, Martha (2018). Vocational Education and Training for Farmers and Other Actors in the Agri-Food Value Chain in Africa.

165. Christinck, Anja; Rattunde, Fred; Kergna, Alpha; Mulinge, Wellington; Weltzien, Eva (2018). Identifying Options for the Development of Sustainable Seed Systems -Insights from Kenya and Mali.

166. Tambo, Justice A. (2018). Recognizing and rewarding farmers' creativity through contests: experiences and insights from four African countries.

167. Von Braun, Joachim (2018). Innovations to Overcome the Increasingly Complex Problems of Hunger.

168. Maksud, Bekchanov; Evia, Pablo (2018). Sanitation system and investment climate for Resources Recovery and Reuse (RRR) options in South and Southeast Asia: The cases of India, Bangladesh, Nepal, Sri Lanka, Laos and Myanmar.

169. Kirui, Oliver K.; von Braun, Joachim (2018). Mechanization in African Agriculture. A Continental Overview on Patterns and Dynamics.

170. Beuchelt, Tina; Nischalke, Sarah (2018). Adding a gender lens in quantitative development research on food and non-food biomass production: A guide for sex-disaggregated data collection

171. Daum, Thomas (2018). Of Bulls and Bulbs: Aspirations and perceptions of rural youth in Zambia.

172. Salvatierra-Rojas, Ana; Torres-Toledo, Victor; Mrabet, Farah; Müller, Joachim (2018). Improving milk value chains through solar milk cooling.

173. Desalegn, Gashaw; Ali, Seid Nuru (2018). Review of the Impact of Productive Safety Net Program (PSNP) on Rural Welfare in Ethiopia.

174. Muli, Celestine; Gerber, Nicolas; Sakketa, Tekalign Gutu; Mirzabaev, Alisher (2018). Ecosystem tipping points due to variable water availability and cascading effects on food security in Sub-Saharan Africa.

175. Njiraini, Georgina; Ngigi, Marther; Baraké, Evelyn (2018). Women in African Agriculture: Integrating Women into Value Chains to Build a Stronger Sector.

176. Bekchanov, Maksud; Evia, Pablo; Hasan, Mohammad Monirul; Adhikari, Narayan; Gondhalekar, Daphne (2018). Institutional framework and financial arrangements for supporting the adoption of Resource Recovery Reuse technologies in South Asia.

177. Mirzabaev, Alisher; Njiraini, Georgina Wambui; Gebremariam, Gebrelibanos; Jourdain, Damien; Magaia, Emílio; Julio, Felita; Mosse, Gerivásia; Mutondo, João; Mungatana, Eric. Transboundary Water Resources for People and Nature: Challenges and Opportunities in the Olifants River Basin.

178. Gupta, Anil; Shinde, Chintan; Dey, Anamika; Patel, Ramesh; Patel, Chetan; Kumar, Vipin; Patel, Mahesh. Honey Bee Network in Africa: Co-creating a Grassroots Innovation Ecosystem in Africa.

179. Kabran, E.G. and I. Eguavoen, 2019.Ferry transportation in Abidjan. Establishment, operation and sustainability of a paratransit system.

180. Sakketa, Tekalign Gutu and von Braun, Joachim. Labor-intensive public works programs in sub-Saharan Africa: Experiences and implications for employment policies.

181. Engida, E., A. Srivastava, A. Kuhn and T. Gaiser, 2019. Household income implications of improved fertilizer accessibility and lower use inefficiency: Long-term scenarios for Ethiopia.

http://www.zef.de/workingpapers.html

Working Paper Series

Authors: Ermias Engida Legesse, Amit Srivastava, Arnim Kuhn and Thomas Gaiser
Contacts: ermias.engida@ilr.uni-bonn.de; amit.srivastava@uni-bonn.de;
arnim.kuhn@ilr.uni-bonn.de; tgaiser@uni-bonn.de

Photo: Asrat Gella

Published by:
Zentrum für Entwicklungsforschung (ZEF)
Center for Development Research
Genscherallee 3
D – 53113 Bonn
Germany

Phone: +49-228-73-1861
Fax: +49-228-73-1869
E-Mail: presse.zef@uni-bonn.de

www.zef.de