Irrigation, Environment and Climate Change: A CGE Analysis for Kenya

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Abstract

The Turkana region of Kenya is one of the poorest areas of the country. In September 2013 the identification of two huge aquifers in the Turkana region had been announced. This study, through a single-country comparative static CGE model (STAGE), analyses the economic effects of the new discoveries on Kenya. Preliminary results indicate irrigation investments increases household welfare significantly and that method of finance has an important impact on household welfare.

1. Introduction

The United Nations categorises Kenya as chronically water-scarce country. Almost 40% of Kenya population lack access to safe water, and more than 70% do not have adequate sanitation (World Bank, 2014). Located in Kenya's extreme northwest, bordered by South Sudan, Ethiopia and Uganda; people of Turkana region is even more water insecure: The coverage of water and sanitation services is as low as 24% in rural and 52% in urban areas. The cost of investments required to increase the rate of access to clean water and sanitary services in the region to the level foreseen by Millennium Development Goals is estimated to be around €180 million (Rift Valley Water Services Board, 2007). On the other hand, less than 20 thousand of 5.6 million ha. arable land was irrigated in 2012 in Kenya (National Bureau of Statistics, 2014) while the potential for irrigation adds up to 690 thousand hectares (National Irrigation Board, 2014). Thus, increasing irrigation capacity in the country is definitely a priority of policy makers. For this purpose, Kenya has undertaken 120 development projects which target to increase the irrigation area by 540 thousand hectares. Kenya plans to spend more than €1.7 billion on irrigation projects (Water Resources Management Authority, 2013).

Climate variability and climate change add significant challenges for agricultural sector on top of poor irrigation infrastructure in Kenya. Frequent floods and droughts affect millions of people and cause damages that are measured by hundreds of millions of Euros. Meteorological data shows that the frequency of extreme events has already started to increase as a result of climate change. Kenya's low resilience to climate risks is likely to bring significant additional and potentially significant economic costs. Cost of adaptation to climate change is estimated to be around €375 million per year until 2030s and can be doubled afterwards (Stockholm Environment Institute, 2009).

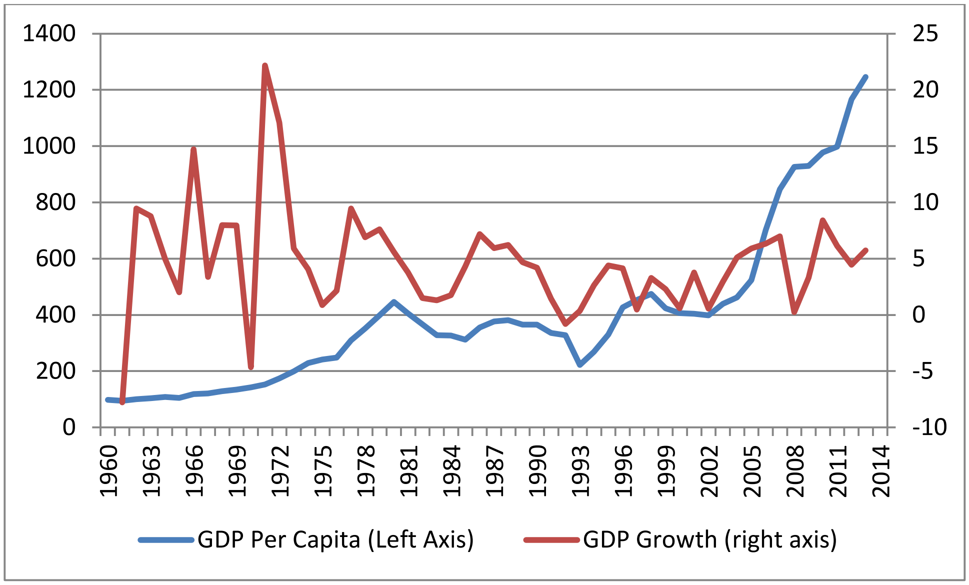
In September 2013, the Kenyan government and the United Nations Educational, Scientific and Cultural Organisation (UNESCO) announced that two huge aquifers had been identified in the Turkana region, which is one of the driest and least developed regions of Kenya with a population around 10 million people overwhelmingly dependent on nomadic (livestock) agriculture and subject to periodic and severe droughts. Although the discovery is based on satellite and radar data, and hence needs to be verified in the field (McSorley, 2014), it has already created excitement among national and local government as well as NGOs and local people (Wanyama, 2014). Kenyan government hopes to end the water scarcity in the country by using these new water resources thanks to the estimated 250 billion m3 of water held in these aquifers which can replenish itself annually with an estimated 1.2 billion m3. However, the use of these new resources has already started a public discussion about environmental effects and sustainability issues, though these issues are yet to be analysed scientifically (Otuki, 2014). **Overexploitation, competition between irrigation and domestic use and drawbacks of extending agriculture such as extensive use of agrochemicals are among these concerns (McSorley, 2014).** In this paper we aim to shed some light on these concerns from the economic point of view by using an analytical model.

We use a static variant of the STAGE model[1] (McDonald, 2007) which is calibrated to a modified version of a detailed regional Social Accounting Matrix (SAM) for Kenya (Kiringai and Thurlow, 2008) for 2007. We then simulate the impact of irrigation investments on Kenyan economy under different assumptions about the cost and financing of the investments reported in You et al. (2014). In this way, the paper will highlight the important dynamics that determine the limits for the use of newly discovered water resources with concrete policy implications that will hopefully help policy makers and other stakeholders to make better informed decisions.

2. Motivations and literature review

In 2013, Kenya's gross domestic product (GDP) was about US$ 55.24 billion and the per capita GDP US$ 1,246. Adjusted in purchasing power parity (PPP) terms, per capita GDP in 2013 was about US$ 2,795. The country's real GDP growth picked up to 8.4 % in 2010 and to nearly 6 % in 2013 (World Bank) (Figure 1).

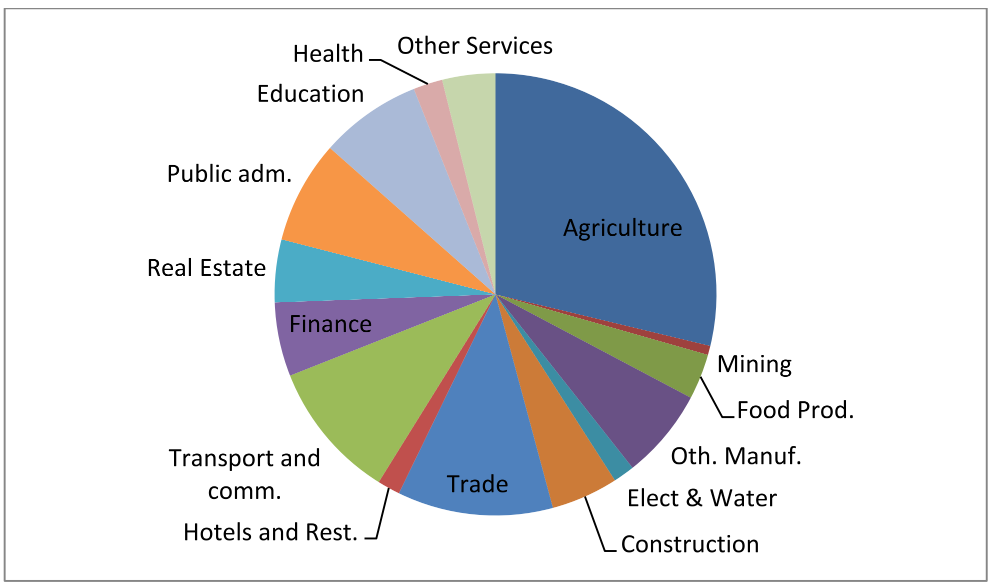
Figure 1: Kenya GDP per capita and growth



Source Data: World Bank

Agriculture is the second contributor to Kenya's GDP, after the service sector (Figure 2). In 2005, the value agriculture added to GDP was 27%, in 2006 and 2007 it fell to 23% but from 2008, it increased until reaching 29.5 %in 2013.

Figure 2: Kenya GDP breakdown by Sector (2013)



Source Data: KNBS (2015a)

The importance of the agriculture sector in the Kenyan economy is even higher if considering employment figures. In 2001, agriculture alone employed around 70% of the workforce, while the service, industry and manufacturing sectors employed 30% of the labour force while contributing to more than 70% of GDP (FAO). The agriculture sector also accounts for an important amount of Kenya's total export value. In 2011, it accounted for more than US$ 240 million on a total merchandise export of US$ 375 million. In contrast, the figure for the import value is quite different, showing that agriculture is not the main sector for Kenya's imports. The agriculture products import value, indeed, was US$ 1,670 million and the total merchandise import value US$ 6,390.

Kenya's chief exports are horticultural products and tea. In 2001, the principal cash crops exported were tea, fruit and vegetables and coffee, while the principal agricultural products imported were wheat, sugar, rice and palm oil. In the same year, the combined value of tea and fruit and vegetables exported was US$1,274 million, about 5 times the value of Kenya's third most valuable export: coffee (Table 1).

In 2005 the poverty gap at national poverty lines was higher in rural areas that in the urban areas, i.e. 17.5% and 11.4%, respectively. Along with the difference in the poverty gap between rural and urban population, income inequality in Kenya represented a major issue for the entire population. As of 2005, 43% of Kenyans lived on less than $1.25 (PPP), the income share held by the highest 10% of the population was around 40% and the Gini index of the country was 47.7 (World Bank).

Table 1: Top 5 agricultural products exported and imported by Kenya in 2011

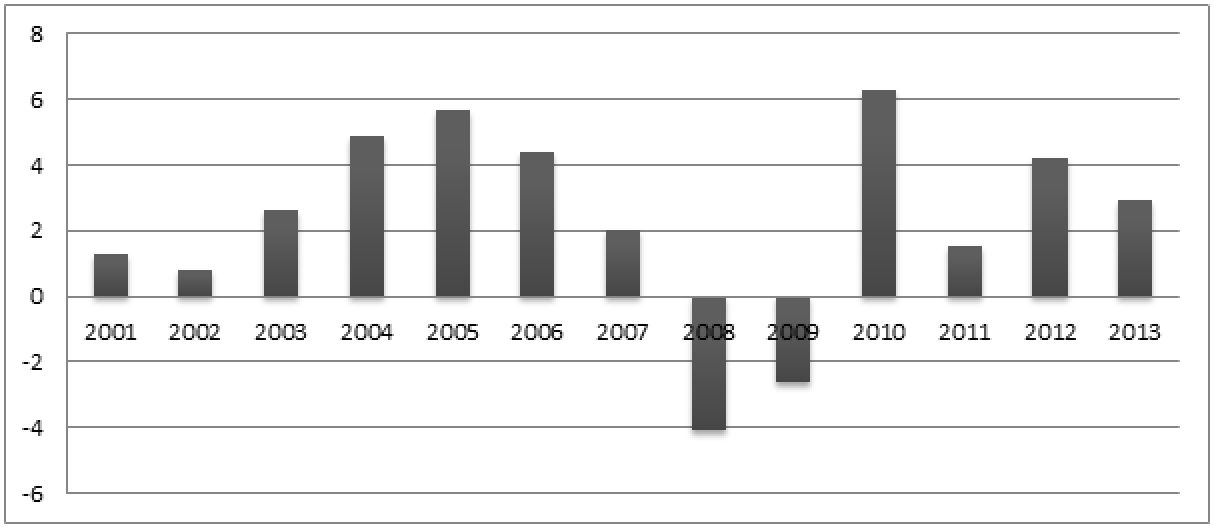
Export (1000$)		Import (1000$)	
Tea	858,250	Wheat	457,146
Fruit and Vegetables	415,773	Sugar	220,858
Coffee	267,809	Palm oil	206,260
Beans	132,983	Rice	191,082
Tobacco	129,025	Tea	168,541

Source Data: FAO (2011)

The Vision 2030 of the Government of Kenya presents the role of irrigation and water supply for a long-term development of the national economy. The agriculture sector is one of the six priority sectors under the Economic Pillar of Vision 2030 in which all sectors constitute nearly half of both Kenya's GDP and the source for the country's total formal employment1. Overall, the target for the Economic Pillar of Vision 2030 is to reach a sustainable economic growth of at least 10% per annum from 2012 and beyond in which the agriculture sector plays a key role. According to Economic Survey Report 2014 of Kenya National Bureau of Statistics (KNBS), the growth in the agricultural sector decreased to 2.9% in 2013 from 4.2% in 2012; which is partly related to inadequate rainfall received in some grain growing regions (Figure 3).

[1] Source: Kenya Vision 2030 http://www.vision2030.go.ke/index.php/pillars

Figure 3: Performance of the growth rate of Agriculture and Forestry sector



Source: KNBS (2015b)

The country already faced below average rains during two consecutive years between 2007 and 2010, giving rise to one the worst droughts in a decade. Besides, Arid and Semi-Arid lands (ASALs) where mean annual rainfall is less than 600mm covers almost 80% of the Kenya's land area (Rain-fed agriculture can be supported by enhancing soil moisture conservation and, where it is possible and feasible, utilizing irrigation. New crop varieties and fertilizers fed by efficient agricultural water management and irrigation systems are important tools for boosting agricultural productivity, and hence, economic growth within agriculture. However, irrigation requires water and this is an essential input in short supply water countries as in Kenya.

Table 2). That proves that relying only on rain-fed agriculture could jeopardize the planned growth rate for agriculture in Kenya. According to the Human Development Index (HDI) (UNDP, 2013), ASALs counties in Kenya show low HDI values. Therefore, there is need for improvement especially in ASALs area to reach Vision 2030 targets of rapid economic growth and urbanization, both necessitating increased water supply.

Rain-fed agriculture can be supported by enhancing soil moisture conservation and, where it is possible and feasible, utilizing irrigation. New crop varieties and fertilizers fed by efficient agricultural water management and irrigation systems are important tools for boosting agricultural productivity, and hence, economic growth within agriculture. However, irrigation requires water and this is an essential input in short supply water countries as in Kenya.

Table 2: Categories of Agricultural Land* ('000 Hectares)

	High[2] Potential	Medium[3] Potential	Low[4] Potential	Total	All Other Land	Total Area
2012-2013	6,785	3,157	42,105	52,047	4,867	56,914

Source: Ministry of Agriculture, Livestock & Fisheries / Kenya Meteorological Service

Kenya has five major basins: Lake Victoria, Rift Valley, Athi River, Tana River and Ewaso Ngiro basins. However, FAO (1998) reports that only two of these basins, Lake Victoria and Tana River, have surplus water resources. The others basins are running a water deficits. Moreover, the source of these five major basins of Kenya lies in five montane forests areas, also known as Kenya's "Water Towers" including the Mau Forest Complex, Mount Kenya, the Aberdares, Mount Elgon and Cherangani. In addition to the decreasing amount of rainfall, the deforestation at The Water Towers in Kenya is negatively affecting the river-flows and water yield (UNEP, 2012). Another stressing factor for the Kenyan water supply is that around 54 percent of Kenya's water resources are shared with neighbouring countries.

World Bank (2011) estimates water requirements for all water-consuming sectors, including Irrigation, Livestock, Commercial and Institutional, Industrial and Domestic sectors (Table 3). The irrigation water requirements are mainly determined by the cropping patterns and climate factors. The analysis results compare 2010 and 2030 future water use for each sector and each geographic area defined by major basins. Irrigation sector is the largest water user with an increasing amount in 2030, followed by domestic usage.

Table 3: Water requirements for irrigation sector and all water consuming sectors (million cubic meters)

	2010		2030	
	Irrigation	**All Sectors***	**Irrigation**	**All Sectors***
Lake Victoria	552 (56%)	990	1,007 (59%)	1699
Rift Valley	260 (59%)	438	470 (62%)	760
Athi River	375 (41%)	917	599 (35%)	1689
Tana River	1,424 (87%)	1638	1,511 (82%)	1853
Ewaso Ngiro North River	230 (68%)	340	290 (62%)	467
Kenya Total	2,840 (66%)	4323	3,877 (60%)	6467

** All sectors include Irrigation, Livestock, Commercial and Institutional, Industrial and Domestic* sectors

2 *Annual rainfall of 857.5mm or more (over 980mm in Coast Province).*
3 *Annual rainfall of 735mm-857.5mm.(735mm-980mm in Coast Province and 612.5mm-857.5mm in Eastern Province).*
4 *Annual rainfall of 612.5mm or less.*

Following those water requirements, Table 3 lists the different studies on the assessment of irrigation potential in Kenya (MoWD, 1980 and 1992; World Bank, 1980; IDB, 1990; JICA, 1992; MoWI, 2009). Irrigation potential reflects the area which can potentially be irrigated and it is estimated while considering mainly the restrictions on physical resources, soil and water, combined with the irrigation water requirements. These estimations were conducted for different purposes using different variables, assumptions and methodologies. As a result, strict comparisons among the columns of Table 4 are not meaningful. Nevertheless, it can be concluded that an approximate range for the estimated irrigation potential in Kenya is between 200,000 ha to 540,000 ha.

Table 4: Irrigation potential (ha) in Kenya

	Basin Area (km2)	1970 Dev Plan	MoWD (1980)	World Bank (1987)	IDB (1990)	MoWD (1992)	JICA (1992)	MoWI (2009)
Lake Victoria	46229		200	57.4	145	200		227630
Rift Valley	130452		64	31.2	85	64		73716
Athi River	66837		40	49.5	40	40		29271
Tana River	126026		205.5	90	100	205		147770
Ewaso Ngiro North River	210226		30	15.7	20	30		19033
Kenya Total	579770	160,000 -200,000	539500	243800	390000	539000	471860	497420

Source:?????????

On the other hand, cost of building and running irrigation systems depends on many issues; such as:

- Availability of water and how it is made to be available; drilling a well, building a pod,…etc.
- The size of the irrigation system
- Type of irrigation system; surface, sprinkler, drip, underground or sub-irrigation,…
- Operation type of the system; through manual labor, gravity flow, pumps[5],…

Any combination requires a significant amount of capital; especially for smallholder farmers. Ragwa et al (1998) gives an overall picture for the average costs of varios irrigation types used in smallholder irrigation development (Table 5).

Table 5: Average cost ('000 Ksh/ha) of smallholder irrigation development

Type of the Operation	Average Cost
Gravity-fed open canal conveyance and distribution	80
Pump-fed open canal conveyance and distribution	150

[5] This also links the cost to fuel usage and the cost of fuel.

Gravity-fed open canal conveyance, piped distribution	150
Gravity-fed piped conveyance and distribution	200
Pump-fed piped conveyance and distribution	250

Source:?????????

In order to improve irrigation in Kenya, there are three main types of irrigation develepment schemes developed[6]:

1. *Smallholder Schemes* are owned and operated by the individual farmers andirrigation water user groups or associations.
2. *Public Schemes* are developed and centrally managed by public agencies, mainly National Irrigation Board or the Regional Development Authorities, from which farmers tenancy rights for utilizing the irrigation facilities.
3. *Private Schemes* are owned and operated by individual farmers or companies run as commercial enterprises.

Table 6: Development of Irrigation in Kenya (1963-2009)

Scheme Category	1963	1975	1983	1985	1990	1992	1995	1998	2003	2005	2009
Smallholder	1,500	2,400	17,500	18,907	20,490	20,490	33,000	34,650	48,045	47,000	49,000
Public	3,200	8,500	11,500	10,325	10,325	9,020	11,700	12,000	42,700	16,000	20,600
Private	750	10,000	23,000	22,979	22,979	23,280	37,000	40,700	12,458	42,800	53,600**
Total	5,450	20,900	52,000	52,211	53,794	52,790	81,700	87,350	103203*	105,800	123,200

*3,670 hectares not operational

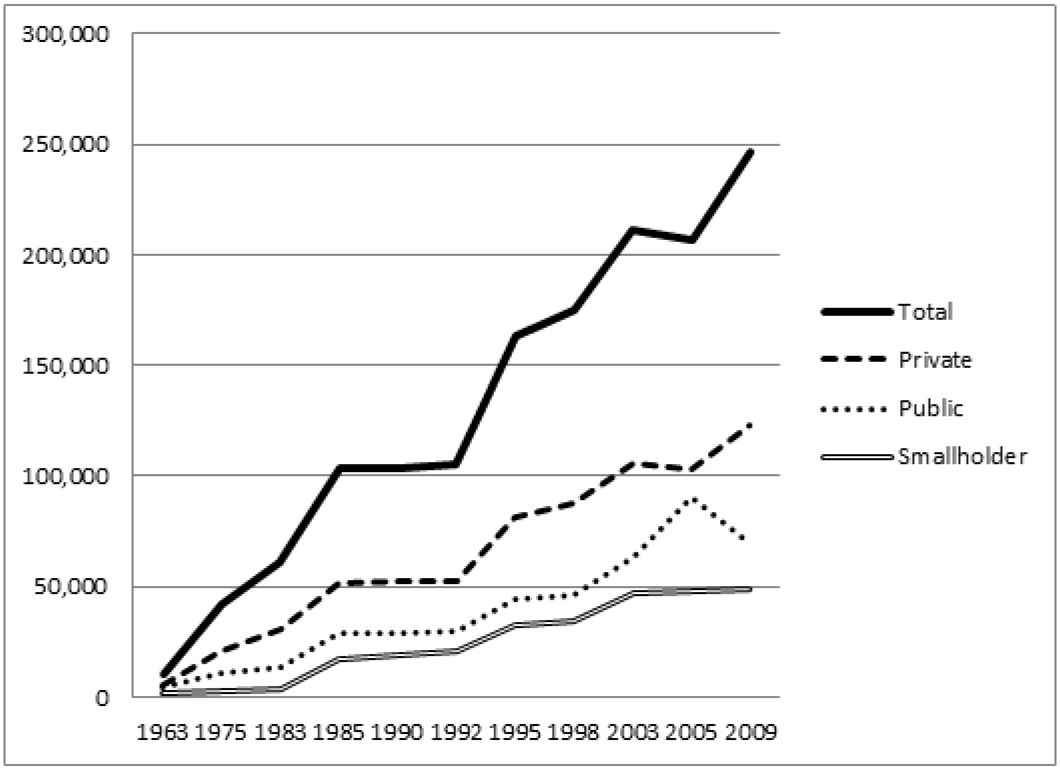
**Includes uncounted irrigated areas

Source:

There are different sources of information about irrigation development (which is reflected by the area under irrigation) through those schemes (IDB,1990; Ragwa et al, 1998), Ogombe, 2000, FAO, 2005, MoWI, 2010 and World Bank, 2011) (Table 6). Moreover, in the light of that table, Figure 4 presents the trend in irrigation development.

Figure 4: Trend in Irrigation Development in Kenya

[6] More details on the list of schemes and geographic distributions can be found through http://www.nib.or.ke/



Source:

After 1975 smallholder irrigation schemes shows a large increase due to the increased attention to small-scale farmers by national authorities and donors. The irrigation potential and development numbers (presented in Table 4 and Table 6, respectively) can be used to analyze the need and opportunity of investment in irrigation. The most recent information in 2009 highlight that, out of the total potential 497,420ha, only 25% have been developed[7].

2.1 Literature Review

Water use and irrigation are central aspects of development, natural resources and environmental economics. Dudu and Chumi (2008) and Ponce *et al*., (2012) review the partial and general equilibrium literature on modelling water at country and global levels. The most recent literature demonstrates how CGE model are well equipped to answer questions related to water, in particular water scarcity and irrigation issues. CGEs prove to be flexible enough to adapt their nested production function to include water both as a production factor (in different position of the nest according to the choice of the modeller) used mainly by farmers and as a commodity consumed by households. Besides, the economy-wide approach allows researchers to consider effects of water scarcity on all economic sectors, not only in agriculture, and to

[7] In addition to being the recent available data on both irrigation potential and development, it should be noted that the source of the data is also the same for both, MoWI which makes the comparison more reliable.

consider indirect effects as income effects due to changes in water supply (or policies affecting the water sector). At the same time, these surveys pinpoint that the areas of irrigation, water allocation and agricultural productivity are scarcely explored in the literature and the need for further research.

Investments in irrigation schemes are part of a more comprehensive aspect related to agricultural investment in developing countries. Investments in agriculture are recognised as one of the keys for development process in developing countries and in many African countries. Increase of agricultural investments by governments is necessary, even if not sufficient condition, to achieve economic transformation and sustained growth. Investments should be targeted to strategic sectors or priorities, especially – but not exclusively – within agriculture (UNCTAD, 2014).

CGE models are employed regularly in the evaluation of impacts and fiscal implications of agricultural investments in general in Africa. Investment in irrigation is one of the specific topics, among other possible investments possibilities, regularly explored by many researchers. Mitik and Engida (2013) present an example of how to employ a CGE to model public investment and particularly irrigation with the aim to increase supply of skilled agricultural labour and of irrigated land. They calibrate the model to a SAM of Ethiopia for the fiscal year 2005/06 and show that agricultural investments in irrigation and training have great potential for reducing poverty and food insecurity. Their results also reveal that an agriculture-led development is less likely to occur because of weak forward and backward production linkages between agriculture and manufacturing sectors (and most manufacturing inputs are imported). Moreover, the authors underline that public investments have a crowding-out effect that may affect the expansion of manufacturing and services sectors which are highly intensive in private capital.

Other authors have a specific focus on Kenya. Employing a dynamic CGE linked with microsimulations, Thurlow et al., (2007) increase agricultural spending up to 10 percent of the Kenyan budget. They explore two areas of investment within agricultural: expenditure on research and extension (R&E)[8] and on irrigation and water management. Investments in irrigation favours the Lowlands and the poorest segment of the population, while investments in R&E favour the Midlands and Highlands, and have the highest returns in growth and poverty reduction. Results indicate that poverty is unlikely to decline significantly without an acceleration of agricultural growth. Therefore investments in R&E and irrigation and water management

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should be complemented with non-agricultural investments (e.g. roads, market development) which would aim at reducing agricultural transaction costs. Similar outcomes are reported for Zambia (Thurlow et al., (2008)). Mabiso, Pauw & Benin (2012) scrutinize investments options across three Kenyan Agro-Economic Zones (AEZ) to identify priority sub-sectors and commodities. Results show that Kenya can significantly reduce national poverty if more investments are directed to semi-arid areas' irrigation and road infrastructure. Adopting a sub-sector approach, adequate investments in maize and root crops in the semi-arid and high rainfall areas would be critical.

3. The database

The study used a variant of the STAGE model (McDonald, 2007) calibrated using a modified version of a detailed Social Accounting Matrix (SAM) for Kenya. The data used to calibrate the base year of the model is drawn from a variety of data sources, but the core dataset underlying the CGE model is a variation of a 2007 social accounting matrix (SAM), estimated by Thurlow and Benin (2008) for IFPRI (in an unpublished work for Kenya's Comprehensive Africa Agricultural Development Programme (CAADP) Roundtable Discussion). This SAM was constructed using 2007 national accounts and the supply-use tables from the 2003 IFPRI-KIPPRA SAM (Kiringai et al., 2006). Province-level agricultural production and area data were provided by the Ministry of Agriculture (MOA) from their 2007 provincial agricultural production database. Non-agricultural production, employment data, income and expenditure patterns for household group were obtained from 2005/06 Kenya Integrated Household Budget Survey (KIHBS) and National Accounts. Demand-side data and information on intermediate demand and factor's use were taken from the 2003 Kenya SAM (Kiringai et al., 2006).

The modified 2007 Kenya SAM used is made of 53 commodities / activities, 4 production factors (labour, capital, land and livestock) with 3 types of labour (skilled, unskilled and semi-skilled), a Government account, a mixed Save-Investment account, 3 types of taxes, a Rest of the World sector and households accounts disaggregated by rural and urban, expenditure deciles and regions. Activities and factors accounts are also disaggregated by regions.

Table 7: Structure of Kenyan Economy

	Value Added (%)	Intermediate inputs use (%)	Gross Output (%)
Agricultural activities	28.89	8.18	19.37
Natural resources	0.73	0.87	0.79
Food	2.98	9.86	6.14

Industrial	7.51	14.39	10.67
Utilities	1.77	5.17	3.34
Construction	4.30	10.95	7.35
Services	53.82	50.59	52.33

Source: Authors elaboration on modified SAM 2007

The Kenyan economy is polarised towards primary and tertiary sectors (Table 7). Agricultural activities sum 29% of value added while services near 54%. Among agricultural activities, Tea is the most developed activity (3.9% of national value added, using more than 22% of arable land) then maize (3.9% of national value added and 18% of arable land), dairy products, vegetable, fruits and pulses (Table A. 1, appendix). In terms of labour, education and health employ most of the skilled labour (38% and 15%) while most of the unskilled labour is absorbed by other services and the trade and transportation sectors. In the agricultural sectors, tea and maize are the most labour intensive sectors.

In terms of trade (Table A. 2, appendix), tea (17%) is the most important export crop; Almost all of this crop are produced for the export market. In terms of food security and dependency, it is worthy to underline that near the 50% of domestically demanded wheat and more than 70% of rice is imported. Kenya is strictly dependent from imports in the petroleum (83% imported), chemicals (82%) and machinery (92%) sectors where domestic production can fulfil only a very small fraction of final demand.

4. The model

This study employs a comparative static variant of the single-country CGE STAGE[9] (McDonald, 2007), a descendant of the USDA ERS model (Robinson, Kilkenny, & Hanson, 1990).The version of STAGE employed for this paper is a comparative static modified version of the model where households are assumed to choose the bundles of commodities they consume so as to maximise utility where the utility function is Stone-Geary[3], which translates into a Linear Expenditure System (LES).

The households consume ‘composite’ commodities, aggregates of domestic and imported commodities formed as Constant Elasticity of Substitution (CES). The optimal ratios of imported

[9] STAGE model is an open source model the code for which can be downloaded from www.cgemod.org.uk or is available by request from the developer.

and domestic commodities are determined by the relative prices of the imported and domestic commodities, the so-called Armington ‘insight’.

Domestic production uses a nested production process aggregating intermediate and aggregate value added (primary inputs) using either CES or Leontief technologies.

The activities are defined as multi-product activities; hence for any given vector of commodities demanded there is a unique vector of activity outputs that must be produced. The vector of commodities demanded is determined by the domestic demand for domestically produced commodities and export demand for domestically produced commodities. Using the assumption of imperfect transformation in the form of a Constant Elasticity of Transformation (CET) function, the optimal distribution of domestically produced commodities between the domestic and export markets is determined by the relative prices on the alternative markets. The model is specified as a small country, i.e., price taker, on all export markets. The other behavioural relationships in the model are generally linear.

This version of the model departs from the original one in three main directions: production activities with the introduction of home production for home consumption (HPHC) water, demand functions, and labour market modelling.

Most CGE models applied to developing countries do not identify or model HPHC (Lofgren et al., 2001 is an exception); even if the issue related to HPHC is relevant to model semi subsistence agriculture in most developing countries, in this paper we concentrate on the issue form the water pint of view. Following the main theoretical and empirical insights offered by McDonald (2010) and Aragie and McDonald (Aragie & McDonald, 2014), firstly we include HPHC water in our SAM and then we modify the model accordingly. To introduce HPHC in the SAM HPHC, we introduce a new activity which employs unskilled labour to produce HPHC water which is then consumed by households. All these entries are valued in basic prices, which are equal to the purchaser prices since there are no commodity taxes or trade and transport margins associated with these commodities.

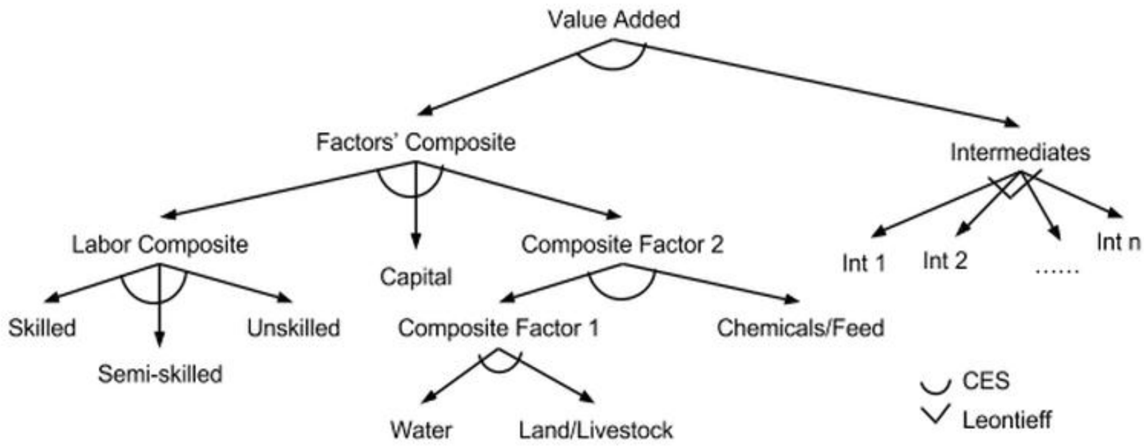
Consumers’ behaviour is defined by a two-stage LES/CES consumption nesting. At the bottom of the nest a CES function allocates identical home produced and marketed water to provide aggregate consumption of the commodity. Consumers decide on the optimal combination of these two types of commodities based on their relative prices subject to the imperfect substitution elasticity defined effectively as part of the CES function. The implication of using a

CES at this stage of the nest is that households' subsistence levels of consumption is decided only at the top of the nest. In the top nest, consumers maximise their utility from the consumption of a set of combined commodities (from the lower nest) subject to their budget constraints and the LES demand systems derived from Stone-Geary utility function[10]. This demand system clearly separates subsistence from discretionary consumption, where the discretionary demand is a residual component of total household consumption budget and committed expenditure on subsistence demand (Aragie & McDonald, 2014).

The production system is also modified on the input side by changes to the production nest. The system has been modified in order to allow the modeller full flexibility in choosing, for each group of activities, the production nest that better describe it. In general, at the top level intermediate inputs are aggregated using a Leontief (fixed coefficient) technology and are then aggregated with all other inputs using CES or Leontief technology to produce activity outputs. Aggregate value added is defined as a CES aggregation of aggregate labour, which is an aggregate of all identified labour types and capital. Crops and livestock sectors are modelled in a different way. In the case of crops, the intermediate consumption of chemicals commodities (fertilisers and phyto-sanitary agro-chemicals) and water are modelled as part of the CES nest substitutable with land. In other words, we create a sort of effective land defined as CES aggregate of natural land, water and chemicals (fertilisers and agro-chemicals) since water and chemicals are land augmenting substitutes. In the livestock production activities, the value added is decomposed into a livestock-water-feed component and a capital-labour one. Following the same reasoning as in the crop sectors, water and feed are considered as livestock augmenting substitutes.

Figure 5: Nest structure of agricultural production in the model

[10] For a developing country a Stone-Geary function is preferable since it allows for subsistence consumption expenditures, a realistic assumption with many very poor consumers.



5. Scenarios description and results

Kenya has a very limited irrigation infrastructure which allows irrigation of only 0.3% of the agricultural land. Hence the country has a huge potential to increase the area of irrigated land by enhancing the irrigation infrastructure (You et al., 2014). Being aware of this fact, government of Kenya had developed a National water investment Plan (JICA, 2013). You et al. (2014) analyzes the impacts of the foreseen investments on agricultural sector through the increases in yields. They report the expected change in the irrigated area and yields and use this data to analyze the feasibility of the suggested projects. Hence, they estimate the increase in irrigated area and cost of the investments required for this increase. We use their estimates to simulate the impact of planned irrigation investment on the Kenyan economy. For this purpose we run 9 scenarios which summarize two different policy options and three alternative cost assumptions.

In these scenarios we shock 3 exogenous variables and one parameter in the model. First, we increase the water supply by assuming that the increase in water availability will be proportional to the increase in the area of irrigated land. Then we also shock the efficiency parameter of the "composite factor 1" which implies that this water-land nest contributes more to the production. These two shocks generate a "free lunch" scenario. Then we increase the investments in construction sector with the cost of investment reported in You et al. (2014).

We run three groups of scenarios differentiated by the assumptions on the cost of irrigation investments reported in You et al. (2014): Low, medium and high cost. Under these three assumptions about the cost of investments, we first simulate a 'free lunch' scenario where we only increase the water supply[11]. Hence this group of scenarios constitutes the benchmark results to observe the impact of different financing options. Then we run 2 scenarios with different options to finance the investments. In the first one we increase the investment in construction sector by the amounts reported in Table 2. Naturally, the increase in investment is financed by an increase in private savings of households. In the second one we force government savings to increase and let model to choose the optimal level of income tax. That is, government collects higher taxes to finance the cost of irrigation investments. Comparison of the results of these three scenarios allows us to decompose the benefits of increasing water supply and irrigation efficiency and the feedback effects caused by the required spending for the investments.

Table 8: Investment and Irrigated area assumptions in the simulations

		Central	Coast	East	N. East	Nyanza	R. Val.	West	Kenya
Base	Area	49,200	6,661	13,986	2,000	5,803	8,575	4,000	90,225
Low	Investment	7,978	324	4,142	4	3,145	5,803	5,272	26,668
Cost	Area	72,223	2,926	37,503	38	28,468	52,533	47,715	241,406
Medium	Investment	3	136	6,119	6	421	775	5,784	13,244
Cost	Area	16	832	37,503	38	2,575	4,749	35,450	81,163
High	Investment	0	125	6,666	9	0	3	4,884	11,687
Cost	Area	0	579	30,884	37	0	11	22,623	54,134

Note: Area is in hectares and shows the additional irrigated land after investment. Insvestment is in million KSh.
Source: Authors'calculation from You et al. (2014).

Table 9 reports the change in household welfare. Results differ significantly among scenarios, regions and household types. Under the free lunch scenarios, we observe welfare of urban household declines in all regions except north-east region welfare of farm households are increasing and much higher in absolute value. The net impact is positive for all regions except for the coast where there is a slight decline in the welfare of the farm households. In general the results are insensitive to the assumption about the cost of the investment. The real impact follows from the method of financing.

The welfare impact becomes positive for all regions but the North East which suffers from a significant welfare loss when the investments are financed by increasing government savings,. Considering that the source of increasing government savings is increasing income tax and the

[11] Although the costs of investments are not introduced in the 'free lunch' scenarios, the increase in the area of irrigated land differs according to the assumption about costs. However, our results suggests that this difference is not significant and the results are very similar under all cost assumptions.

north east regions are relatively poorer, this is expected. Note that the gains are significantly reduced when the investments are financed by increasing government savings.

Table 9: Change in household welfare (percentage of household expenditure)

		Free	Government	Pays		Private Pays		
		Lunch	Low	Med	High	Low	Med	High
Centre	Farm	5.6	2.4	-2.2	2.0	5.6	5.7	5.7
	Non-farm	-2.0	2.0	6.8	2.5	-2.0	-2.0	-2.0
	Total	4.1	2.3	-0.2	2.1	4.2	4.2	4.2
Coast	Farm	-0.1	3.5	7.9	4.0	0.1	0.2	0.1
	Non-farm	-1.0	0.9	3.3	1.2	-0.9	-0.9	-0.9
	Total	-0.6	1.9	5.1	2.2	-0.6	-0.5	-0.6
East	Farm	4.6	2.5	-0.5	2.2	4.7	4.7	4.7
	Non-farm	-1.4	1.5	5.0	1.8	-1.4	-1.4	-1.4
	Total	3.9	2.4	0.2	2.1	3.9	4.0	3.9
Nairobi	Non-farm	-3.0	1.2	6.1	1.7	-3.0	-3.1	-3.0
N. East	Farm	10.7	-1.7	-24.5	-3.6	10.7	10.8	10.7
	Non-farm	5.3	-1.7	-12.6	-2.7	5.3	5.3	5.3
	Total	8.7	-1.7	-19.8	-3.3	8.8	8.8	8.8
Nyanza	Farm	4.0	2.6	0.8	2.4	4.0	4.0	4.0
	Non-farm	-2.6	1.8	7.1	2.4	-2.7	-2.7	-2.7
	Total	2.5	2.4	2.3	2.4	2.5	2.5	2.5
River Valley	Farm	4.6	3.2	1.4	3.1	4.6	4.6	4.6
	Non-farm	-0.3	1.2	3.2	1.4	-0.4	-0.4	-0.4
	Total	3.1	2.6	1.9	2.5	3.1	3.1	3.1
West	Farm	6.6	1.2	-7.0	0.5	6.7	6.8	6.7
	Non-farm	-1.8	1.5	5.6	2.0	-1.8	-1.8	-1.8
		5.8	1.3	-5.4	0.6	5.8	5.9	5.8

Source: Model results

Financing through increasing private savings affects welfare of rural households positively for all regions except river valley. Even the change on the welfare of coastal region becomes positive. Further, the increase is even slightly higher than the one in the free lunch scenario. On the other hand, urban households are adversely affected with significant welfare losses, except the North Eastern region. Similar to the case of rural households, adverse welfare impact on urban households are slightly higher than the one under free lunch scenario. That is, financing the irrigation investments through private savings inevitably involves some intra-household transfers from urban households are the main saving agents to the rural households.

The welfare impact according to the income groups also supports the findings above. Change in the welfare of richest and poorest households as a ratio of the household expenditure is below the national average.

Table 10: Change in household welfare according to income groups (percentage of household expenditure)

		Free	Government Pays			Private Pays		
		Lunch	Low	Med	High	Low	Med	High
Farm Households	Poorest	4.5	5.2	4.8	4.8	4.6	4.5	4.5
	Second	6.4	-0.6	3.1	3.5	6.5	6.4	6.4
	Third	5.9	-0.9	2.7	3.1	6.0	6.0	6.0
	Fourth	5.2	-1.8	1.9	2.3	5.2	5.2	5.2
	Richest	3.4	-1.4	1.1	1.3	3.4	3.4	3.4
	All	4.9	-0.8	2.2	2.5	4.9	4.9	4.9
Urban Households	Poorest	5.5	-9.9	-1.4	-0.5	5.7	5.6	5.6
	Second	3.6	-5.1	-0.5	0.0	3.7	3.6	3.6
	Third	2.5	-2.9	-0.1	0.3	2.6	2.5	2.5
	Fourth	0.2	1.9	1.0	0.9	0.2	0.2	0.2
	Richest	-2.9	6.5	1.9	1.4	-3.1	-3.0	-3.0
	All	**-2.0**	**5.2**	**1.6**	**1.2**	**-2.1**	**-2.1**	**-2.1**

6. Conclusions

The results suggest irrigation investments increases the welfare of rural households and that the way the irrigation investments are financed does matter and has a significant impact on household welfare.

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Appendix

Table A. 1: Structure of Kenyan Economy

	Share on total		Share on agricultural	
	Value Added (%)	Domestic Output (%)	Value Added (%)	Domestic Output (%)
Maize	3.6	2.4	12.4	12.3
Wheat	0.6	0.3	2	1.8
Rice	0.1	0.1	0.4	0.4
Sorghum	0.3	0.2	1.2	1
Millet	0.4	0.2	1.4	1.2
Cassava	0.2	0.1	0.6	0.7
Other roots	2.2	1.6	7.8	8.5
Pulses	2.1	1.4	7.4	7
Oil seeds	0.7	0.4	2.3	2.2
Fruits	2.7	1.9	9.4	10
Vegetables	2.2	1.4	7.8	7.2
Cotton	0	0	0.2	0.2
Sugarcane	0.4	0.4	1.4	2.2
Coffee	0.4	0.3	1.3	1.3
Tea	3.9	2.5	13.6	12.8
Tobacco	0.1	0.1	0.5	0.4
Other cash crops	0.3	0.2	0.9	0.9
Beef	2.8	2	9.9	10.3
Dairy	2.2	1.6	7.6	8.5
Poultry	0.6	0.4	2.1	1.8
Ovine for slaughter	0.9	0.5	3.2	2.9
Other livestock	0.4	0.3	1.2	1.4
Fishing	0.5	0.3	1.6	1.6
Forestry	1.1	0.7	3.8	3.4
Mining	0.7	0.8		
Meat & dairy	0.9	2.1		
Grain milling	0.7	1.8		
Sugar & bakery	0.3	0.5		
Beverages & tobacco	1	1.6		
Other manufactured food	0.1	0.2		
Textile & clothing	0.4	0.6		
Leather & footwear	0.4	0.8		
Wood & paper	0.2	0.4		
Printing and publishing	0.5	0.8		
Petroleum	0.3	1.4		
Chemicals	0.6	1		
Non-metallic products	1.9	1.5		
Metals and metal products	0.3	0.6		
Mach. and electronic machinery	0.3	0.6		
Other manufactures	2.5	2.90%		
Water	1.2	1.6		
Electricity	0.6	1.8		
Construction	4.3	7.4		
Trade	10.7	11.5		
Hotels	1.8	3		
Transport	8.1	11.9		
Communication	2.7	2.4		
Finance	4.4	3.3		
Business services and real estate	5.6	3.6		
Other services	4	3.2		
Administration	5.7	5.5		
Health	3	2.3		
Education	7.9	5.6		

Source: Authors elaboration on modified SAM 2007

Table A. 2: Structure of Kenyan Exports and Imports

	Share on Imports	Share on Exports	EXP/OUT	IMP/DEM
Maize	0.54	0.04	0.21	5.14
Wheat	1.15	0.06	2.50	47.39
Rice	0.81	0.01	1.58	73.74
Sorghum	0.07	0.01	0.49	8.04
Millet	0.00	0.00	0.01	0.18
Cassava	0.00	0.00	0.02	0.26
Other roots	0.00	0.00	0.00	0.01
Pulses	0.33	0.33	3.52	6.16
Oil seeds	2.24	0.47	15.61	61.38
Fruits	0.08	0.18	1.31	1.05
Vegetables	0.05	4.01	37.09	1.18
Cotton	0.21	0.04	20.22	86.77
Sugarcane	0.24	2.15	73.32	42.21
Coffee	0.08	1.72	98.48	90.37
Tea	0.10	16.98	98.82	56.75
Tobacco	0.11	0.42	70.40	56.72
Beef	0.00	0.00	0.02	0.00
Dairy	0.01	0.02	0.17	0.09
Poultry	0.03	0.00	0.15	1.85
Sheep, goat and lamb for slaughter	0.00	0.04	0.93	0.02
Other livestock	0.00	0.04	2.19	0.20
Fishing	0.00	0.92	43.03	0.00
Forestry	0.05	0.01	0.14	1.98
Mining	0.09	2.12	38.23	4.60
Meat & dairy	0.14	0.03	0.23	1.70
Grain milling	1.35	0.06	0.45	16.21
Sugar & bakery & confectionary	1.27	0.77	22.31	45.97
Beverages & tobacco	0.60	0.50	4.33	8.94
Other manufactured food	6.43	1.01	85.69	98.56
Textile & clothing	4.90	4.09	97.11	98.63
Leather & footwear	0.82	0.35	6.52	22.79
Wood & paper	0.70	2.69	95.82	91.42
Printing and publishing	2.83	0.00	0.00	47.93
Petroleum	19.16	3.03	30.06	82.98
Chemicals	13.98	1.09	16.26	81.67
Non-metallic products	0.95	1.12	10.46	15.11
Metals and metal products	3.86	1.98	45.23	74.31
Machinery and electronic machinery	13.12	2.34	53.66	92.10
Other manufactures	11.15	3.92	19.08	54.58
Trade	2.14	10.69	13.26	5.22
Hotels	2.45	14.93	70.68	41.54
Transport	6.81	21.74	26.17	16.61
Communication	0.00	0.00	0.00	0.00
Finance	1.17	0.12	0.53	8.31

*EXP-OUT: share of exports on domestic production; IMP-DEM: share of imports on supply of composite commodity

Source: Authors elaboration on modified SAM 2007

Table A. 3: Change in household welfare (level, million Ksh)

	Free	Government Pays			Private Pays		
	Lunch	Low	Med	High	Low	Med	High

Centre	Farm	8,875	-3,238	2,974	3,679	9,002	8,940	8,932
	Non-farm	-764	2,849	995	785	-780	-772	-771
	Total	8,111	-390	3,969	4,464	8,222	8,168	8,161
Coast	Farm	-24	3,610	1,740	1,529	93	36	29
	Non-farm	-681	2,448	836	654	-647	-664	-666
	Total	-706	6,058	2,576	2,183	-554	-628	-637
East	Farm	7,594	-799	3,501	3,989	7,777	7,687	7,677
	Non-farm	-323	1,245	444	352	-326	-325	-325
	Total	7,271	446	3,944	4,342	7,450	7,362	7,352
Nairobi	Non-farm	-9,014	20,474	5,431	3,712	-9,516	-9,271	-9,242
N. East	Farm	1,738	-2,866	-508	-240	1,770	1,755	1,753
	Non-farm	491	-984	-233	-147	491	491	491
	Total	2,229	-3,850	-741	-387	2,261	2,245	2,243
Nyanza	Farm	5,351	969	3,194	3,449	5,394	5,373	5,371
	Non-farm	-1,020	3,054	979	742	-1,041	-1,031	-1,030
	Total	4,331	4,023	4,173	4,191	4,353	4,342	4,341
River Valley	Farm	9,592	2,718	6,221	6,621	9,569	9,580	9,581
	Non-farm	-317	2,997	1,288	1,095	-360	-339	-337
	Total	9,275	5,715	7,509	7,716	9,209	9,241	9,245
West	Farm	6,942	-6,367	446	1,221	7,099	7,022	7,013
	Non-farm	-212	703	240	186	-213	-213	-212
	Total	6,729	-5,664	685	1,407	6,886	6,810	6,800

Source: Model results