Appendix 2. Model descriptions and selection of quantitative results from East Africa scenarios

This appendix presents descriptions of the IMPACT and Globiom models used to quantify the East Africa scenarios, a description of model drivers and examples of quantified results along with a summary of insights. These results are revised versions, based on a change proposed by the scenarios process participants upon reviewing a first set of outputs. The change made was that upon reflection of the relative effects of yields and GDP and farmer inputs on the first results, participants decided that the GDP inputs for Herd of Zebra should be the highest of the set (where previously it was slightly lower than Industrious Ants), to reflect more strongly that this scenario focuses on large-scale economic growth while support for yields and farmer inputs in Herd of Zebra should be less favourable than in Industrious Ants.

A2.1 Model descriptions

GLOBIOM

The International Institute for Applied Systems Analysis (IIASA) developed and uses the Global Biosphere Management Model (GLOBIOM (Havlík et al., 2011)) to provide insight for global land use competition by integrating the major land based production sectors: agriculture, bioenergy, and forestry. GLOBIOM can be used in scenarios analysis to assess how socio-economic development resulting from different governance and policy strategies affect not only the agricultural sector through food availability but also the environment through deforestation by area growth in pasture and crop land. The model accounts for changes in supply and demand for 20 globally important crops, livestock production activities, major forestry commodities, and multiple bioenergy transformation pathways using a detailed representation of each sector. The model is spatially explicit and accounts for all major land use types in terms of production. Demand for agriculture, bioenergy, and forestry products is determined for the 30 regions within GLOBIOM. Trade is modelled under the homogenous good assumption and where optimal bilateral trade flows result from the minimization of the international trade costs, which include tariffs and transportation costs.

IMPACT

The International Food Policy Research Institute (IFPRI) developed and uses the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT (Nelson et al., 2010)) to provide long term scenarios for the global agricultural sector. In regional scenarios development, it can be used to focus on the countries in a region, their interactions with the world through trade, and how this relates to agricultural production. IMPACT models global trade though world prices for 44 commodities and livestock products which are determined by the domestic supply and demand of the 115 regions. IMPACT is a partial equilibrium model with thematic focuses on water demand and availability as well as the effects of climate change on limiting crop yields and area potential. IMPACT has been widely used in food security scenarios analyses including the *Global Food Projections to 2020* (Rosegrant et al. 2001) and more recently with a commodity investment study in *Food Security, Farming, and Climate Change to 2050* (Nelson et al. 2010).

A2.2 Drivers

Drivers used as inputs into both models were based on interactions with diverse regional stakeholders involved in the East Africa scenarios process, who provided semi-quantitative assessments of these drivers of change and the assumptions behind those assessments (see main text). Once the first model outputs were generated based on these inputs, representatives of the participants in the process were able to criticize the results on their plausibility and usefulness for the region, after which subsequent iterations of the model runs were done. Scenarios were run for Ethiopia, Uganda, Tanzania, Kenya, Rwanda and Burundi, up to 2030.

The following input drivers were used:

Population

Population growth projections follow the medium variant growth projections from the UN population database 2010 revision (United Nations Population Division, 2010). This growth in population is assumed to be the same for all scenarios and also between the models. In East Africa from 2010 to 2030, population is projected to grow by more than 60 percent, exceeding 360 million by 2030. Globally, population is projected reach 8.2 billion people, an increase of 21 percent from 2010 to 2030.

Gross Domestic Product

GDP projections in the quantitative scenarios follow the narrative assumptions, based on historic GDP and guided by comparing the narrative assumptions to scenarios in Nelson et al. (2010). Gross Domestic Product is an important driver for demand for commodities in the models. GDP is highest in Herd of Zebra with its push for large scale development. Industrious Ants, with slowed, more balanced growth, follows, then Lone Leopards and Sleeping Lions.

Farm input costs

GLOBIOM applies farm input costs as an external driver. The model finds a market equilibrium solution by maximizing the consumer and producer surplus under market conditions and resource constraints. Producer surplus takes into account the various costs of production and these have been included in the scenarios by inferring that the different quality of governance and level of regional integration have implications for the production costs for farmers. Farm input costs are moderated the most in Industrious Ants through enabling institutions and infrastructure and are the highest in Sleeping Lions due to the absence of these elements.

Crop Yields

Each scenario has different consequences for improvements on crop yields, driven by technologies but also by enabling or restrictive governance conditions (Mandemaker et al., 2011). Industrious Ants produces an umbrella of favorable conditions for yield increase. In Herd of Zebra, yield increases are restricted to commercial crops. Lone Leopards sees slow and uneven increases of yields depending on different national priorities. In Sleeping Lions, yield increases are the lowest or sometimes nonexistent since there are no successful efforts for change.

Livestock numbers, yields and production systems

GLOBIOM and IMPACT characterize livestock production into four large species groups: bovines, small ruminants, pigs, and poultry. The additional classification for livestock production systems used in the GLOBIOM model takes into account the agro-ecological zone, the intensity of livestock production and feeding methods. Increase in intensification or extensification and feed substitutions are ways in which the GLOBIOM model allows for shifts between production systems. Industrious Ants sees a moderate but broad increase in livestock yields across livestock commodities, reflecting the support in this scenario of diverse livelihoods. Herd of Zebra mainly sees increases in livestock yields for commodities intended for urban consumption. This is also the case in Lone Leopards, but livestock yield increases are more effective. Sleeping Lions sees no yield increases.

Land use change emissions tax

Any efforts (or absence of efforts) to minimize the effect of economic growth on environmental services are outlined in the scenarios narratives. GLOBIOM can address this is by including a tax on the greenhouse gas emissions resulting from land use change. GLOBIOM classifies six different land cover categories: managed and unmanaged forests, short rotation tree plantation, grassland, cropland, and other natural vegetation. GLOBIOM takes into account the profitability of each land type and allows land to move from one type to another. Industrious Ants has the highest land use change tax, while Herd of Zebra has very light tax applied to land use change. Lone Leopards only applies land use change tax to deforestation due to specific pressure groups. Sleeping Lions has no land use change tax.

A2.3 Model outputs

Figures A.1 to A.5 provide examples of results from the two models for the East Africa scenarios up to 2030.

Figure A.1 Shows demand for maize. GDP drives demand for commodities in the models. However, increases in production (Figure A.2), while being affected by demand, is different depending on yield increases, affecting regional prices and this in turn affects demand. The Industrious Ants scenario produced by the GLOBIOM model shows this effect most strongly, since in GLOBIOM, markets are regional whereas IMPACT uses a single, integrated market, which means that regional effects of production on price are minimized. Feed demand for livestock also makes up a small part of the demand for maize.

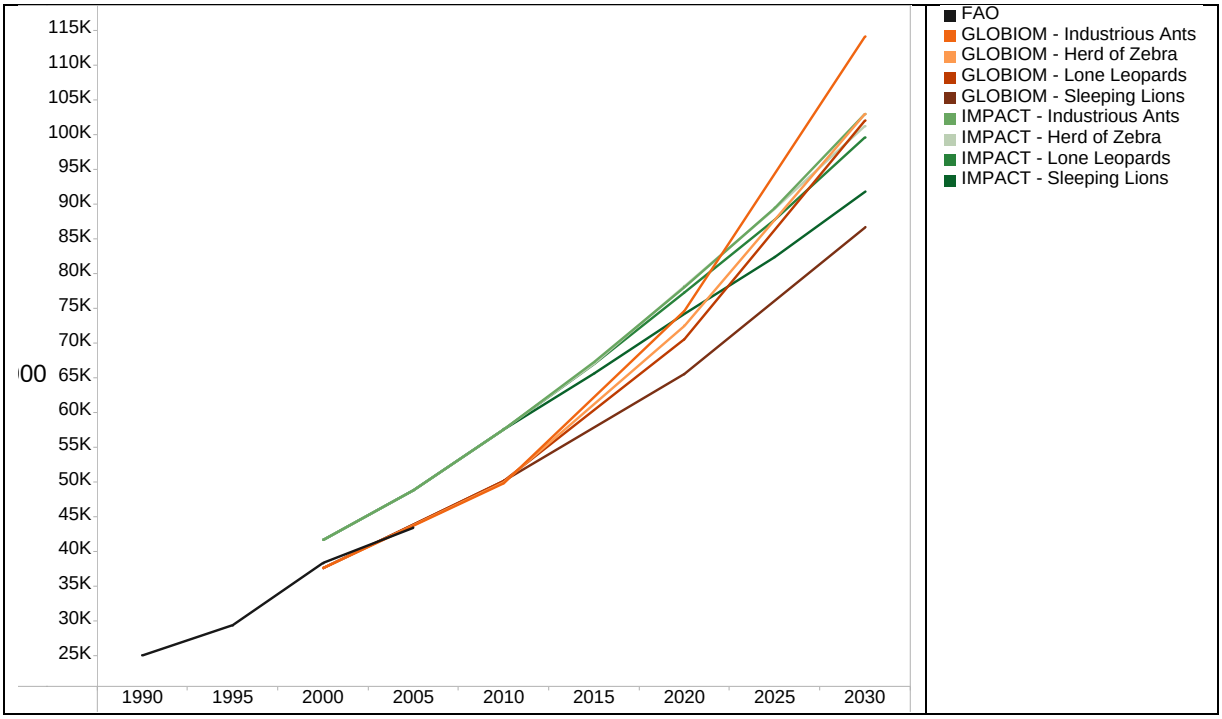

Figure A.1: Total demand for maize across the four scenarios up to 2030 as simulated by GLOBIOM and IMPACT.

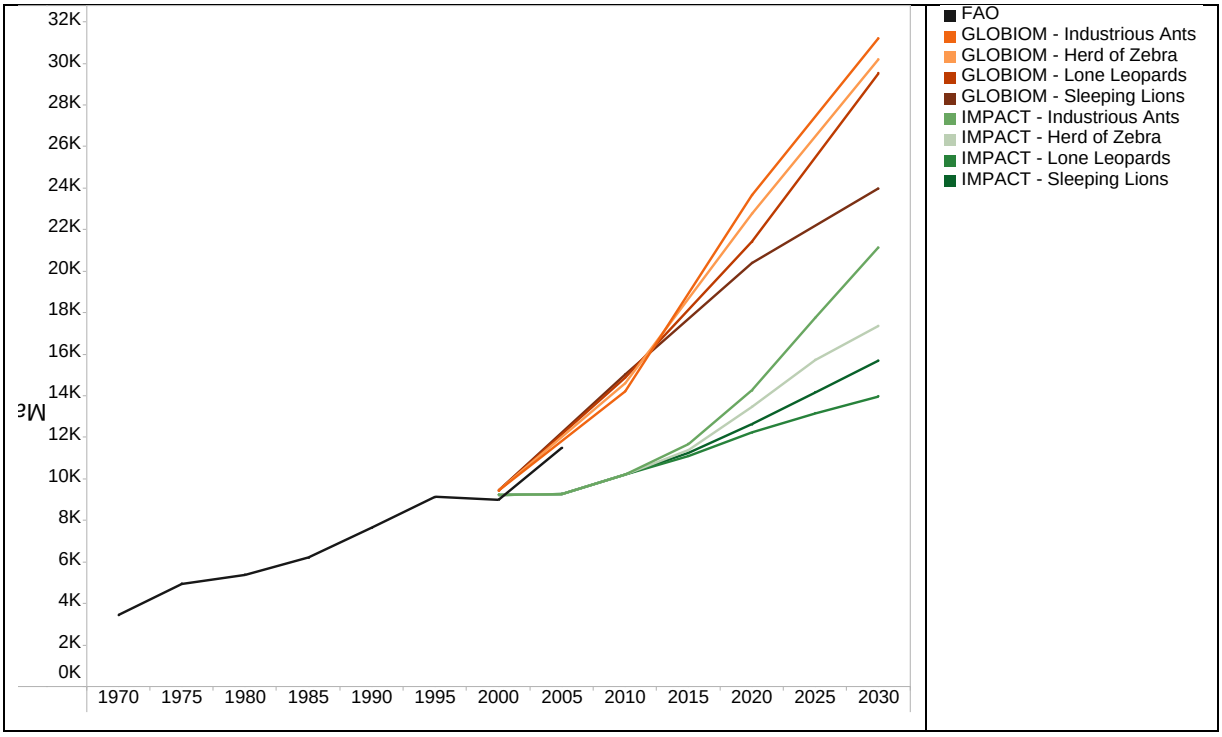

Figure A.2: Production across four scenarios for maize in 2010, 2020 and 2030 as simulated by GLOBIOM and IMPACT.

The differences in production increases for maize between the models are large due to the fact that Globiom uses crop production systems, and because the Globiom scenarios include effects on farmer input costs.

Populations and GDP increase across all scenarios, driving a rising demand in a number of agricultural products. It has been observed that with increased incomes (represented by GDP in the models) individuals adjust their diets, increasing the quality and diversity of their food expenditures. Both IMPACT and Globiom assume this relationship is true in East Africa, leading to increased demand for animal proteins alongside rising GDP (figure A.3 for beef demand).

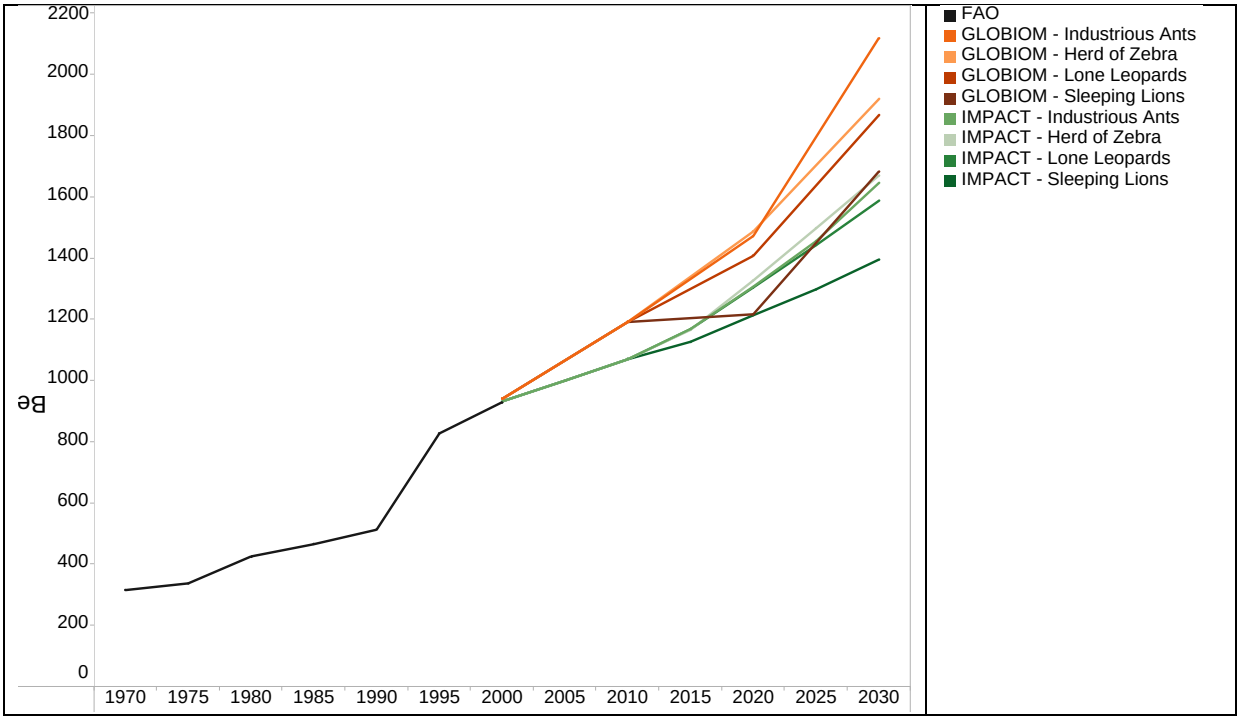

Figure A.3: Regional demand for beef across the four scenarios up to 2030 as simulated by GLOBIOM and IMPACT.

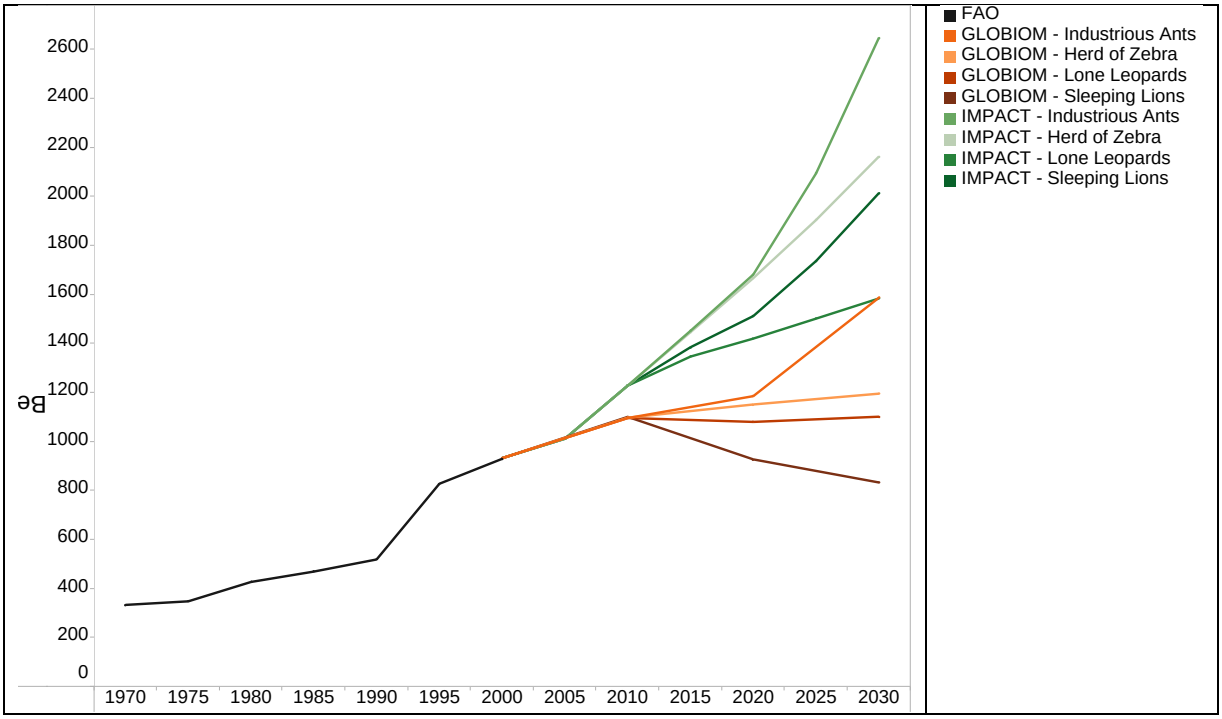

Figure A.4: Regional beef production across the four scenarios from 2010 to 2030 as simulated by GLOBIOM and IMPACT

Eastern Africa contributes a relatively small amount of agriculture production to the global totals. This fact is important when considering that GLOBIOM and IMPACT model global trade in different ways. The different representation of global trade can result in significant differences in model outputs from a change in agricultural production. GLOBIOM's regional approach to international trade allows it to capture some of the regional effects on production and commodity prices that would occur from the proactive investments of state and non-state actors in the 4 scenarios.

For instance (figure A.4), in the Industrious Ants scenario, investments in improving yields, support for smallholders and pastoralists, and investments that lower production costs, increase production. In the Herd of Zebra scenario, investments are less effective, and in the Lone Leopards scenario, there is a mix of highly successful and less successful investments and the overall emphasis is on livestock for urban consumption such as poultry. Sleeping Lions sees little to no investments overall, with poultry as an exception.

Figure A.5 shows that both models have different assumptions about trade by the region with the rest of the world. This is related to different treatments of land use which translate in different capacities for production, as well as the fact that trade is organized fundamentally differently between the models: IMPACT is organized around a global market while GLOBIOM organizes trade through multi-regional interactions. As a result, in the GLOBIOM versions of the scenarios, production temporarily outstrips demand in Industrious Ants and Herd of Zebra. All scenarios, however, end with a situation of net demand for maize in 2030.

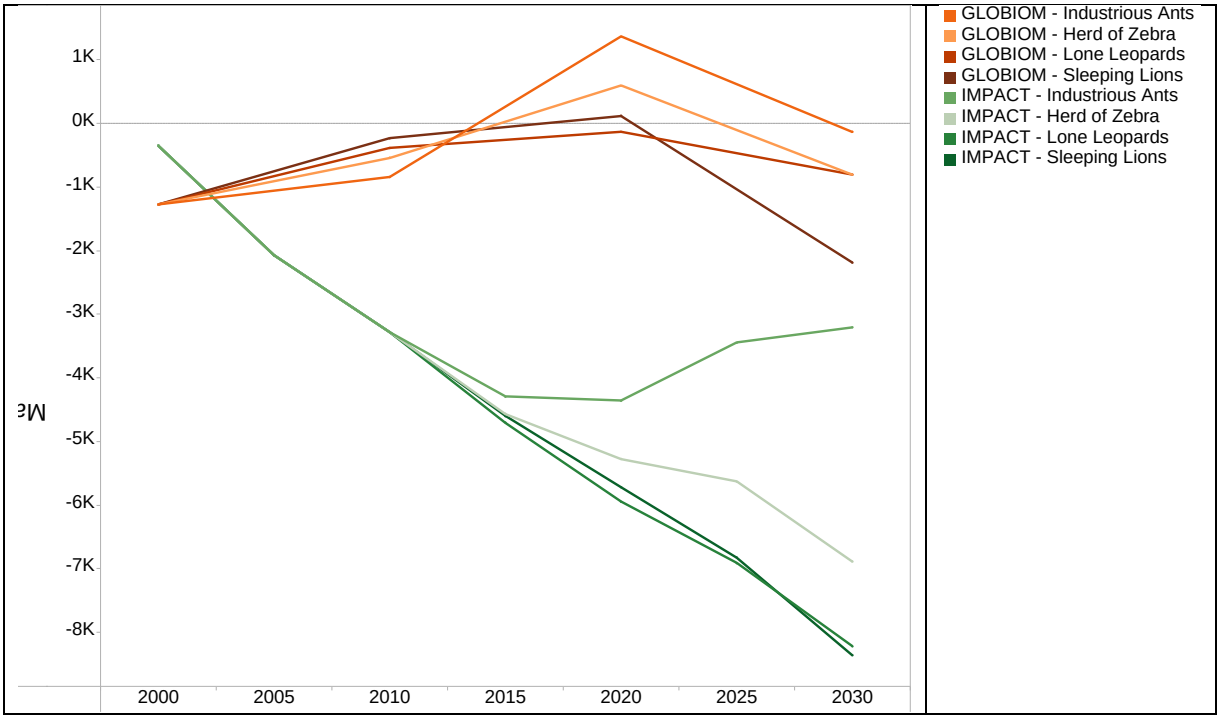

Figure A.5: Regional net trade across four scenarios for maize in 2010, 2020 and 2030 as simulated by GLOBIOM and IMPACT

Commodity yields are generally higher in the *Industrious Ants* scenario due to the broad support for agricultural development throughout the period. As discussed previously, increased yields results in an increase regional production in both models. In GLOBIOM (Figure A.6), the increase in production leads to lower regional prices, and an increase in food demand from consumers. In GLOBIOM, calorie availability per capita is highest for the *Industrious Ants* scenario, which as mentioned earlier has the most investment in agricultural development. Calorie availability per capita is lowest in the *Sleeping Lions* scenario for both models. This is due in part to the low/negative agricultural productivity growth in the scenario over the time period (resulting in higher regional prices for consumers) and also the assumed low GDP growth.

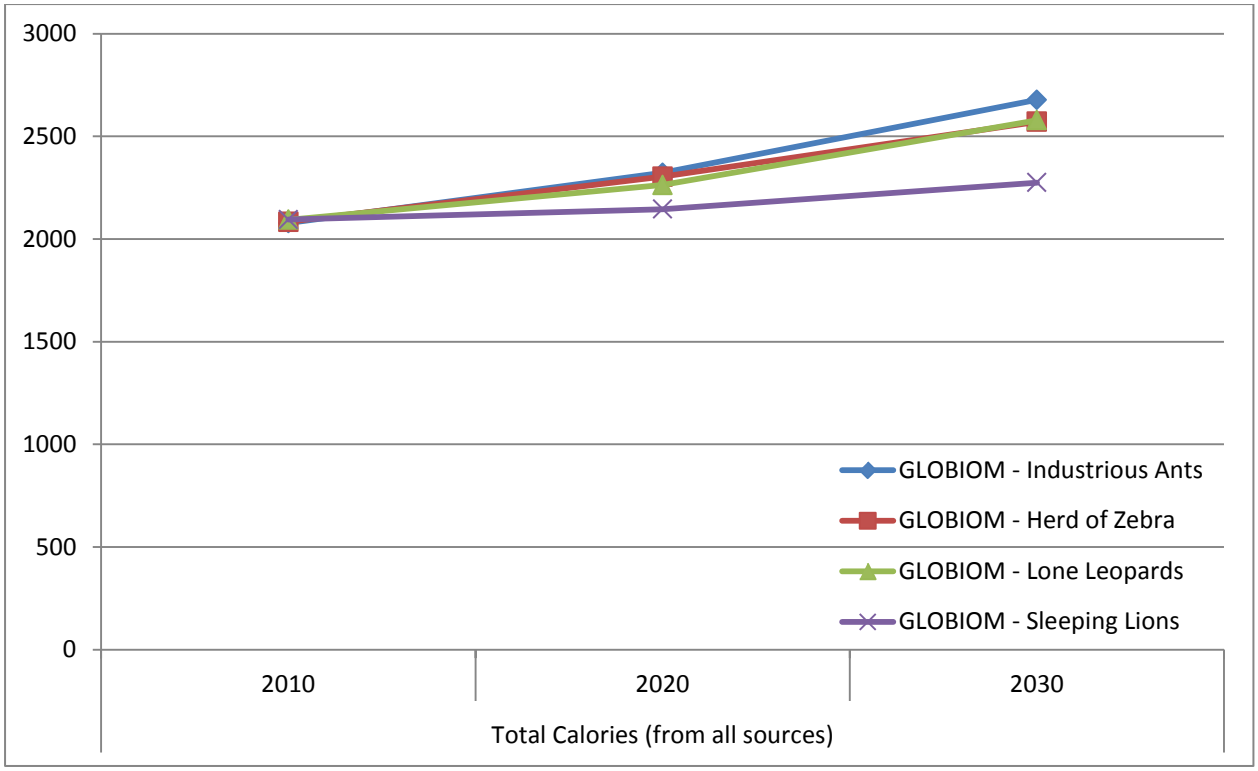

Figure A.6: Calorie availability per capita per day up to 2030 for East Africa, from GLOBIOM.

GLOBIOM produces land use change (see figure A.7).Land shifts to different goods based on the overall profitability of each land use sector. Different land use tax regimes determine the extent of land use change. Land use taxes that prohibit changes to natural lands (forests, other natural vegetation) are highest in Industrious Ants.

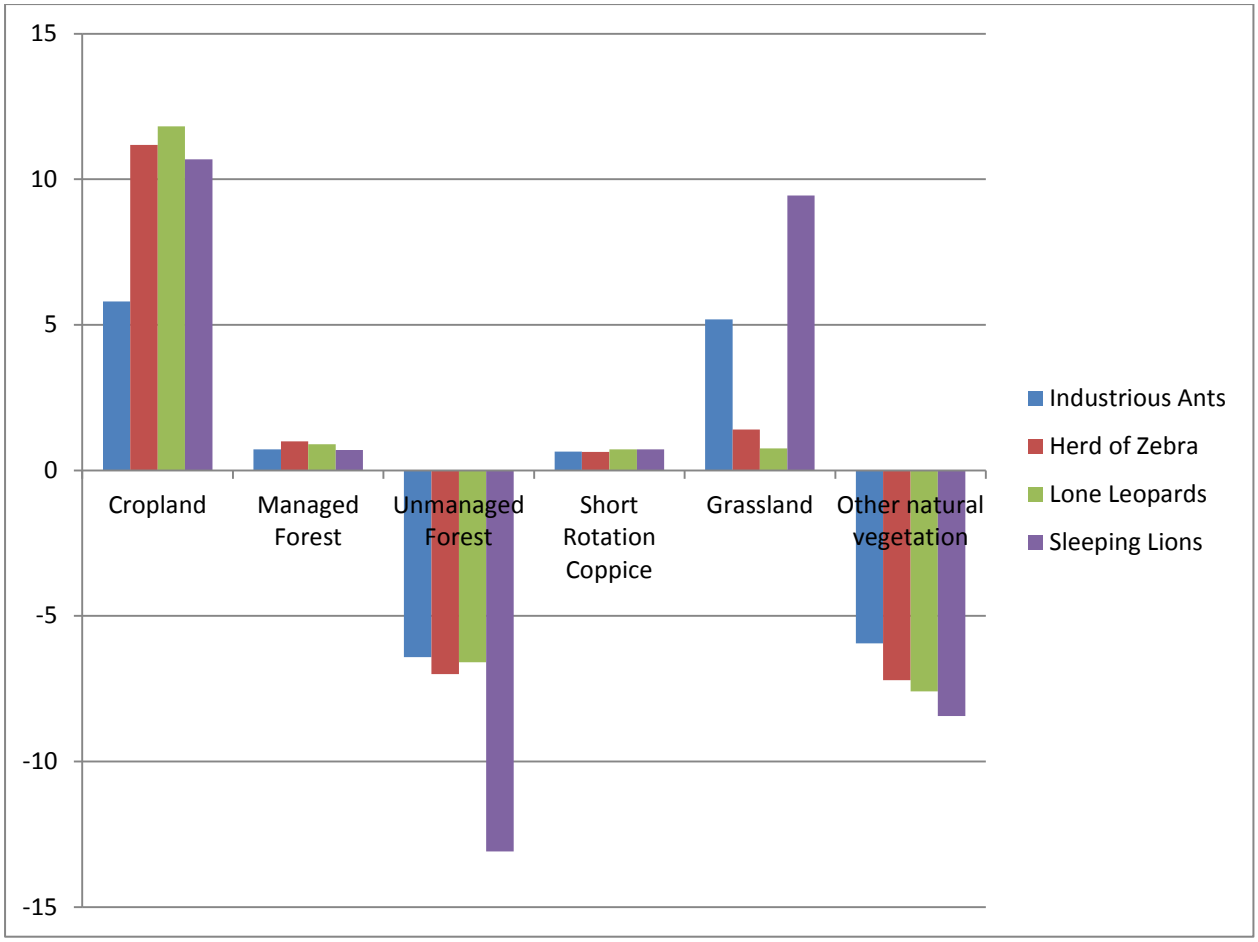

Figure A. 7: Cumulative land use change (Mha) in 2030 compared to 2000 with different emissions from land use change tax regimes for the scenarios, from GLOBIOM.

The quantification of the scenarios through the two models produced insights that can be summarized as follows:

- The quantitative analyses indicate that even with highly proactive policy conditions, global market pressures and changing populations will make it difficult to improve upon the current level of food security.
- Growing populations drive demand for many food products. Demand for poultry and milk increases with changing consumption patterns because of urbanization in the region – and policy conditions can help determine how this affects livestock agriculture.
- In all scenarios – even the more environmentally friendly scenarios – food security and livelihoods take precedence in policies over environmental health.
- It is, however, possible to minimize the degradation of ecosystems and still increase regional food self-sufficiency.
- Pastoralists face difficult prospects in all future scenarios and move to other sources of income unless governments choose to subsidize heavily.
- For most commodities in the scenarios, East Africa's demand ultimately outstrips production due to increasing global and regional populations and GDP. This means that in all the scenarios, East Africa is importing many commodities.

- In all East African scenarios, there is a tendency towards increased mixed and intensive agriculture and livestock among small-scale farmers.

A.4 Presenting the results and responses of users

The presentation of the quantitative results to users in the initial back-casting workshops was done in a manner that highlighted both the differences between the scenarios as well as the different assumptions of the models. Focusing on the model differences helped to emphasize the point that the models represent particular perspectives rather than predictions of the future. For instance, in the discussion it was highlighted that neither model links agricultural production to GDP, that there is no differentiation between different socio-economic groups and between rural and urban areas, and that short-term/high-resolution impacts of the scenarios cannot be incorporated. See appendix 3 for an example of participant responses to the model information.

References

Havlík, P., Schneider, U.A., Schmid, E., Böttcher, H., Fritz, S., Skalský, R., Aoki, K., Cara, S.D., Kindermann, G., Kraxner, F., Leduc, S., McCallum, I., Mosnier, A., Sauer, T., Obersteiner, M. (2011) Global land-use implications of first and second generation biofuel targets. Energy Policy 39, 5690-5702.

Mandemaker, M., Bakker, M., Stoorvogel, J. (2011) The role of governance in agricultural expansion and intensification: A global study of arable agriculture. Ecology and Society 16, 8.

Nelson, G.C., Rosegrant, M.W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., Tokgoz, S., Zhu, T., Sulser, T.B., Ringler, C., S., M., You, L., (2010) Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options, IFPRI research monograph. International Food Policy Research Institute, Washington D.C.

United Nations Population Division, (2010) World Population Prospects: the 2010 Revision.