Impact of the transition to a healthy diet on food security, agriculture and the environment in Ethiopia.

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Introduction

Countries have committed themselves to achieve Sustainable Development Goals, such as Zero Hunger (SDG2), and Life on Land (SDG15). Many countries are still far from reaching the targets as expressed in these goals. To help steer these developments, the necessary transitions in the food system of a country for achieving healthy and affordable diets for all people need to identified, while minimizing negative environmental impacts.

The transition to healthy diets means a change in the demand for and consumption of various agricultural commodities. This change in demand will drive price changes, both for consumers and at the farm gate. This affects agricultural incomes, domestic food production and patterns of trade. Changes in domestic food production will in turn alter land use patterns, fertilizer use and other agricultural inputs which have environmental consequences with respect to land demand for agriculture, nutrient emissions, greenhouse gas emissions and irrigation water demand.

In this study we investigate a number of aspects of this challenge by linking a biophysical (BIOSPCAS) and an economic (MAGNET) model, and simulating consequences of a transition to a healthy diet in Ethiopia in 2030.

The impacts of economic and environmental consequences of a transition to a healthy diet in Ethiopia are compared with the SSP2 (O'Neill et al. 2017) business as usual future projections of the Ethiopian economy and agricultural system in 2030 with the current patterns of consumption, to illustrate the differences and highlight the impacts of the transition. Further as domestic food prices are linked to the global marketplace for agricultural commodities, we explore a scenario where the rest world makes the transition to a healthy diet as well. This global transition will affect the demand for Ethiopian exports and the prices for imports facing farmers and consumers.

For this study we use the MAGNET model (Woltjer and Kuiper, 2014), a global computable general equilibrium model based on the GTAP model (Hertel, 1997). MAGNET is built in a modular fashion allowing the relevant model extensions (modules) to be used as necessary to explore a given research question. Bilateral trade flows between all countries in the model facilitate the interpretation of global trends to the national level context. By matching the core economic flows with outside data sets from the FAO and others, the MAGNET model can also report on physical quantities in selected sectors, for example food production and consumption in weight and nutritional content, land use and greenhouse gas emissions.

As the MAGNET model has mapped its food commodities to the FAO food and crop categories, a logical point of connection between MAGNET and other food systems models are the FAO categories.

For further detail into biophysical changes of domestic food production, we use the BIOSPACS model (Conijn et al. 2018). BIOSPACS (Balancing Inputs and Outputs for the Sustainable Production of Agricultural CommoditieS) is a food system model for the production and consumption of food and calculates required land and fertilizer inputs (N and P), other N and P flows among five different system components and across the boundary of the whole system as a function of diet, population size and trade. It includes calculations of various nutrient losses, waste streams, and GHG emissions, linked to food production (CO_2 from energy use in agriculture, CH_4 and N_2O). BIOSPACS is a target-oriented model to analyse consequences of diet choices of the above-mentioned variables in an integrative system approach.

The results of this study can be used as input for developing food policies to direct national food system transitions towards achieving a healthy diet as well as ending hunger (SDG2) in synergy with other related Sustainable Development Goals.

Methods

MAGNET

The Modular Applied GeNeral Equilibrium Tool (MAGNET) model is a multi-regional, multi-sectoral, applied general equilibrium model based on neo-classical microeconomic theory. The core of MAGNET is an input–output model, which links industries in value added chains from primary goods, over continuously higher stages of intermediate processing, to the final assembly of goods and services for consumption. Primary production factors are employed within each economic region, and hence returns to land and capital are endogenously determined at equilibrium, i.e., the aggregate supply of each factor equals its demand. On the consumption side, the regional household is assumed to distribute income across savings and (government and private) consumption expenditures according to fixed budget shares. Private consumption expenditures are allocated across commodities according to a non-homothetic constant difference of elasticity (CDE) expenditure function and the government consumption according to Cobb-Douglas expenditure function.

The MAGNET model, in comparison to GTAP, uses a more general multilevel sector specific nested CES (constant elasticity of substitution) production function, allowing for substitution between primary production factors and (land, labour, capital and natural resources) and intermediate production factors and for substitution between different intermediate input components (e.g. energy sources, and animal feed components). MAGNET includes an improved treatment of agricultural sectors (like various imperfectly substitutable types of land, the land use allocation structure, a land supply function, substitution between various animal feed components, agricultural policy (like production quotas and different land related payments) and biofuel policy (capital-energy substitution, fossil fuels-biofuels substitution. On the consumption side, a dynamic CDE expenditure function is implemented which allows for changes in income elasticities when purchasing power parity (PPP)-corrected real GDP per capita changes. Segmentation and imperfect mobility between agriculture and non-agriculture labour and capital are introduced in the modelling of factors markets.

BIOSPACS

BIOSPACS quantifies N and P flows between five interacting components in the food system and those across the system's boundary as a function of food demand (see example of N flows in Figu). Related agricultural land requirements and GHG emissions from agricultural production are also calculated. The five components are: (1) human *population* consuming food items, (2) the *food balance* supplying (non-)food items, (3) *livestock* producing animal-based products, (4) *organic fertilizer* consisting mainly of excreted manure from livestock and (5) *agricultural land* comprising arable land and permanent grassland for the production of food crops and feed for livestock. N and P stock changes are determined for agricultural land, the food balance and the population.

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Non-agricultural land areas, aquatic systems and the atmosphere are not described in BIOSPACS, except for those flows that cross the food system boundary. Requirements for non-food demands such as non-food crops like cotton, and non-feed use of residues like straw for bedding, are not yet taken into account. Extra food crop demand due to other use of food crops such as for biofuels, is included.

Statistical data from FAOSTAT and additional information from other sources are used to derive quantitative input–output relations of each component in the food system. These relations are then used to calculate the output as function of the food demand, e.g. required mineral fertilizer and related losses. The model can be used to study a current situation by calculating the various input-output efficiencies, their interlinkages and ultimate leakages from the system. Alternatively, it can also be used to explore possible improvements and future situations of changing diets and population densities to calculate the consequences for land requirement fertilizer demand, N and P losses, GHG emissions, etc.

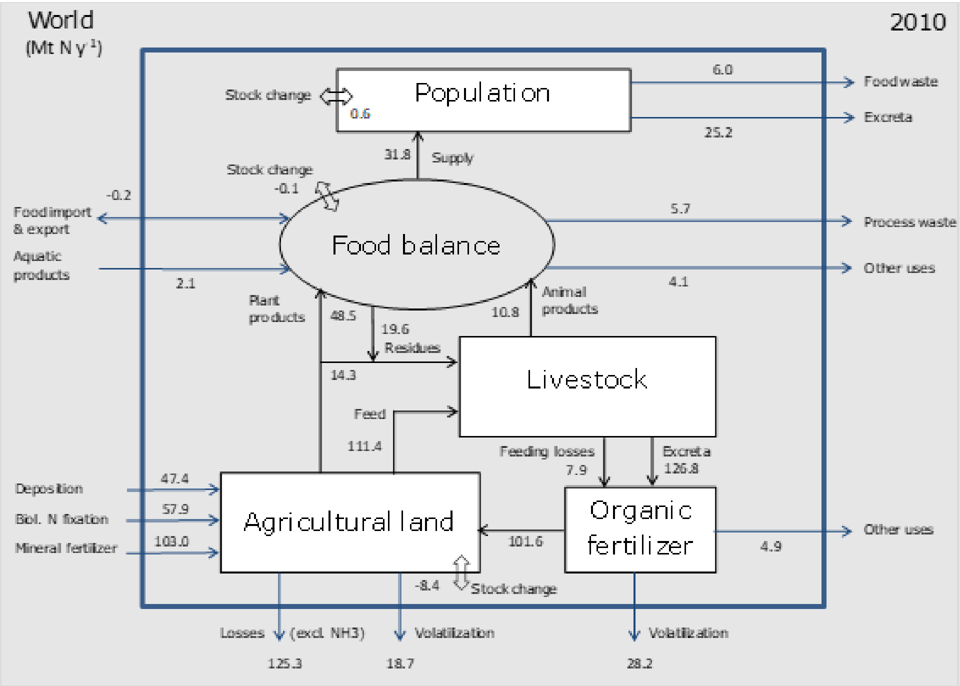

Figure 1: Nitrogen flows of the global food system for 2010. Volatilization from organic fertilizer refers to total N-NH_3 emissions from manure storage and application, whereas volatilization of N-NH_3 from agricultural land is due to the application of mineral fertilizers (Conijn et al., 2018).

Table 1: Showing the common commodities and variables for comparison and data exchange between MAGNET and BIOSPACS.

Commodity Name	**Description**	**Variable Name**	**Description**
CERA	Cereals	POPT	Total population
FRUT	Fruits Vegetables and Nuts	LAND	Land physical area
SUGR	Sugar Crops	YILD	Crop yield
OILC	Oil Crops	FOOD	Food use
STIM	Stimulants, Spices and other	IMPO	Imports
FIBR	Fiber Crops	EXPO	Exports
		CALO	p.c. calory availability

BOVM	Bovine Meat	PROD	Production
MUTM	Mutton & Goat Meat	CONS	Domestic availability
PIGM	Pig meat and other meat	NETT	Net trade
POLM	Poultry Meat	EMIS	Total GHG emissions
MILK	Milk and Dairy	ECO2	Total CO2 emissions
FISH	Fish, Seafood	ECH4	Total CH4 emissions
SWET	Sugar & Sweeteners	EN2O	Total N2O emissions
OILS	Fats and Veg oil		
OTHR	Alcohol and Other Food		
FERT	Fertilizer		
Feed	Feed		

Scenarios

The scenarios explored in this study are:

- A business as usual reference scenario (SSP2) for the year 2030, assuming no intervention in diet choices.
- A healthy diet for an intake of circa 2300 kcal/cap/day is applied to Ethiopia, while the other countries follow the business as usual reference scenario. This diet is based on the reference consumption basket of Willett et al (2019) combined with an estimate of the per capita energy requirement for Ethiopia from the food security indicator data set of the FAO (diet scenario '*HDadj*' in Conijn et al., forthcoming).
- The healthy reference diet for an intake of circa 2300 kcal/cap/day is applied to all countries in the world in 2030.
- A healthy diet is used for Ethiopia that is assumed to end hunger in the country in 2030, based on the indicator '*Prevalence of Undernourishment*' in the above mentioned data set of the FAO. It is comparable to scenario 2, but for a higher intake of circa 2800 kcal/cap/day (diet scenario '*ZHadj*' in Conijn et al., forthcoming).
- The zero hunger healthy diet for an intake of circa 2800 kcal/cap/day is applied to all countries in the world in 2030.

The current average per capita total calorie consumption is already at the minimum level prescribed by the healthy diet scenario (HDAdj). Rather the healthy diet scenario prescribes a shift in the food consumption basket away from cereals and towards vegetables fruits and nuts, oil crops, dairy and Chicken. The zero hunger scenario prescribes an increase in the average per capita total calorie consumption while maintaining the same share of food commodities in the consumption basket as the healthy diet scenario. Table 2 shows the calorie consumption of the current diet pattern and the two diet scenarios.

Table 2: Calory consumption in Ethiopia by commodity in 2014 and the diet scenarios

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	kcal/capita/day			Share kcal per commodity	
	2014	HDAdj	ZHAdj	2014	HDAdj and ZHAdj
CERA	1558	748	919	0.66	0.32
FRUT	459	519	638	0.20	0.23
SUGR	67	111	136	0.03	0.05
OILC	133	649	798	0.06	0.28
STIM	34	0	0	0.01	0.00
BOVM	26	18	22	0.01	0.01
MUTM	10	7	9	0.00	0.00
PIGM	4	3	3	0.00	0.00
POLM	4	75	92	0.00	0.03
MILK	50	141	173	0.02	0.06
FISH	1	36	45	0.00	0.02
Total	2346	2306	2835		

Preliminary Results

Following the socio-economic developments of the 2nd Shared Socio-Economic pathway (SSP2) Ethiopia sees significant population and economic growth. Where the population grows by 40 percent over the 16 year period from 2014 to 2030, while the economy nearly triples. While the current political situation in Ethiopia might require a revision to these projections such a revision is outside of the scope of this study and we will remain with the standard SSP2 projected developments. Table 3 shows the projected GDP and population growth in Ethiopia from 2014-2030.

Table 3 GDP and population growth in Ethiopia from 2014-2030 according to the SSP2 projections.

	2014	2030	% change
GDP mill $ U.S.	55557	165737	198
Population millions	97	136	40

The following shows the results from the baseline SSP2 projection in Ethiopia from the MAGNET model. The projected economic growth in Ethiopia also brings a transformation for economy, shown in figure 2. The share of total value added and the share of labor income shifts largely from agriculture to services. This shift is more pronounced when examining total value added however, even in 2030 just over one third of labor income come from agricultural jobs.

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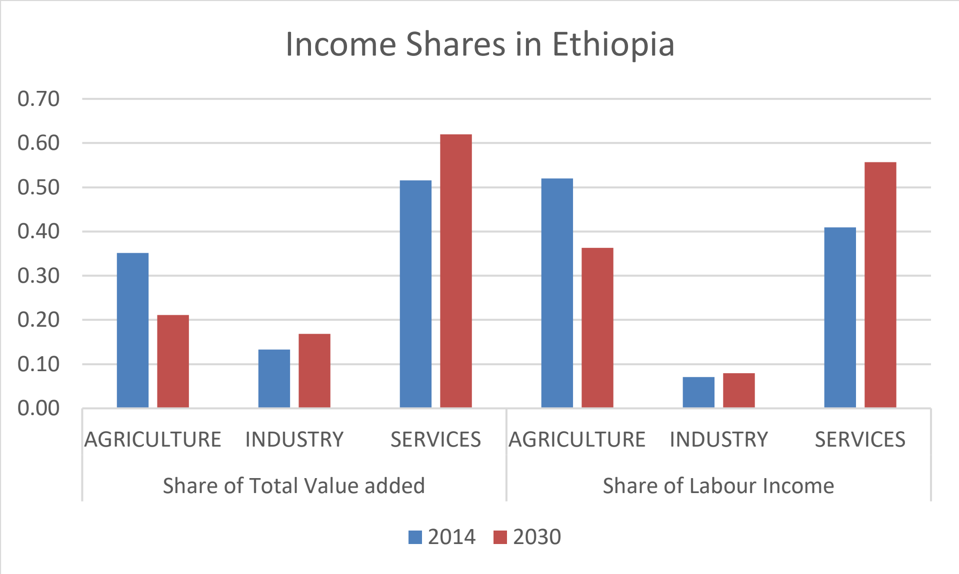

Figure 2: *The share of total value added and the share of labor income in agriculture industry and services.*

The projected growth in the GDP per capita increases the average per capita total calorie consumption from 2346 to 2775. This is nearly the average per capita total calorie consumption of the zero hunger diet, however the source of the calories in the consumption basket remains largely the same as in 2014. Table 4 shows the share of the calories consumed by commodity distinguishing between domestic and imported sources. Similarly the share of labor, shown in figure 3, in each of agricultural sectors also remains largely unchanged from 2014 to 2030.

Table 4: The share of calories consumed by commodity in Ethiopia distinguishing between domestic and imported sources.

	2014		2030	
	Domestic	Imported	Domestic	Imported
CERA	0.63	0.02	0.59	0.03
FRUT	0.22	0.00	0.22	0.00
OILC	0.04	0.01	0.05	0.01
SUGR	0.02	0.01	0.02	0.01
STIM	0.01	0.00	0.01	0.00
BOVM	0.01	0.00	0.01	0.00
PIGM	0.01	0.00	0.01	0.00
MUTM	0.01	0.00	0.01	0.00
POLM	0.00	0.00	0.00	0.00
MILK	0.03	0.00	0.03	0.00
FISH	0.00	0.00	0.00	0.00
Total	0.96	0.04	0.95	0.05

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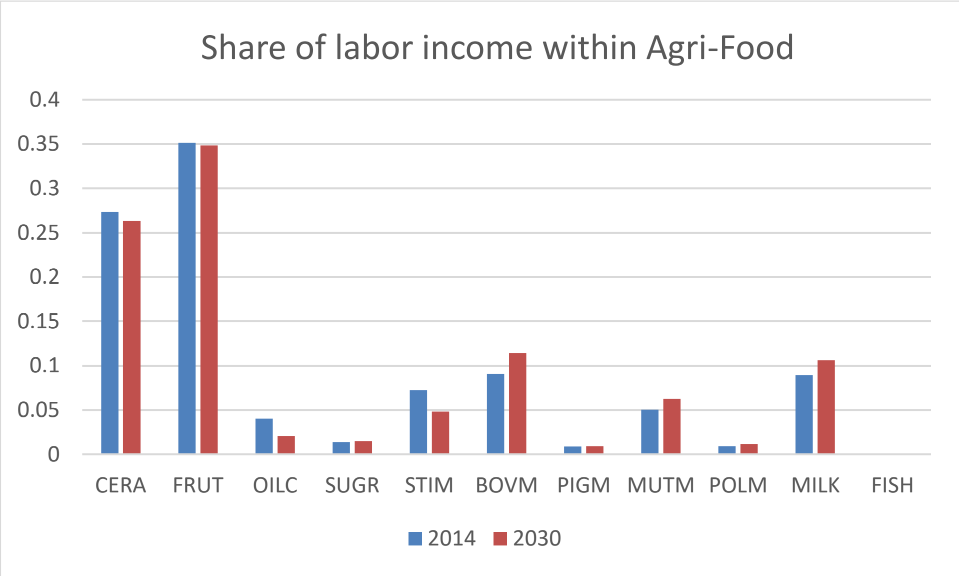

Figure 3: *The share of labor in each of agricultural sectors in Ethiopia in 2014 and 2030.*

Table 4 shows that most of the food consumption is domestically sourced and therefore a change in the consumption basket in accordance with the healthy diet and zero hunger scenario would also have a significant effect on the demand for labor and wages in each of these sectors.

As this study progresses we will include results from the healthy diet and zero hunger scenarios as well as results from the BIOSPACS model.

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