Quantified future challenges to sustainable food and nutrition security in the EU

Deliverable No. 10.2

SUSFANS DELIVERABLES

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This deliverable quantifies future challenges for the EU sustainable FNS using the SUSFANS toolbox.

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DELIVERABLE SHORT SUMMARY FOR USE IN MEDIA

The European food system will evolve in the coming decades in the context of several important macro drivers such as the demographic and economic growth, technological progress, integration of global markets, or climate change. At the same time, it will be asked to not only provide enough food but also to contribute to the many goals stipulated in the 2030 Agenda for Sustainable Development as adopted by the United Nations General Assembly in 2015, including health, poverty eradication, responsible consumption and production, terrestrial and marine biodiversity conservation, as well as climate stabilization.

The aim of this paper is to provide a forward looking assessment of the baseline and alternative contextual scenarios in terms of their impacts on the sustainability of European Union (EU) food and nutrition security (FNS). Our approach, on the one hand, allows to identify the future challenges and opportunities for the EU agro-food sector, and on the other hand provides a basis against which agro-food policies and innovations can be tested and evaluated in terms of their contribution to sustainable development.

The assessment relies on a suite of state of the art economic models – the SUSFANS modeling toolbox. The geographic – EU *versus* global, sectorial – agro-food *versus* whole economy, as well as thematic – people *versus* markets *versus* environment, complementarity of the models allows for a truly comprehensive coverage of the various sustainability dimensions. The tool box is implemented on three contextual scenarios, including a baseline scenario, which represent a stakeholder based adaptation of the well-established Shared Socio-economic Pathways (SSPs).

The EU baseline is characterized by almost stagnating local population, moderate economic growth and technological change, as well as the current agro-food policies and domestic market protection. This leads in the EU to continuation of the current levels of total food consumption with a slight decrease in the share of fruits and vegetables, stagnation in the share of fish and, depending on the model, stagnation or even slight increase in ruminant meat consumption. Given the stagnating domestic demand, and projected decreases in producer prices, the growth of farm income from agricultural produce is highly depend on the competitiveness of EU products on international markets. The environment is projected to benefit from the stagnation or moderate increases in agricultural production in terms of stagnating GHG emissions, reduced fertilizer use, and a moderate increase in forests and areas for other natural vegetation.

Alternative contextual scenarios assume even a 10% decline in EU population contrasting with a 49% increase in the population in the rest of the world by 2050. Such a scenario would further accentuate the trends observed in the baseline.

Slowing down of the technological improvement compared to the baseline would among other things lead to a more than 10% increase in fertilizer use and an almost 5% decrease in natural vegetation areas compared to the baseline scenario in 2050. Interestingly, the EU farmers could benefit from a global slowdown in technological change, as the rest of the world would be catching up slower with the EU productivity, and thus compared to the baseline, EU could further expand its exports and production.

While climate change impacts would have only limited effect on food consumption in the EU, climate change policies compatible with Paris Agreement climate stabilization targets, when implemented in the form of a carbon tax, would lead to food consumption reduction, most pronounced in the case of ruminant meat, -10%. This decrease is relatively small compared with the global reduction of ruminant consumption, which would reach -20%. These developments are due to higher GHG emission efficiency of EU production compared with the rest of the world, as well as due to the lower price sensitivity of EU demand.

Overall, the projected stagnating or even decreasing demand for food in the EU provides opportunities to re-think the current EU food system to shift it further from quantity to quality. This would mean, on the one hand, to make it more sustainable from the environmental perspective by further improving its efficiency, and in specific contexts also by extensification, which would allow for the traditional coexistence of agriculture and other ecosystem services, and on the other hand, to further increase supply of agricultural products with high nutritional value, such as fruits and vegetables, or fish. As the future growth opportunities come from the international markets, where the competitiveness of EU production relies rather on the reputation of high safety standards and traditional quality, than on pure cost consideration, such a re-orientation of the domestic food system would not only improve the sustainability of the EU food and nutrition security, but also the business opportunities of EU farmers.

TEASER FOR SOCIAL MEDIA

Future food demand in European Union is projected to stagnate due to saturation by individual consumers and limited growth in European population. This provides a unique opportunity to re-think the food system "from quantity to quality". This shift would improve the nutritional value for consumers, provide new business opportunities for the farmers, and reconcile agricultural production with the environment.

The future socio-economic developments represent a unique opportunity to make the European food system great again – for people, businesses, and the environment.

ABSTRACT

This deliverable applies the SUSFANS modeling toolbox to quantify alternative contextual scenarios of macro drivers development with the aim to identify future challenges and opportunities for sustainability of food and nutrition security (FNS) in the European Union (EU). The deliverable provides an analysis of the complete set of contextual scenarios as defined in D10.1 and in addition a deep dive into the individual scenario drivers to consider their contribution to the challenge for sustainable EU FNS. This is the first attempt for a forward looking EU food system assessment along a comprehensive set of indicators stretching from consumers throug agro-businesses down to the environment. Our results suggest that stagnating EU food demand, resulting from already saturated individual demand and lacking future population growth, together with continued technological change, represent an opportunity for the environment but a challenge for agro-business enterprises, and on its own have a limited impact on the nutritional value of the human diets. In this context, high quality nutritional products represent an opportunity for both consumers and producers, at domestic and international markets. However, accompanying policies supporting further development and adoption by consumers of nutritional products, such as fruits and vegetables, or fish, on the one hand, and continuous improvement of environmental standards, on the other hand, will be necessary to untap these looming potentials.

INTRODUCTION

The European food system will evolve in the coming decades in the context of several important macro drivers such as the demographic and economic growth, technological progress, integration of global markets, or climate change. At the same time, it will be asked to not only provide enough food but also to contribute to the many goals stipulated in the 2030 Agenda for Sustainable Development as adopted by the United Nations General Assembly in 2015, including health, poverty eradication, responsible consumption and production, terrestrial and marine biodiversity conservation, as well as climate stabilization.

The overall objective of the work package 10 in SUSFANS is to provide foresight on the future development of sustainable food and nutrition security (SFNS) in the European Union (EU). This concept encompasses sustainable food systems and sustainable and balanced diets (Zurek et al., 2016). Our approach recognizes that the future of EU food system will be, on the one hand, outcome of the development of the above mentioned macro drivers, and on the other hand, of policies and innovations potentially contributing to sustainable development beyond the business as usual. For this deliverable, a suite of state of the art economic models - the SUSFANS model toolbox (Rutten et al. 2016, Kuiper et al. 2018) – was applied to quantify future scenarios of alternative developments, including a baseline, as defined in the SUSFANS contextual scenarios (HavlÍk et al. 2017). In parallel, assessment of agro-food policies and innovations is being carried out in deliverables D10.3 and D5.4, respectively. A comprehensive foresight synthesizing these three streams will ultimately be provided in D10.4.

Forward looking assessments of the European and global agri-food sector development have a very long tradition and are extensively used as a basis for policy impact assessment or as means to inform strategic investment decisions. OECD/FAO Agricultural Outlook, most recent edition OECD/FAO (2017), further refined for the European context in the form of the EU Agricultural Outlook, most recent edition DG AGRI (2017), makes the reference in EU. It provides baseline projections for the medium term, the most recent until 2030, focusing on agricultural markets and income, although recently also impacts on several environmental indicators have been considered. For long term baseline development, the work by the FAO Global Perspectives Studies team was for long time considered as authoritative, however it shared with the above mentioned Outlooks the relatively narrow focus on the agricultural sectors, and by now, the most recent edition of the "World agriculture towards 2030/2050" (Alexandratos and Bruinsma, 2012) is becoming outdated. For long term assessments, it is worth noting also the developments in the Integrated Assessment Modeling (IAM) community, which traditionally focused on mostly energy system modeling in support of the development of climate mitigation strategies within the Intergovernmental Panel on Climate Change (IPCC), which however improved substantially the agricultural sector representation relying on some of the models from the SUSFANS toolbox – GLOBIOM and MAGNET, in order to, on the one hand, provide robust insights in land based mitigation options potentials, and on the other hand, to be able to assess potential trade-offs with other goals such as food security (Hasegawa et al. 2018, Popp et al. 2017). Still, this work also covers only part of the food system and lacks the necessary detail for an EU level analysis.

The present study builds on the above mentioned efforts and brings them further in several dimensions key for a forward looking assessment of the sustainability of the EU food and nutrition security. First of all, it takes a comprehensive approach to the sustainability assessment, and puts the consumer, and the sustainability of his diet from nutritional perspective, if not in the center of the analysis, then at least at equal parts with other sustainability dimensions – economics and the environment. Second, it adopts a cross scale approach, focusing on EU but in the global context, where sustainability indicators can be provided for most of the EU members at the country level, but the same indicators are calculated also for all global regions, allowing to account for potential trade-offs and complementarities in domestic and global sustainability. Finally, the assessment covers both the medium and long term, providing a consistent framework for a wide range of policies assessment, going from market stabilization policies through agricultural and food policies up to climate mitigation Mid-century strategies in line with the Paris Agreement.

Besides providing an analysis of the complete set of contextual scenarios as defined in D10.1, with focus on the baseline scenario, the study carries out a deep dive into the individual scenario drivers to consider their contribution to the challenges for sustainable EU FNS. This approach allows to disentangle the underlying causes of future developments and thus to better focus the policy responses.

METHODS

Scenario design

Based on Deliverable 10.1 "Quantified SUSFANS scenario drivers ready to be used by the modeling toolbox" a set of 19 scenarios was quantified by the SUSFANS model cluster in this deliverable. Three contextual scenarios, eight scenarios that further decompose the effect of different challenges on the EU food and nutritional security (FNS), in particular related to macro-economic and technological developments and trade policy, and eight climate change related scenarios were quantified. The quantified scenarios encompass several dimensions/drivers that were identified in previous WPs to affect future FNS in the EU:

- Demographic and income trends: One of the drivers of future food demand and consequently FNS are socio-economic developments. These were identified in WP6 as an important scenario component and quantified in Task 10.1 in the scenario database.
- Technological change: Besides future food demand, the speed of change and character of technical change (adaptation of new technologies or technology transfer) is important for future FNS but also for environmental impacts of the agricultural production system.
- Policy context: The European agro-food sector develops within a complex policy framework. A prominent example examined here is international trade policy.
- Climatic change: Agriculture is on the one hand, a major source of greenhouse gas (GHG) emissions, and on the other hand, it will be one of the sectors most directly affected by climate change.

The reference scenario (REF0) is a baseline scenario aligned with the Shared Socio Economic Pathway 2 and represents a business as usual scenario (O'Neill et al., 2014; Fricko et al., 2016) with moderate challenges for food and nutritional security and climate change mitigation. In the reference scenario the continuation of historic trends with respect to population and GDP growth, technological change, and no climate change mitigation and climate change impacts are assumed. In order to test the robustness of results with respect to less favorable socio-economic developments, a scenario representing high challenges for EU sustainable FNS was implemented, the REF- scenario. To take into account also the potential alternative of highly positive development in socio-economic parameters and their capacity to contribute to solve the EU sustainable FNS issues, a contextual scenario representing low challenges for the EU FNS, REF+ scenario, was also applied. Table 1 provides the full list of scenarios quantified by the model toolbox.

Since the contextual scenario includes a combination of different scenario drivers that increase or decrease challenges for the EU FNS, additional scenarios were quantified based on the reference (REF0) scenario where additional socio-economic, technological, and trade policy challenges or climate change related scenario elements were included. Eight scenarios were quantified that include single challenges for EUs FNS one by one to test their impact and decompose results from the contextual scenarios while other scenario drivers were kept at REF0 levels. Finally, to quantify the impact of climate change and climate change mitigation on the EU FNS, seven different climate change impact scenarios and two climate change mitigation scenarios were quantified and contrasted with the REF0 scenario.

Table 1. SUSFANS scenario matrix quantified by the modeling toolbox.

Scenario acronym	Challenges				Climate change	
	GDP	POP	TEC	TRD	Mitigation	Impacts
REF0	REF0	REF0	REF0	REF0	no	no
REF-	GDP-	POP-	TEC-	TRD-	no	no
REF+	GDP+	POP+	TEC+	TRD+	no	no
GDP-	GDP-	REF0	REF0	REF0	no	no
GDP+	GDP+	REF0	REF0	REF0	no	no
POP-	GDP-	POP-	REF0	REF0	no	no
POP+	REF0	POP+	REF0	REF0	no	no
TEC-	REF0	REF0	TEC-	REF0	no	no
TEC+	REF0	REF0	TEC+	REF0	no	no
TRD-	REF0	REF0	REF0	TRD-	no	no
TRD+	REF0	REF0	REF0	TRD+	no	no
CCI8p5_HadGEM2-ES	REF0	REF0	REF0	REF0	no	RCP 8.5 HadGEM2-ES
CCI8p5_HadGEM2-ES_noCO2	REF0	REF0	REF0	REF0	no	RCP 8.5 HadGEM2-ES noCO2
CCI8p5_IPSL-CM5A-LR	REF0	REF0	REF0	REF0	no	RCP 8.5 IPSL-CM5A-LR
CCI8p5_GFDL-ESM2M	REF0	REF0	REF0	REF0	no	RCP 8.5 GFDL-ESM2M
CCI8p5_MIROC-ESM-CHEM	REF0	REF0	REF0	REF0	no	RCP 8.5 MIROC-ESM-CHEM
CCI8p5_NorESM1-M	REF0	REF0	REF0	REF0	no	RCP 8.5 NorESM1-M
MTG2p0C	REF0	REF0	REF0	REF0	RCP 2.6	RCP 2.6_HadGEM2-ES
MTG1p5C	REF0	REF0	REF0	REF0	RCP 1.9	RCP 2.6_HadGEM2-ES

SUSFANS modeling toolbox

The SUSFANS modeling toolbox conceptualized by Rutten et al. (2016) connects models that stand out in terms of capacity to model EU agriculture and its policies (CAPRI), land use and related environmental parameters globally (GLOBIOM) and economy-wide effects including endogenous income changes

(MAGNET) to individual food intake data and the diet optimization built on these micro data (SHARP) (Kuiper et al. 2018). Consistent implementation of the toolbox allows for an integrated assessment across spatial scales and across a comprehensive set of indicators for assessment of the sustainability of EU food system.

The SUSFANS sustainability metrics covers following four dimensions: balanced diets for EU citizens (PEOPLE), reduced environmental impacts (PLANET), competitive agri-food businesses and equitable outcomes of the food system (PROFIT). The ultimate metrics relies on a hierarchical approach to aggregating from *Individual Variables* to *Derived Variables* to *Aggregate Indicators* to *Performance Metrics*, with the aim to provide decision makers with a small set of powerful indicators (Zurek et al. 2017).

While the approach has been successfully tested on several cases (Götz et al. 2017), the full implementation across the toolbox is still ongoing. Here, we thus still rely on individual variables, which have been however selected to provide good insight in the considered sustainability dimensions (Table 2). The PEOPLE indicators focus on the nutritional value of EU diets, and besides the standard per capita energy availability, cover also the role of ruminant meat, fruits and vegetables, and fish in the diets, as well as an indicator of relative availability of qualifying nutrients compared to disqualifying. Enhancement of the existing economic models by these indicators is one of the major achievements of this project (Kuiper et al. 2018). For PLANET, GHG emissions from agricultural production are taken as a proxy of the pressure on climate, fertilizer use is reported as a potential indicator of water and air pollution, and area of natural vegetation and of forests, as indicators for biodiversity. Finally, total agricultural production and the share of net exports compared to domestic production have been retained as indicators of business opportunities in the PROFIT category.

Table 2. Preliminary indicators of EU food and nutrition security sustainability.

Area	Indicator name	Description
PEOPLE	Total calories	Food availability in kcal per capita per day
	Rum calories	Beef and sheep and goat meat availability in kcal/cap/day
	Nutr. av. (fruits)	Share of fruits in available food expressed on energy basis
	Nutr. av. (fish)	Share of sea food in available food expressed on energy basis
	Nutr. av. (vegetables)	Share of vegetables in available food experessed on energy basis
	Nutrient rich diet 8	Relative availability of 8 qualifying nutrients over 1 disqualifying nutrient expressed on energy basis
PLANET	Ag GHG emissions	Methane (CH4) and Nitrous oxide (N2O) emissions from agriculture in tons CO2 equivalent
	Fertlizer use	Total use of synthetic nitrogen fertilizer in tons of nutrient
	Forest area	Forest area in hectares
	Natural vegetation	Area of other natural vegetation in hectares
PROFIT	Ag production	Total agricultural production in dry matter tons
	Net ag trade	Share of net exports over domestic production

RESULTS

Baseline scenario (REF0)

People - demand side indicators

Macro-economic developments such as population and GDP growth are an important driver of global agricultural demand especially in developing and emerging countries. Between 1970 to 2010 global population almost doubled (+90%) and global GDP more than tripled (+250%) resulting in a substantial increase in demand for agricultural commodities such as cereals (+100%), meat (+190%), or milk (+115%) according to FAOSTAT data. While strong population growth is expected by 2050 especially in developing and emerging countries, in the European Union (EU), population is anticipated to increase only very moderately over the coming decades in our baseline scenario (REF0). Within member states, growth rates vary with some countries like Luxemburg, Belgium or Sweden showing more pronounced population growth of up to 40% (Figure 1), whereas in the Baltic countries population is projected to decrease until 2050. At aggregate EU level, a stabilization of population at around 530 million people is anticipated. In contrast, global population is expected to continue to increase over the next 40 years, though at lower pace, to around 9 billion people (+30% compared to 2010) by 2050.

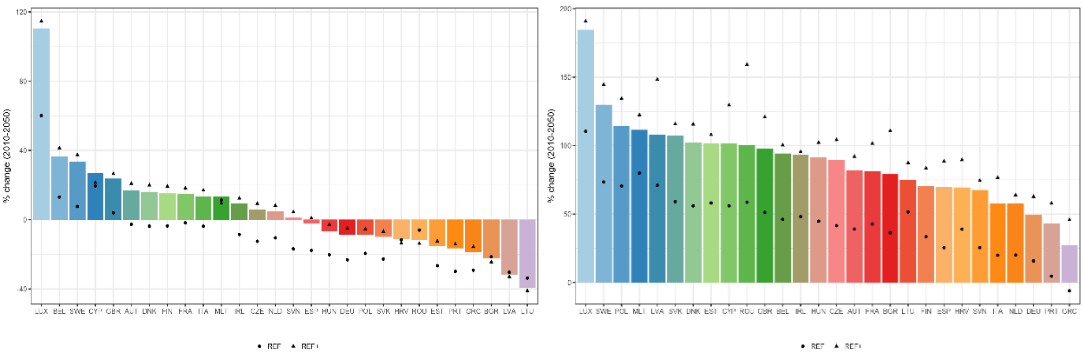

Figure 1. Relative population (left) and GDP (right) change in EU28 in baseline scenario (REF0) by 2050 compared to 2010.

In contrast to population, gross domestic product (GDP) in the EU is still expected to significantly increase though less rapidly compared to the rest of the world. By 2050, GDP is projected to increase by around 80% resulting trough the stagnating population growth in almost doubling of GDP per capita. In contrast to population growth, GDP growth is distributed more equally across EU member states with the majority of countries achieving a GDP increase by

50-100% by 2050 (Figure 1). At global scale even more pronounced effects are anticipated as global GDP is projected to almost triple by 2050 (+180% compared to 2010) resulting in a doubling of GDP per capita too. Especially developing and emerging regions like China, India, or Sub-Saharan Africa experience significant GDP per capita growth by 2050.

Despite the significant GDP per capita increases in the EU by 2050, per capita demand for agricultural commodities increases only slowly because at even at the initial income levels the demand is already fairly inelastic. Together with the stabilization in population, these trends drive only a modest growth of EU demand for agricultural commodities (on average 10% across models, Figure 2) in the baseline scenario by 2050. The increase in demand for agricultural products is mostly driven by additional crop feed demand for livestock production i.e. pig and poultry, and growing demand for oilseeds. Projected demand quantities are in similar range with the most recent OECD-FAO Agricultural Outlook (OECD/FAO, 2017; further referred to as the Outlook) for the EU agriculture which anticipates mainly an increase in demand for coarse grains by 11% (4-9% across models), wheat by 8% (6-13% across models), and oilseeds by 16% (10-18% across models) until 2030. For livestock products, the Outlook anticipates a stagnation in ruminant meat consumption levels in the EU while SUSFANS models project small increases between 2-8% by 2050. The trend in demand for non-ruminant products (pig and poultry meat, eggs) is again comparable (+9% in the Outlook, 7-11% across SUSFANS models).

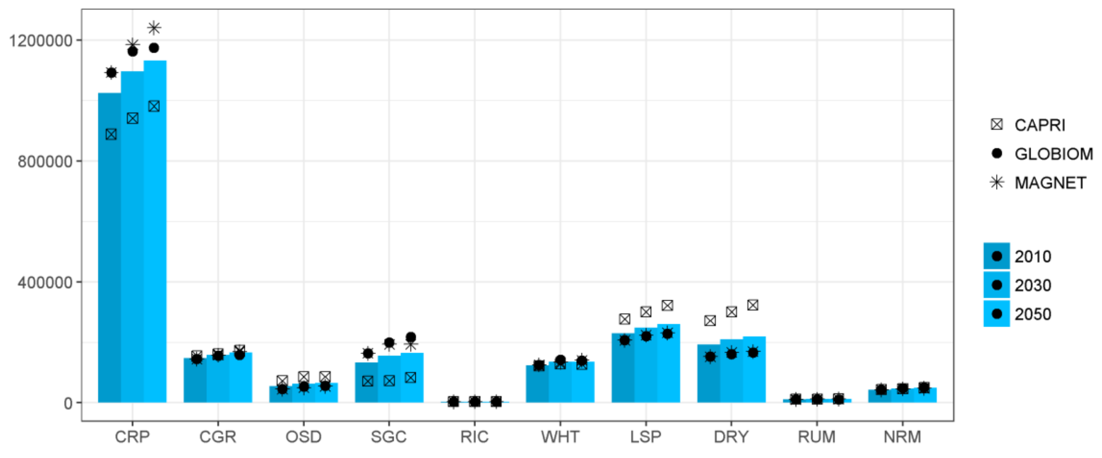

Figure 2. Development of crop and livestock consumption in baseline scenario in the EU28 [1000 t] (CRP – total crops, CGR – coarse grains, OSD – oil seeds, SGC – sugar crops, RIC – rice, WHT – wheat, LSP – total livestock products, DRY – dairy products, RUM – ruminant meat, NRM – pork and poultry).

At global scale, the sustained population and GDP growth, especially in regions like China, India or Sub-Saharan Africa, drives continued growth in demand for agricultural products, in particular livestock products and feed crops, and total agricultural commodities demand increases by around 50-70% across models at global scale in 2050.

Models consistently project limited growth (CAPRI) or even stabilization (GLOBIOM, MAGNET) in per capita food consumption in the EU by 2050 (Figure 3) related to the underlying macro-economic drivers (Figure 1). While slightly more pronounced growth is anticipated for pig, poultry, milk and oilseeds, demand for cereals and ruminant meat are projected to grow only marginally. On average, calorie consumption increases from around 3600 to 3700 kcal/cap/day in the EU by 2050, the majority of the increase being related to livestock products. Across EU member states, demand increases more significantly in Eastern European countries such as Bulgaria, Croatia or Romania as economic development catches up, while a stagnation in food demand is anticipated for Central and Northern European countries.

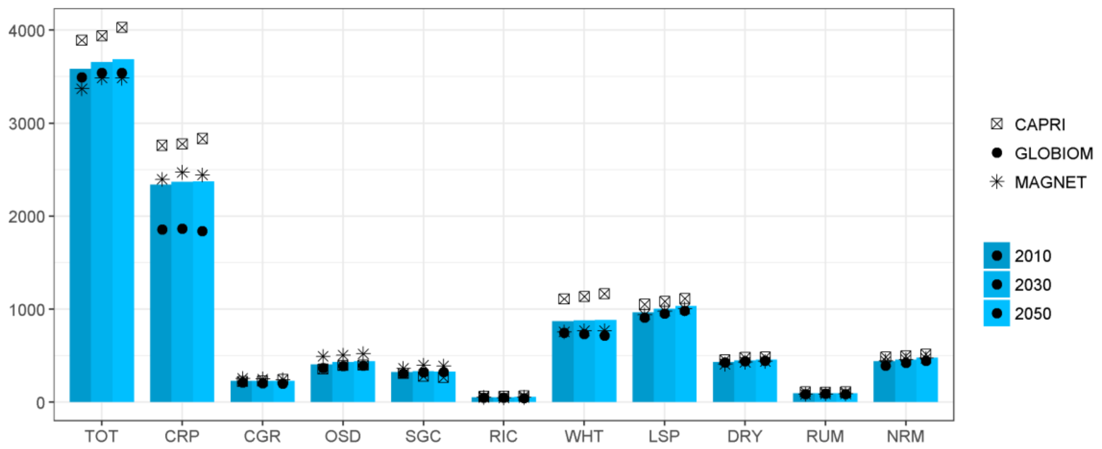

Figure 3. Calorie consumption across models in the baseline scenario for EU28 [kcal/capita/day] (TOT – total, CRP – total crops, CGR – coarse grains, OSD – oil seeds, SGC – sugar crops, RIC – rice, WHT – wheat, LSP – total livestock products, DRY – dairy products, RUM – ruminant meat, NRM – pork and poultry).

Outside Europe more significant growth in food demand and calorie consumption is projected as developing and emerging regions become wealthier. Global per capita calorie consumption increases by around 12% reaching 3100 kcal/cap/day on average by 2050. Especially countries in Sub-Saharan Africa or Asia can significantly increase per capita calorie intake levels driven by significant GDP per capita growth. Even though consumption of livestock calories increases over time (+60 kcal/cap/day by 2050), the majority of additional calories at global scale origins from crop products such as coarse grains (+110 kcal/cap/day) and oilseeds (50 kcal/cap/day).

Profit: Supply side & trade indicators

Crop yields are projected to grow only moderately by around 16-30% in the EU by 2050 whereas significant yield growth is anticipated for the rest of the world. At global scale, crop yields increase by around 33-59% by 2050 and regions outside the EU are able to increase their competitiveness and catch up with respect to crop productivities. Inside the EU, especially oilseed yields are expected to grow substantially by around 50% supported by increasing demand trends whereas more limited yield growth is projected for cereals and other crops where less pronounced demand increases are anticipated. The Outlook for the EU anticipates yield increases by 18-20% for rapeseed and soybeans, 18% for wheat, 17% for other cereals, and 15% for maize in the EU until 2030. While for wheat (14-19% across models) and coarse grains (7-19% across models) our projections are close to the Outlook projections, SUSFANS models anticipate more optimistic yield development for soybeans.

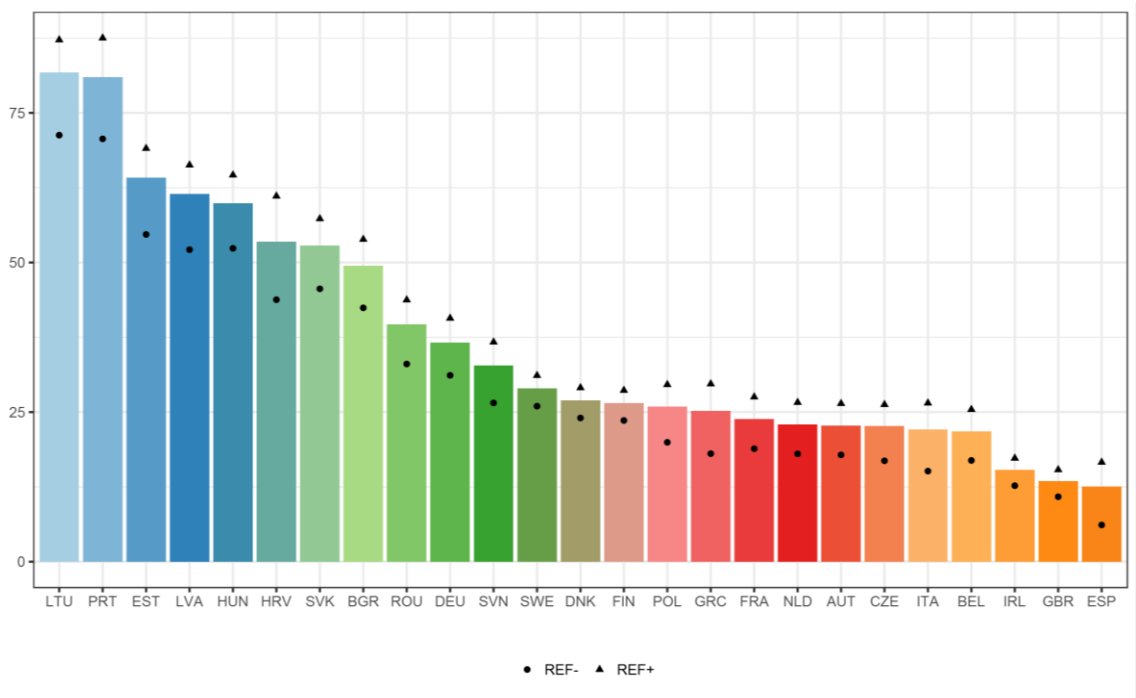

Figure 4. Exogenous technological change in crops at member state level in the baseline scenario (REF0) by 2050 compared to 2010.

Stabilization of agricultural commodity demand and modest yield growth explain the continued decrease in agricultural areas inside the EU though at lower rate compared to historic trends. On average, cropland is projected to decline by around 4.5 and 7 Mha until 2030 and 2050, respectively, with cereals like coarse grains or wheat being most affected. In GLOBIOM and MAGNET, crop area decreases are more pronounced compared to CAPRI (Figure 5). Projections are consistent with the Outlook for the EU which anticipates a decline in cropland by around 5 Mha until 2030. With respect to pasture areas the models project a less pronounced decrease by on average 1.5 Mha by 2050 due to the increasing demand for milk products inside the EU. By 2030 the drop in pasture area is slightly less pronounced than the Outlook projections of 2.5 Mha for the EU. Agricultural area developments in the EU are in contrast to global developments where agricultural areas are projected to steadily increase by around 20% for crop products and 6% for livestock products driven by demand growth.

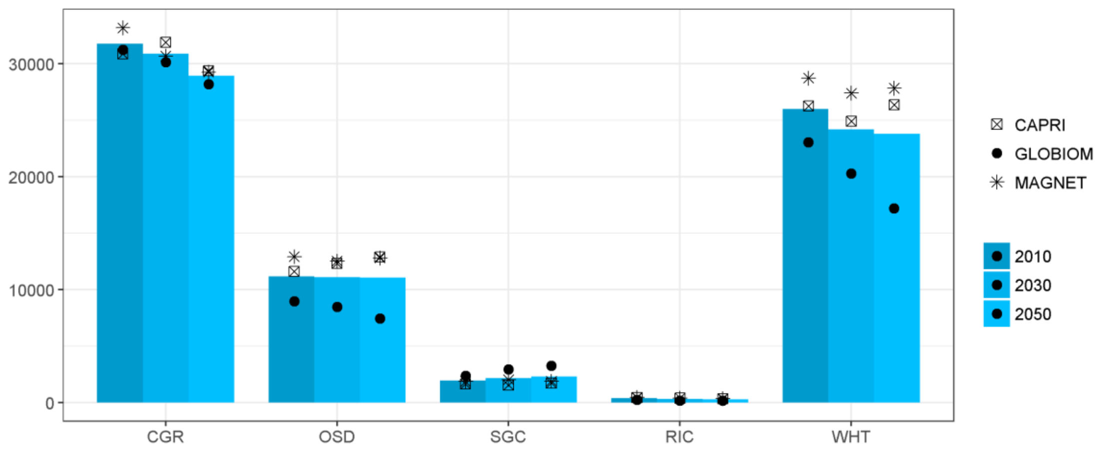

Figure 5. Crop area development in EU28 in the baseline scenario [1000 ha] (CGR – coarse grains, OSD – oil seeds, SGC – sugar crops, RIC – rice, WHT – wheat).

Changes in crop production in the EU mirror yield and area developments across models. Whereas GLOBIOM projects a stabilization in crop production beyond 2030 in the EU driven by modest domestic demand growth and continued decrease in agricultural areas, MAGNET and CAPRI project a steady increase in crop production and increasing net exports outside Europe. For livestock products all models consistently project modest production increases driven by continued demand for livestock commodities i.e. dairy milk, pig and poultry meat (Figure 6). On average, agricultural production in the EU increases by around 15% for both crop- and livestock commodities. At global scale, agricultural production increases much more significantly with global crop production rising by around 65% and livestock production by around 55% by 2050.

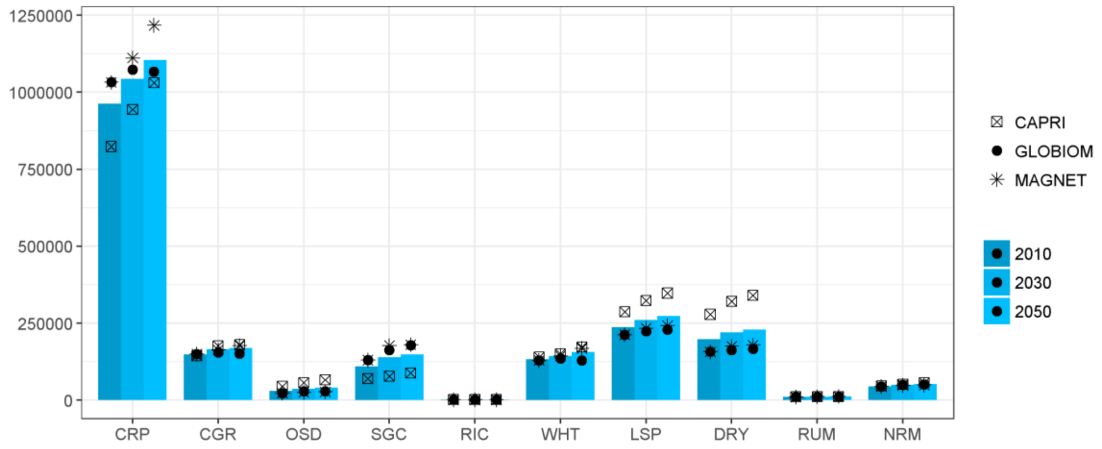

Figure 6. Development of crop (left) and livestock (right) production in EU28 in the baseline scenario [1000 t] (CRP – total crops, CGR – coarse grains, OSD – oil seeds, SGC – sugar crops, RIC – rice, WHT – wheat, LSP – total livestock products, DRY – dairy products, RUM – ruminant meat, NRM – pork and poultry).

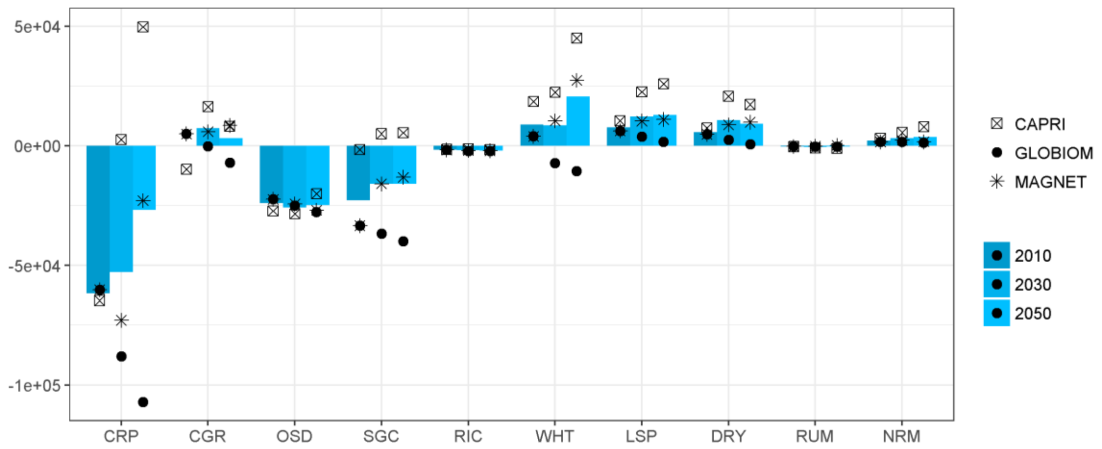

Figure 7. Development of net trade in major crop (left) and livestock (right) products in EU28 in the baseline scenario [1000 t] (CRP – total crops, CGR – coarse grains, OSD – oil seeds, SGC – sugar crops, RIC – rice, WHT – wheat, LSP – total livestock products, DRY – dairy products, RUM – ruminant meat, NRM – pork and poultry).

Planet: environmental indicators

Fertilizer use is closely linked to development of agricultural production and technological change. Due to stagnation in agricultural production in the EU, fertilizer use related to crop production is also slightly decreasing in the long run with potential benefits for the environment. While in GLOBIOM fertilizer use is projected to decrease by 3% compared to 2010, CAPRI anticipates, driven by more pronounced production growth, a slight increase in fertilizer use of 3% by 2050. Across EU member states quite diverse effects can be observed ranging from significant decreases in fertilizer use i.e. in Spain or Czech Republic, up to modest increases i.e. for Bulgaria. While fertilizer use is projected to increase for sugar crops and oilseeds, fertilizer demand for other crops, in particular cereals, is declining in the EU. In contrast to the modest development of fertilizer use in the EU, global fertilizer demand is projected to grow much more significantly, +70% by 2050.

Agricultural CH_4 (enteric fermentation, manure management, and rice cultivation) and N_2O (synthetic fertilizer, manure management, manure dropped and applied to soils) are projected to only marginally increase by 2050 related to the modest increase in agricultural production in the EU and continuous improvement in greenhouse gas (GHG) efficiency. At EU level, the livestock sector is responsible for the majority of non-CO_2 emissions. While CAPRI and GLOBIOM anticipate a stabilization of livestock emissions at 2010 levels over time, MAGNET projects an increase by 15%. Depending on the model used, N_2O emissions from crop production are projected to either slightly in- or decrease. Overall, non-CO_2 emissions from agriculture are expected to remain rather stable (0-6% increase) until 2050. At global scale however, agricultural emissions from crop production increase by 24-33% and emissions from livestock production even by 31-55% compared to 2010 levels.

Baseline summary

Overall, the models implemented in the SUSFANS toolbox agree that with respect to the considered sustainability indicators the baseline scenario within the EU shows stagnation until 2050 when compared to 2010. Related to stabilization of population and moderate GDP growth, only marginal growth in total food demand is projected. This applies also to ruminant meat consumption. The share of fruits and vegetables in the diets declines. This is at odds with the need to increase the share of fruits and vegetables required for a healthy nutrition. Increases in production levels can be expected in the livestock sector where demand for animal products is still projected to continue to increase, in particular outside of the EU. However, as developing and emerging countries continue to catch up in terms of crop- and livestock productivities, and become increasingly competitive, the opportunities for EU exports are uncertain. CAPRI and MAGNET project substantial increases in EU supply accompanied by increasing exports, GLOBIOM projects rather stable production for most of the commodities besides dairy. Together with projected decreasing producer prices, these developments put pressure on farmers' real incomes. The slowly growing or stagnating production together with continued improvements in efficiency of the sector lead represent opportunities for improved environment. Fertilizer demand and emissions are projected to stabilize or even slightly decline. Sustained yield growth results in continued decline in agricultural areas with potential co-benefits for biodiversity or climate change mitigation i.e. through afforestation.

The EU developments contrast with the global projections, where on average a sustained population and economic growth, together with corresponding shits in dietary preferences, lead to substantial increase in per capita food demand satisfied through almost doubling of agricultural production, accompanied by substantial increase in GHG emissions and fertilizer use, as well as decrease in natural areas.

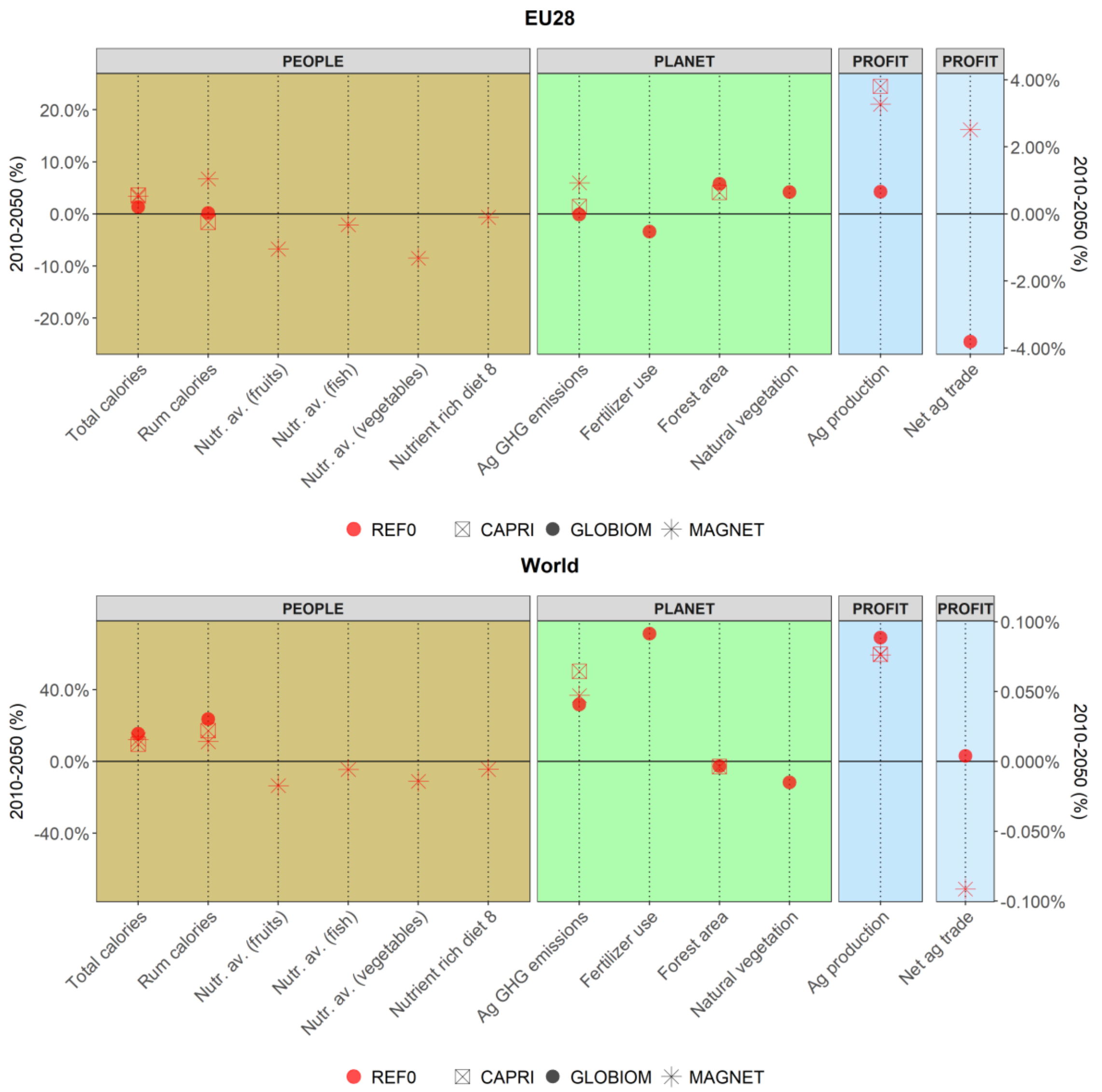

Figure 8. Relative change for people, planet, and profit indicators in baseline (REF0) scenario by 2050 compared to 2010.

Sensitivity to individual drivers

Population development

The EU, together with Former USSR and China, is among the few regions with stagnating population in the baseline (REF0) scenario and even decreasing population in the high challenge scenario (POP-) by 2050 (Figure 9). At the same time, only marginal increase in population is anticipated in the low challenge scenario with increased population growth (POP+) in the EU. Hence, there is no scenario, where growing EU population were a key driver of additional food demand over the next decades. Impact on population growth is not uniform across global regions. While the EU is experiencing a population decline at aggregate level in the POP- scenario, for most regions outside the EU significant population growth is projected resulting in highest global population of the three considered scenarios.

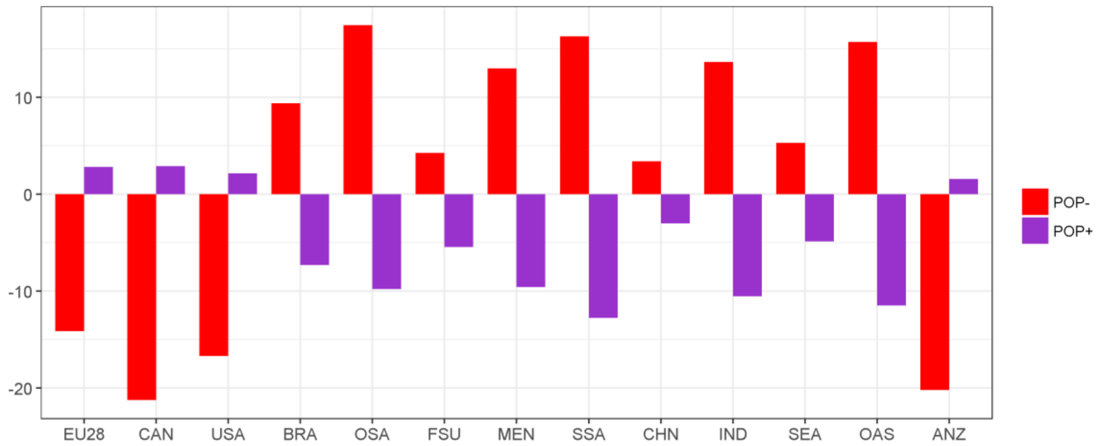

Figure 9. Relative change in population across population scenarios (POP-, POP+) compared to the baseline (REF0) scenario by 2050 [%] (EU28 – European Union, CAN – Canada, USA – United States, BRA – Brazil, OSA – Rest of Latin America, FSU – Former USSR, MEN – Middle East and North Africa, SSA – Sub-Saharan Africa, CHN – China, IND – India, SEA – South East Asia, OAS – Other Asia, ANZ – Australia and New Zealand).

Given the relatively low cost-competitiveness of EU production compared to other regions and the catching up of developing regions with respect to agricultural productivities, the decreasing demand (Figure 10) translates in further reduction of EU agricultural production which may increase the pressure on EU farm structures. Total crop- and livestock demand decreases on average across models in the POP- scenario in the EU by around 10% compared to the baseline in 2050 whereas in the POP+ scenario only modest increases in agricultural demand can be realized related to the underlying population growth assumptions (Figure 9).

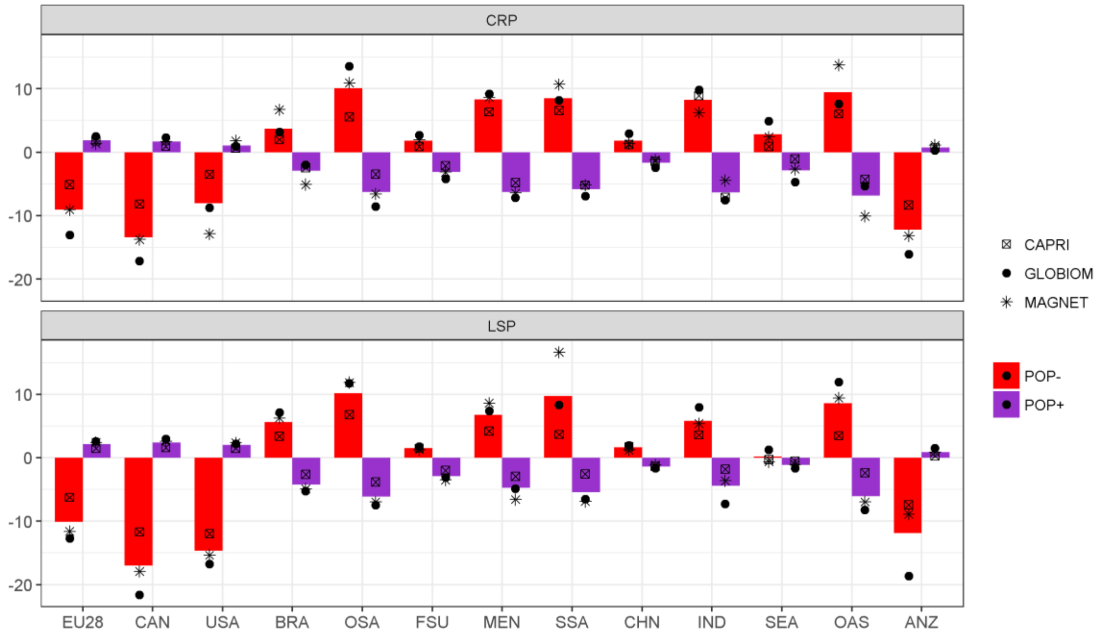

Figure 10. Relative change in crop (upper) and livestock (lower) demand across population scenarios (POP-, POP+) compared to the baseline (REF0) scenario by 2050 [%] (EU28 – European Union, CAN – Canada, USA – United States, BRA – Brazil, OSA – Rest of Latin America, FSU – Former USSR, MEN – Middle East and North Africa, SSA – Sub-Saharan Africa, CHN – China, IND – India, SEA – South East Asia, OAS – Other Asia, ANZ – Australia and New Zealand).

The negative economic impacts of population growth are clearly visible in the POP- scenario where the EU agricultural sector suffers from declining domestic demand while at the same time it does not benefit through international trade (Figure 11), due to lacking competitiveness, from increasing food demand in Asia and Africa. Despite the negative impacts on economic indicators (Figure 11), nutrition and food security indicators such as per capita food consumption are not significantly impacted and may actually indirectly benefit from decreasing overall demand and related price decreases, such as captured by the CAPRI model. In particular, prices for livestock products are projected to decrease across EU member states in the POP- scenario related to the decline in agricultural demand. Varying population projections have also no significant impact on nutritional security in- and outside Europe as nutrient availability remain unaffected. Moreover, environmental impacts of agricultural production in the EU decrease in the POP- scenario, with about a 10% decrease in fertilizer use and GHG emissions, and a 10% increase in natural vegetation areas.

The EU results contras again with the global developments, where growing population under POP- leads to substantial decrease in food availability per capita, as well as in the quality of the food – the share of fish, and fruits and vegetables in the diets decreases compared to the REF0 scenario. At the same time, the overall food demand still increases, leading to an increase in agricultural production and farmers' income. This positive economic development goes however hand in hand with negative environmental effects through increased GHG emissions and fertilizer use.

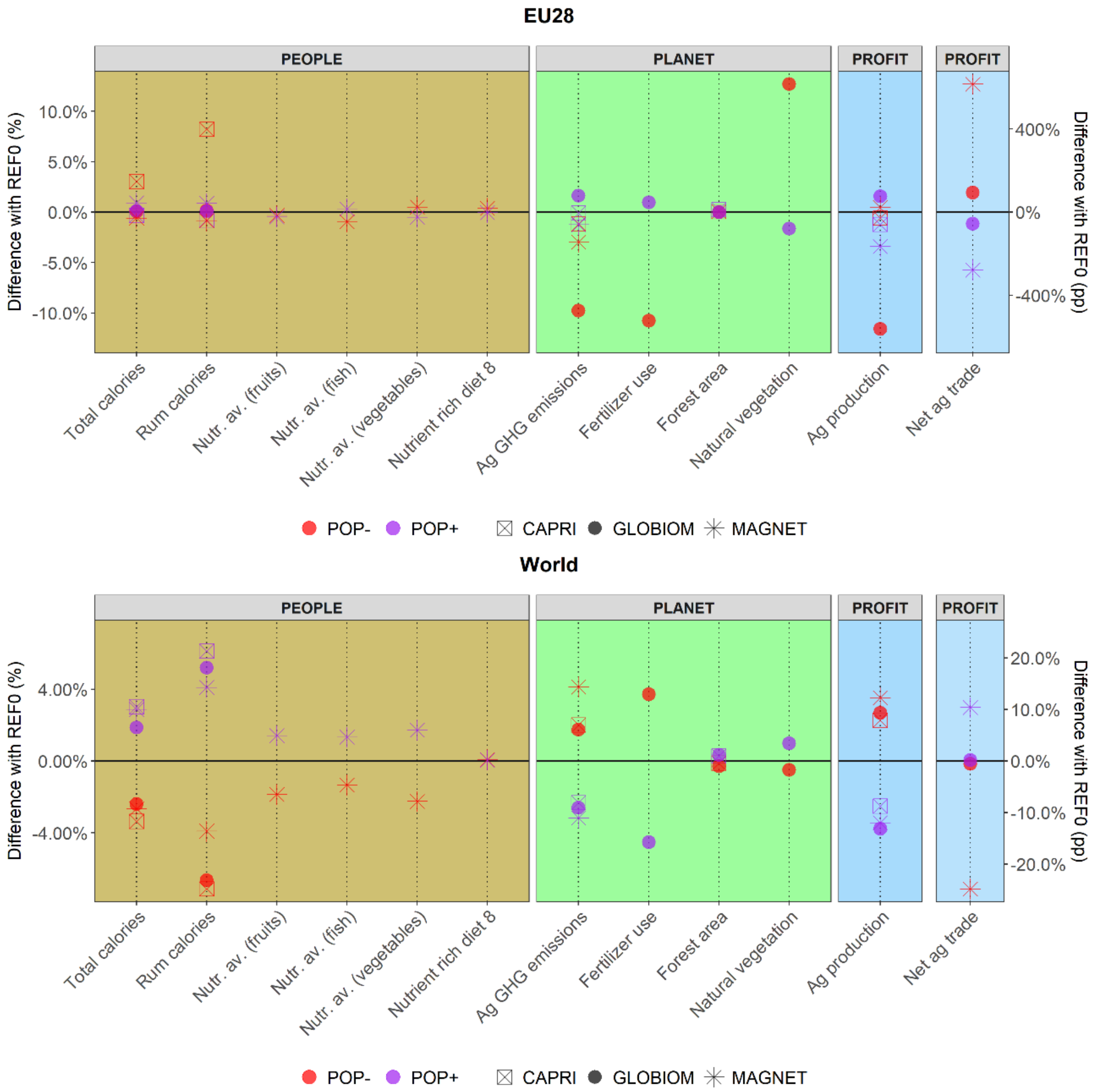

Figure 11. Relative change for people, planet, and profit indicators across population scenarios (POP-, POP+) compared to the baseline (REF0) scenario by 2050.

GDP development

Similarly to population, GDP in the EU is more likely to be negatively impacted across (GDP) scenario variants (-20% in the REF0_GDP- compared to REF0 by 2050) rather than grow more significantly than projected in the REF0 scenario (Figure 12).

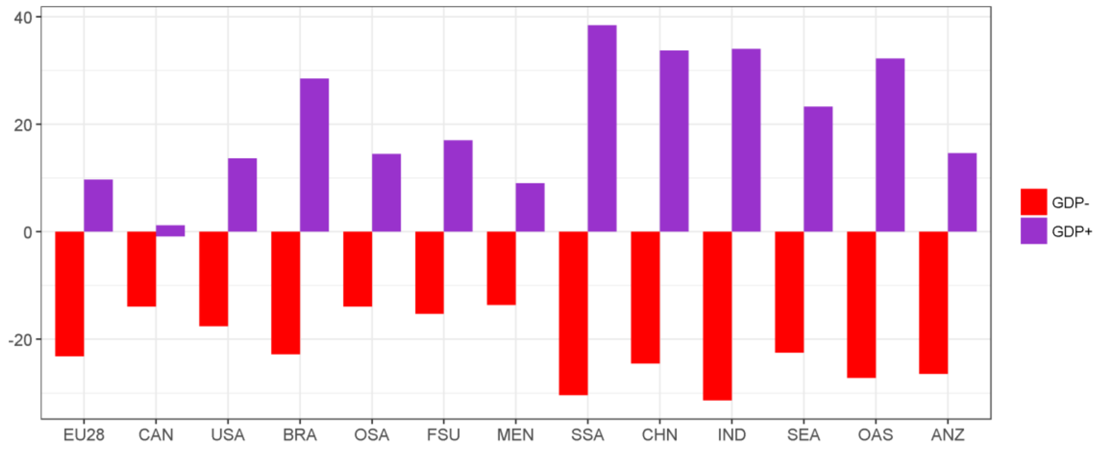

Figure 12. Relative change in GDP across GDP scenarios (GDP-, GDP+) compared to the baseline (REF0) scenario by 2050 [%] (EU28 – European Union, CAN – Canada, USA – United States, BRA – Brazil, OSA – Rest of Latin America, FSU – Former USSR, MEN – Middle East and North Africa, SSA – Sub-Saharan Africa, CHN – China, IND – India, SEA – South East Asia, OAS – Other Asia, ANZ – Australia and New Zealand).

Model results show that GDP growth does not impact agricultural production significantly in the EU as demand is rather inelastic (as in other high-income regions) to income changes (Figure 14). GDP scenario variants show approximately half the impact on the EU agricultural production levels as compared to the population scenarios (POP-, POP+). While population growth does not impact significantly per capita food consumption, increased GDP growth results in some demand growth in particular for livestock products (Figure 13). Mostly Eastern European and Baltic countries may experience further increases in per capita calorie intake levels. Interestingly, decreased GDP growth seems to have a somewhat positive impact on nutrient availability in the diet as it increases the share of vegetables and fruits consumed. At global scale, impacts of GDP growth on consumer's and environment are much more pronounced.

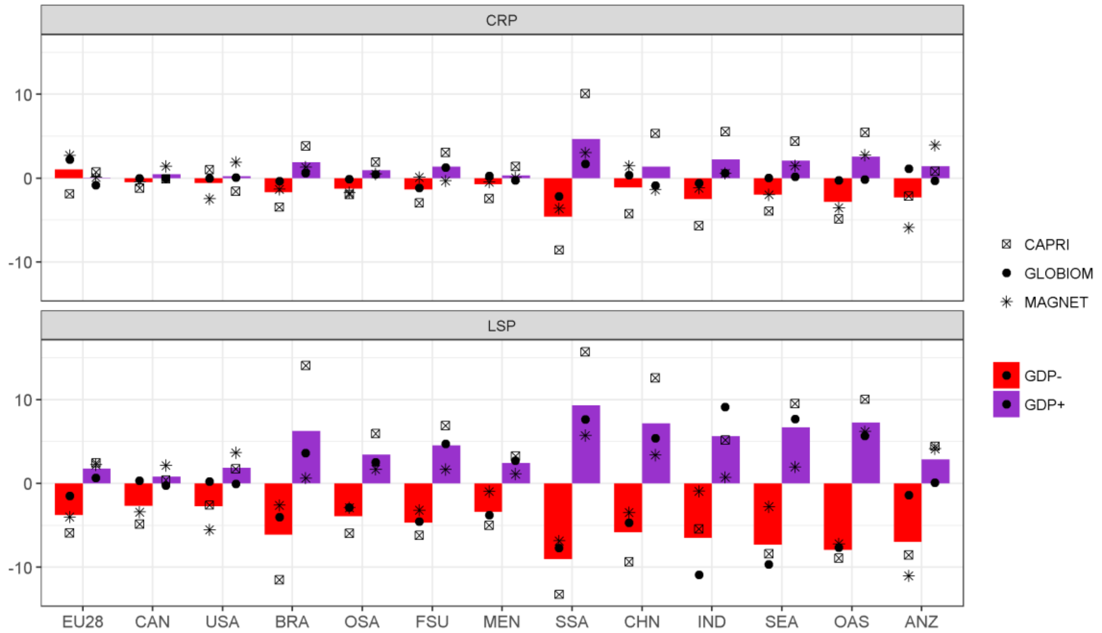

Figure 13. Relative change in total crop (upper) and livestock (lower) calorie consumption across GDP scenarios (GDP-, GDP+) compared to the baseline (REF0) scenario by 2050 [%] (EU28 – European Union, CAN – Canada, USA – United States, BRA – Brazil, OSA – Rest of Latin America, FSU – Former USSR, MEN – Middle East and North Africa, SSA – Sub-Saharan Africa, CHN – China, IND – India, SEA – South East Asia, OAS – Other Asia, ANZ – Australia and New Zealand).

We conclude that expected population growth plays a more important role for the EU's agricultural sector than GDP growth since per capita food consumption (in particular crop products) is rather inelastic to additional income growth in the EU. Interestingly, lower GDP leads to a lower share of fish in diets, but higher share of fruits and vegetables.

Globally, both macro-economic drivers significantly shape the environmental and socio-economic impact of the food system.

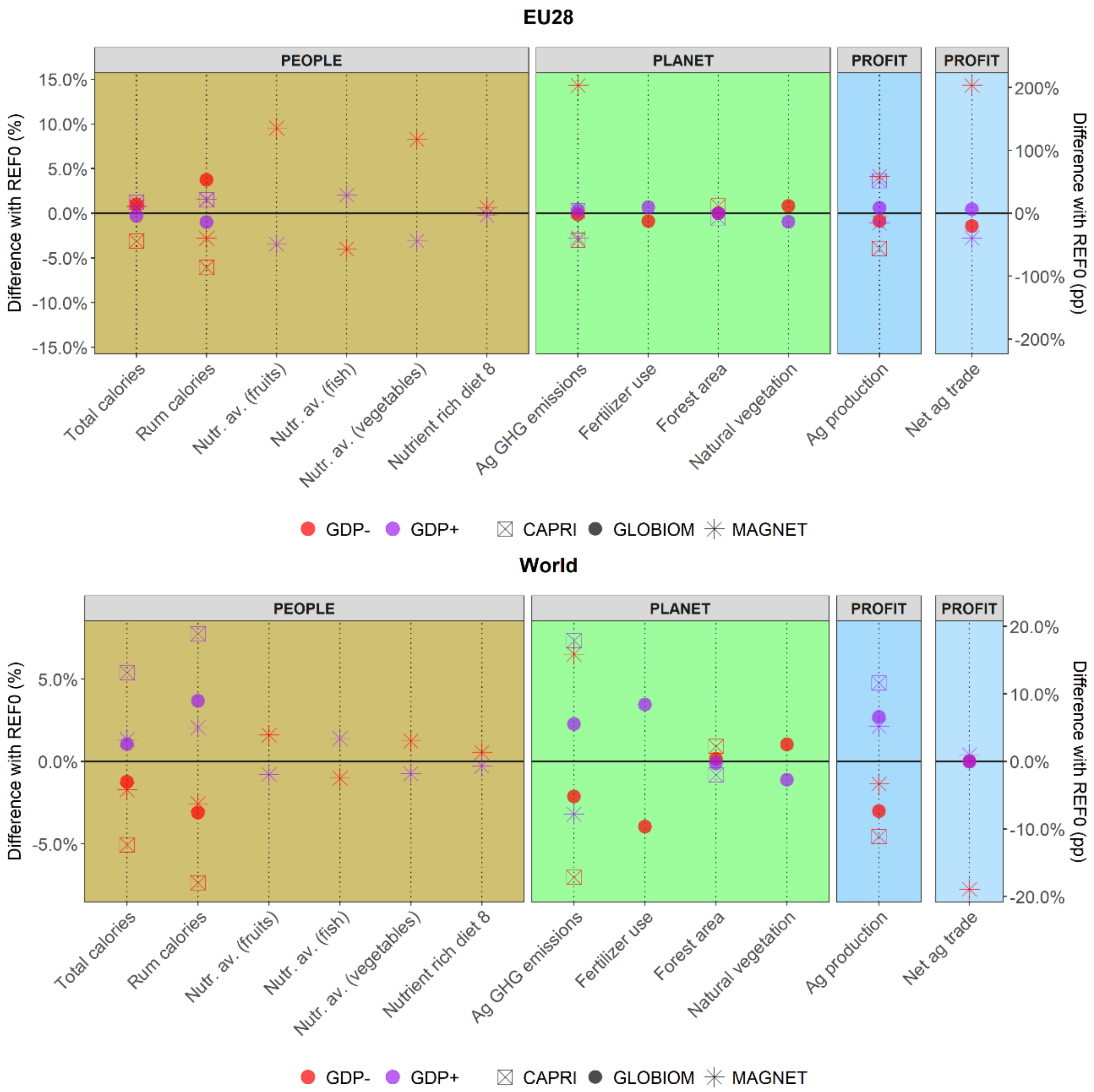

Figure 14. Relative change for people, planet, and profit indicators across GDP scenarios (GDP-, GDP+) compared to the baseline (REF0) scenario by 2050.

Technological change

Sustained technological progress is key to limit GHG emissions, use of inputs and resources. Interestingly EU farmers actually benefit in the low tech scenario (TEC-) as they become relatively more competitive compared to the rest of the world due to high current productivities while developing regions do not manage to catch up as fast as in the baseline scenario (Figure 15).

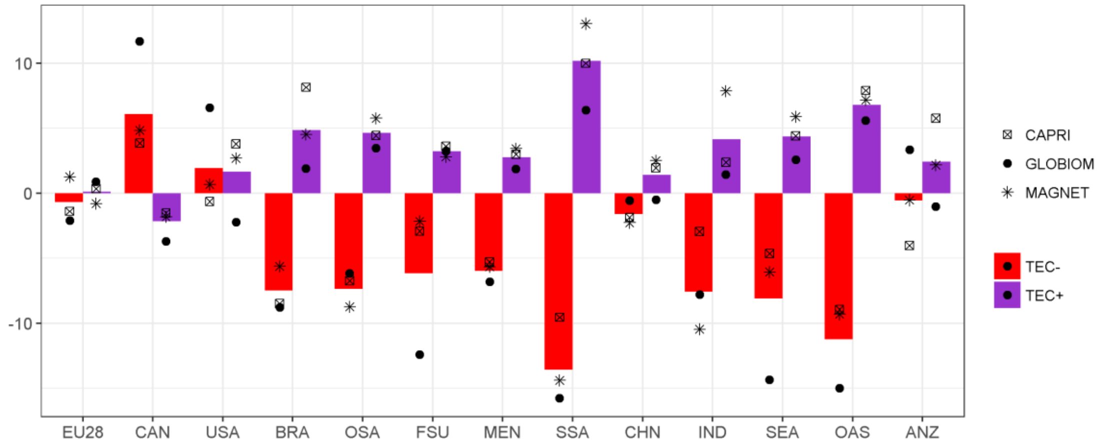

Figure 15. Relative change in crop yields across technological change scenarios (TEC-, TEC +) compared to the baseline (REF0) scenario by 2050 [%] (EU28 – European Union, CAN – Canada, USA – United States, BRA – Brazil, OSA – Rest of Latin America, FSU – Former USSR, MEN – Middle East and North Africa, SSA – Sub-Saharan Africa, CHN – China, IND – India, SEA – South East Asia, OAS – Other Asia, ANZ – Australia and New Zealand).

Consequently, the EU expands production and exports in the TEC- scenario compared to the REF0 scenario while at global scale agricultural production decreases. Assumptions on technological change most visibly impact nitrogen fertilizer use and with increasing productivities, environmental impacts i.e. on GHG emissions can be reduced (Figure 16). The TEC+ scenario also yield co-benefits for avoided land use change and conversion of other natural vegetation to agriculture in the EU. While technological change itself does not impact nutrient availability in diets in the EU, at world level slower technological change would reduce food availability.

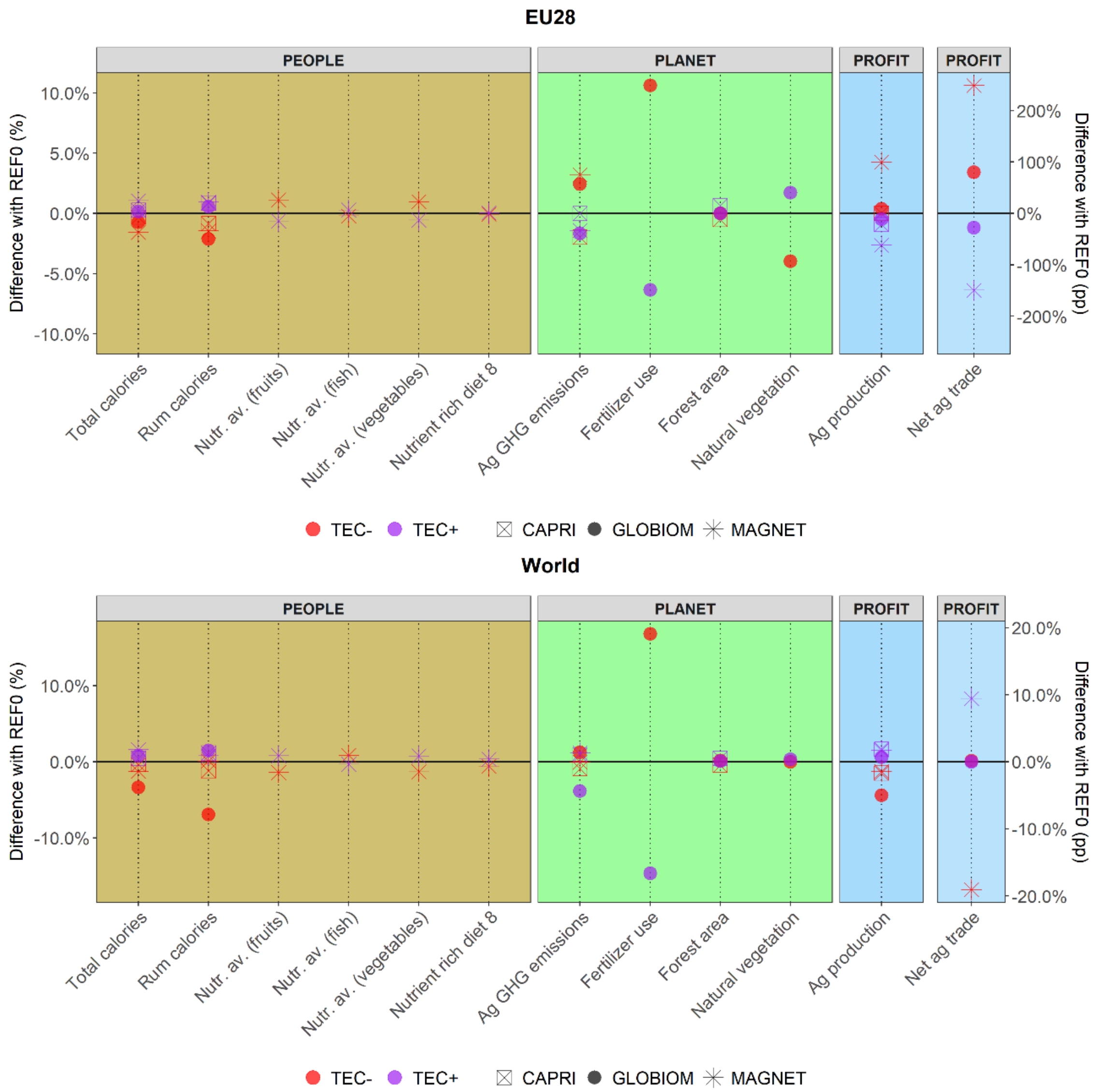

Figure 16. Relative change for people, planet, and profit indicators across technological change scenarios (TEC-, TEC+) compared to the baseline (REF0) scenario by 2050.

International trade policies

Increasing trade barriers, scenario TRD-, would have almost no effect on EU food availability and its nutritional quality, except for a decrease in ruminant meat availability, which in the EU context could contribute to healthier diets. It would lead to a slight increase in domestic agricultural production and producer prices, contributing to improved farm income, with some negative effects on the environment in the form of increased fertilizer use and reduction in natural vegetation area. Trade liberalization, TRD+, would in particular lead to increased ruminant meat availability, and overall slight deterioration of the nutritional value of the EU diets. Through slightly reduced agricultural production and further reduced agricultural prices, the farmers income would on average be negatively affected. However, the EU environment would benefit (Figure 17).

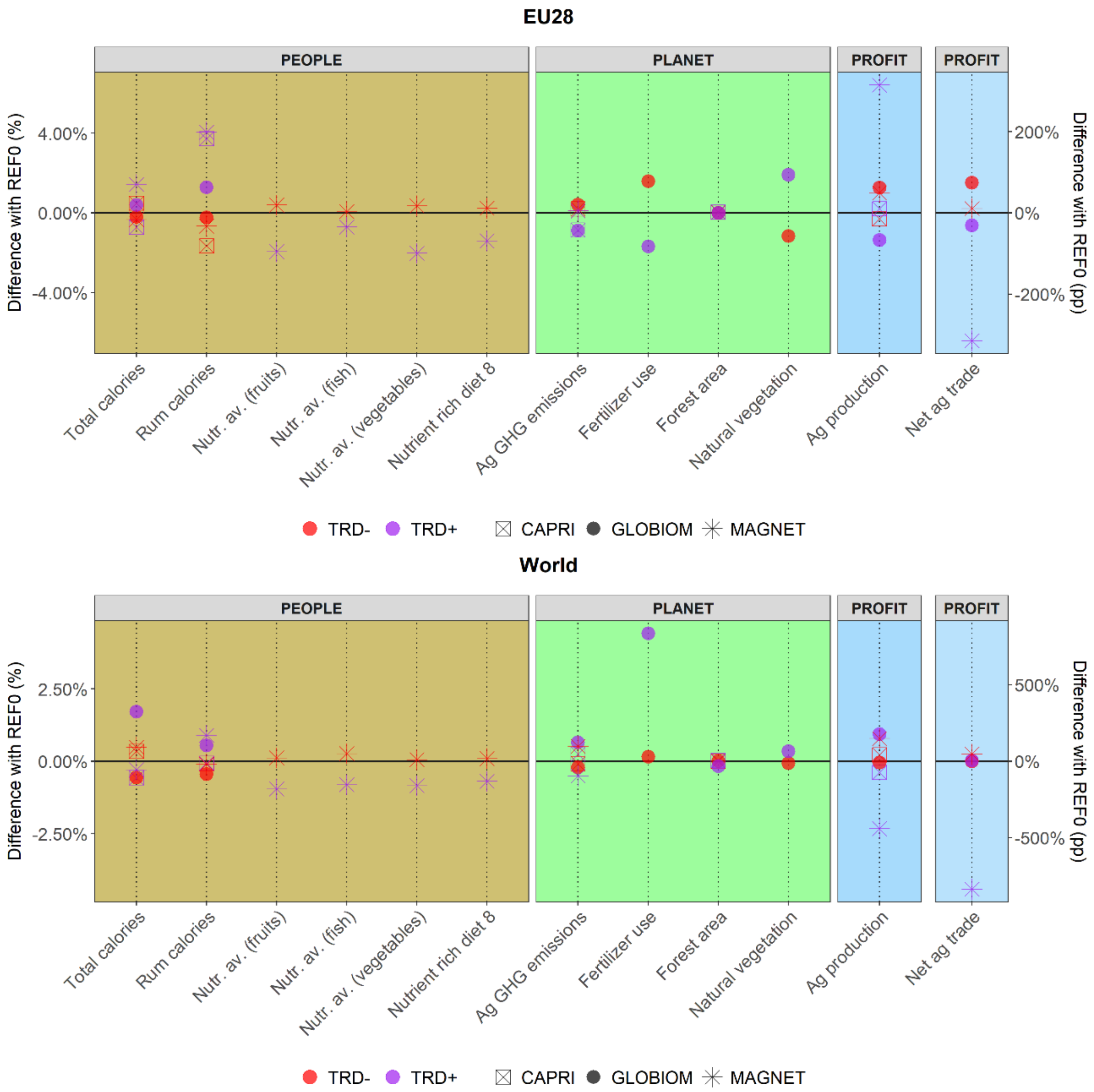

Figure 17. Relative change for people, planet, and profit indicators across trade scenarios (TRD-, TRD+) compared to the baseline (REF0) scenario by 2050.

Climate change impacts and mitigation policies

Climatic change represents relatively little challenge for EU farmers and consumers. However it could lead to increased GHG emissions and hence increased challenge to mitigation. With respect to per capita calorie consumption, even a marginal calorie increase could be anticipated for EU consumers due to slightly positive impacts on productivities (Figure 18). In contrast, applying a global carbon tax on GHG emissions to achieve the 1.5 C target would result in much higher global calorie losses (but also for EU consumers) due to agricultural price increases driven by the carbon tax.

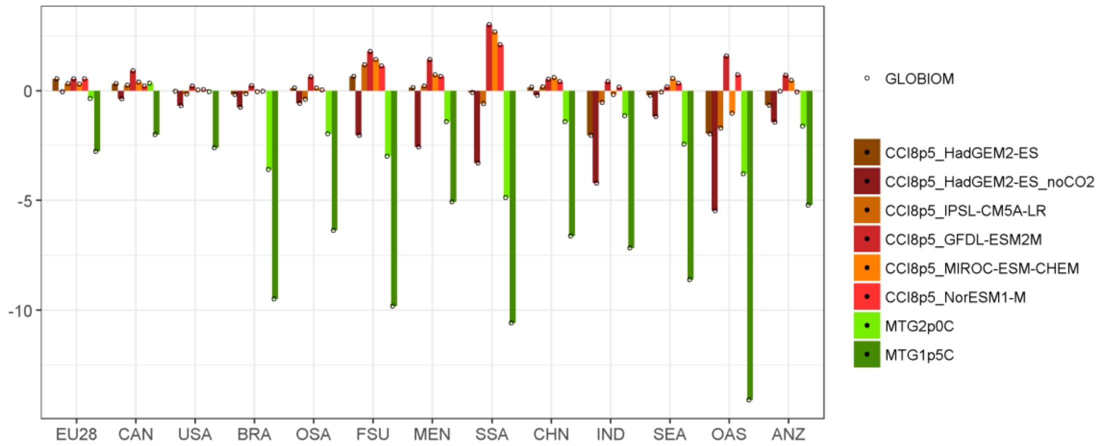

Figure 18. Relative change in per capita calorie availability across climate impact and climate mitigation scenarios compared to the baseline (REF0) scenario by 2050 [%] (EU28 – European Union, CAN – Canada, USA – United States, BRA – Brazil, OSA – Rest of Latin America, FSU – Former USSR, MEN – Middle East and North Africa, SSA – Sub-Saharan Africa, CHN – China, IND – India, SEA – South East Asia, OAS – Other Asia, ANZ – Australia and New Zealand).

With respect to agricultural production, if the climate change mitigation policy is applied consistently across the world, the EU agricultural sector would benefit because of its relatively high GHG emissions efficiency and hence would increase its exports and reduce imports (

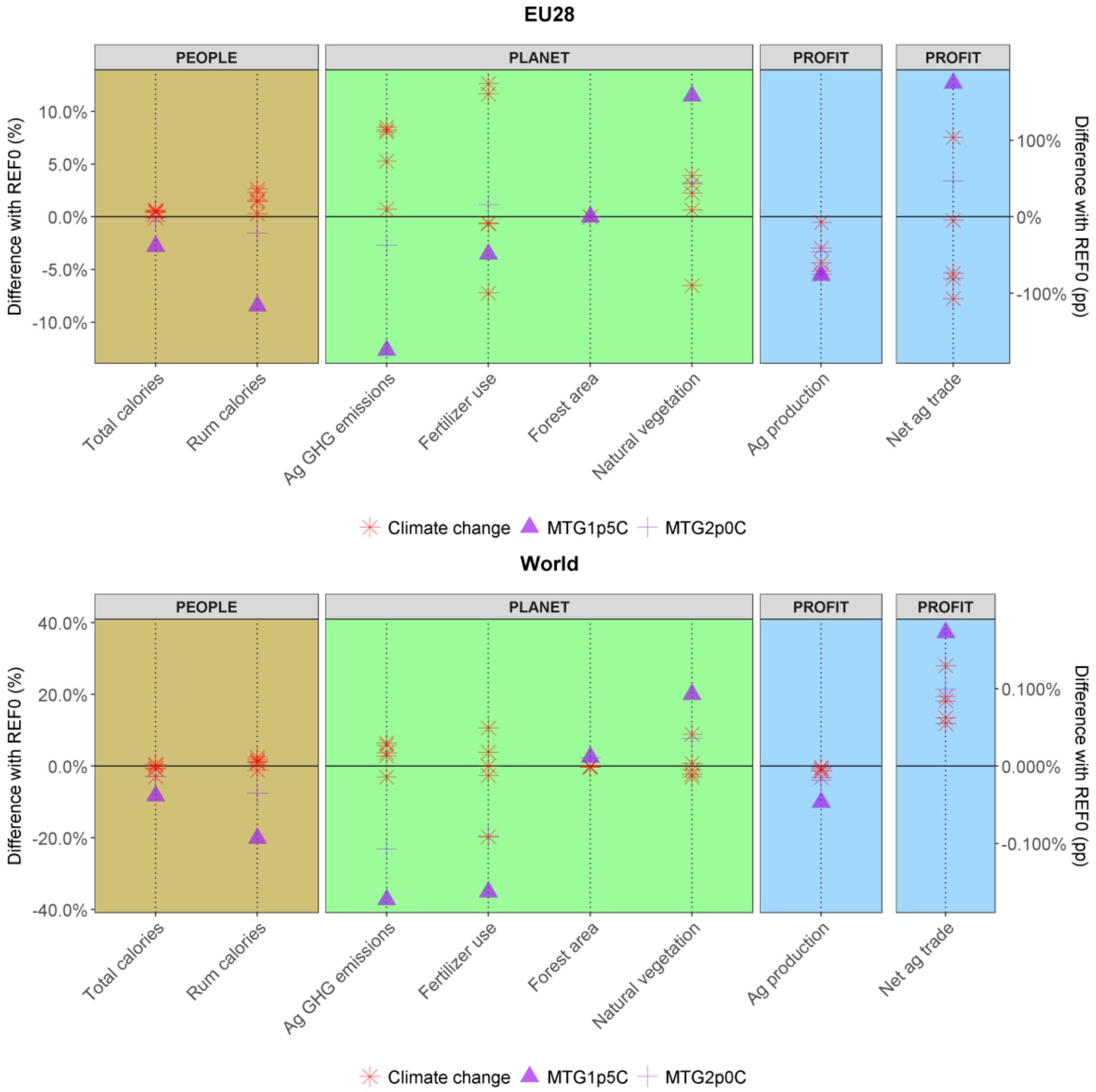

Figure 19. However, unilateral EU climate mitigation policy would have exactly the opposite effect, potentially even increasing global GHG emissions rather than decreasing.

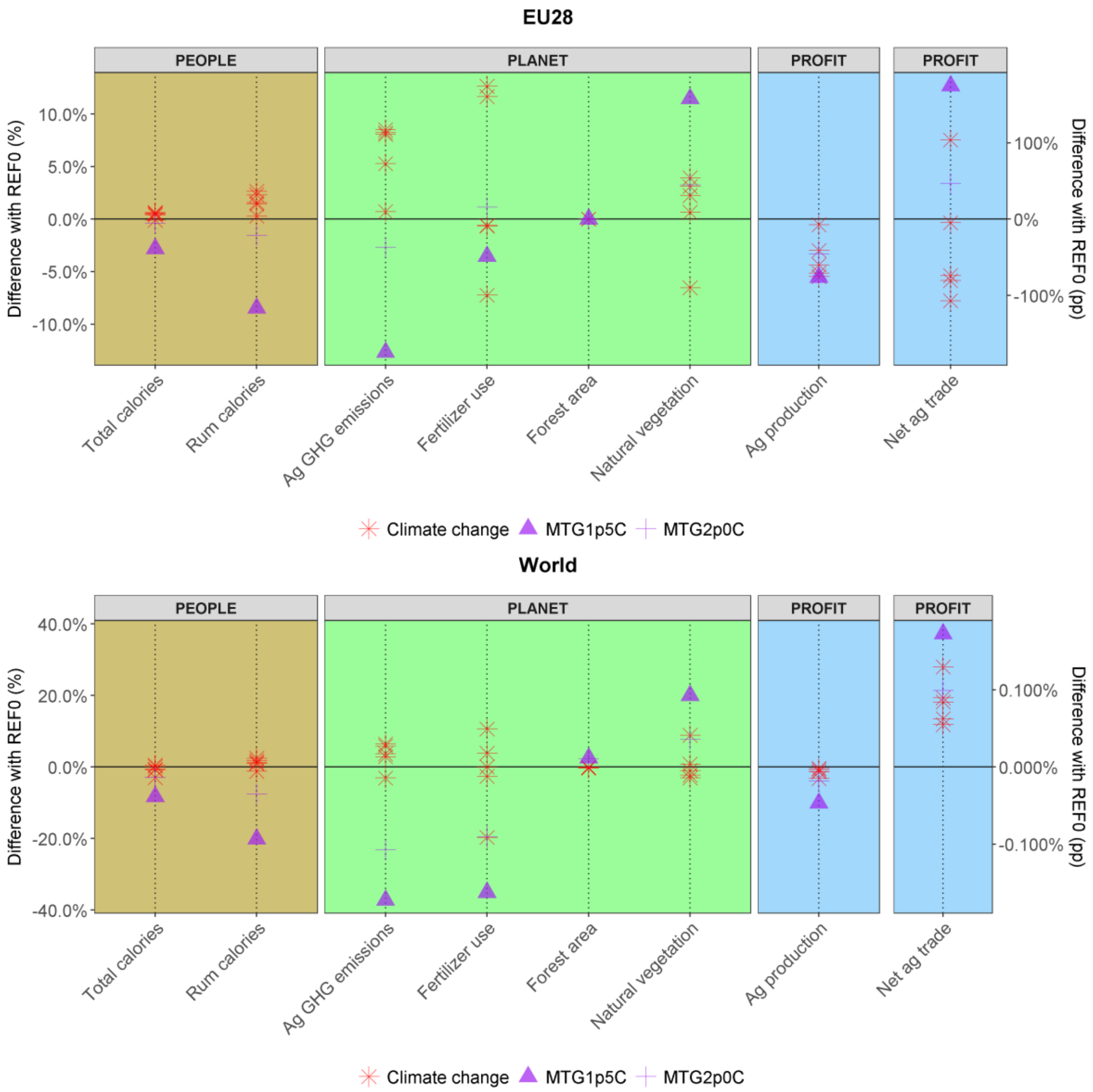

Figure 19. Relative change for people, planet, and profit indicators across climate impact and climate mitigation scenarios compared to the baseline (REF0) scenario by 2050.

Alternative contextual scenarios

Differences across the contextual scenarios (REF+, REF-) compared to the baseline scenario (REF0) represent combined effects of the various challenges (POP, GDP, TEC, TRD) explained in the previous section **Error! Reference source not found.**. While some of these challenges have amplified effects on socio-economic or environmental indicators when applied jointly thereby creating even more synergies, other challenges may have opposing impacts resulting in trade-offs.

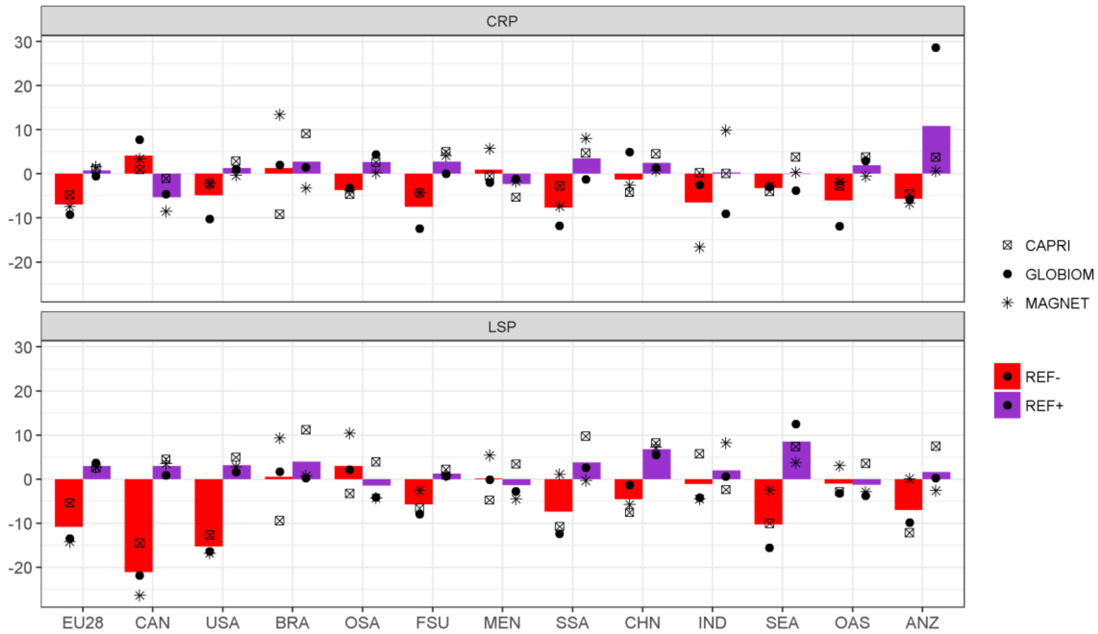

Figure 20. Relative change in crop (upper) and livestock (lower) production across contextual scenarios (REF-, REF+) compared to the baseline (REF0) scenario by 2050 [%] (EU28 – European Union, CAN – Canada, USA – United States, BRA – Brazil, OSA – Rest of Latin America, FSU – Former USSR, MEN – Middle East and North Africa, SSA – Sub-Saharan Africa, CHN – China, IND – India, SEA – South East Asia, OAS – Other Asia, ANZ – Australia and New Zealand).

The REF+ scenario with slightly increased GDP and population growth in the EU (though decreasing population at global scale) shows only marginal impacts on agricultural production levels in the EU while much stronger impacts are observed in the REF- scenario related to more pronounced reduction in population (Figure 20). Changes in GDP growth across the contextual scenario show limited impact on overall food consumption and per capita food consumption at EU aggregate level (Figure 24) due to rather inelastic demand. Nevertheless, especially in Eastern European & Baltic countries like Rumania, Bulgaria, or Lithuania, with lower household income, GDP per capita changes may drive some adjustment in especially livestock consumption levels (Figure 21) in response to GDP per capita changes. We conclude that agriculture in the EU is likely more heavily affected by pessimistic socio-economic developments, in particular population developments, while at the same time not benefitting as substantially from additional domestic GDP growth. Interestingly, the REF- scenario performs slightly better than the REF+ scenario with respect to nutrient availability in the diet.

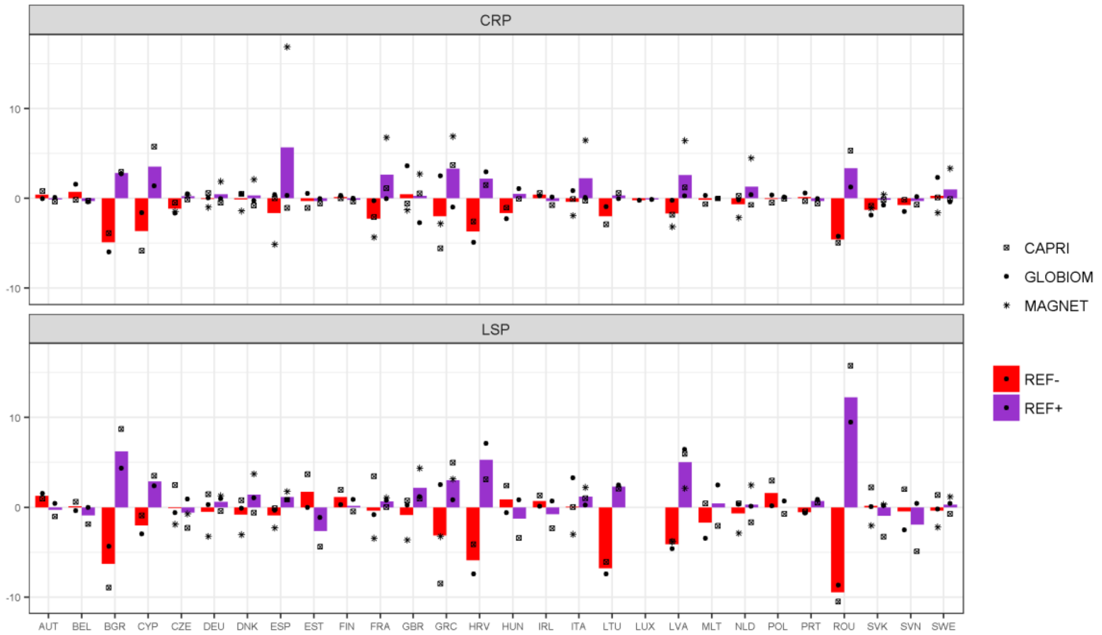

Figure 21. Relative change in crop (upper) and livestock (lower) per capita calorie consumption across contextual scenarios (REF-, REF+) compared to the baseline (REF0) scenario by 2050 [%].

Changes in agricultural production levels across scenarios are well reflected by environmental indicators such as GHG emissions (Figure 22) or nitrogen fertilizer use (Figure 23). For example, assumptions on technological change are key for the environment and amplify co-benefits of production changes for nitrogen fertilizer use, agricultural GHGs, and other natural vegetation. Even though agricultural production increases in the REF+ scenario, environmental impacts can be significantly reduced in the EU which highlights the importance of productivity increases even in highly developed countries for environmental issues. Some indicators such as GHG emissions or other natural vegetation, show a positive outlook in both contextual scenarios as they either benefit through improved technological change or reduced production levels induced by stagnating food demand.

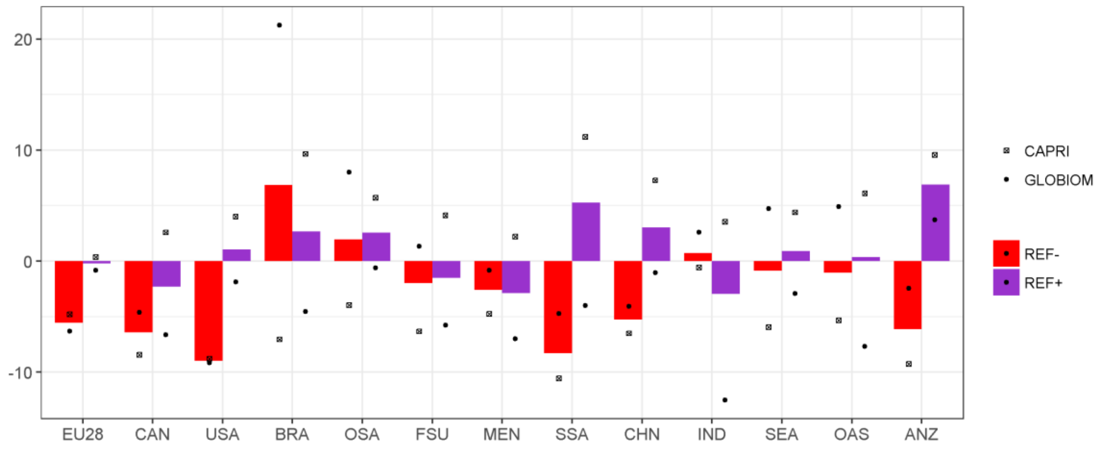

Figure 22. Relative change in agricultural GHG emissions across contextual scenarios (REF-, REF+) compared to the baseline (REF0) scenario by 2050 [%] (EU28 – European Union, CAN – Canada, USA – United States, BRA – Brazil, OSA – Rest of Latin America, FSU – Former USSR, MEN – Middle East and North Africa, SSA – Sub-Saharan Africa, CHN – China, IND – India, SEA – South East Asia, OAS – Other Asia, ANZ – Australia and New Zealand).

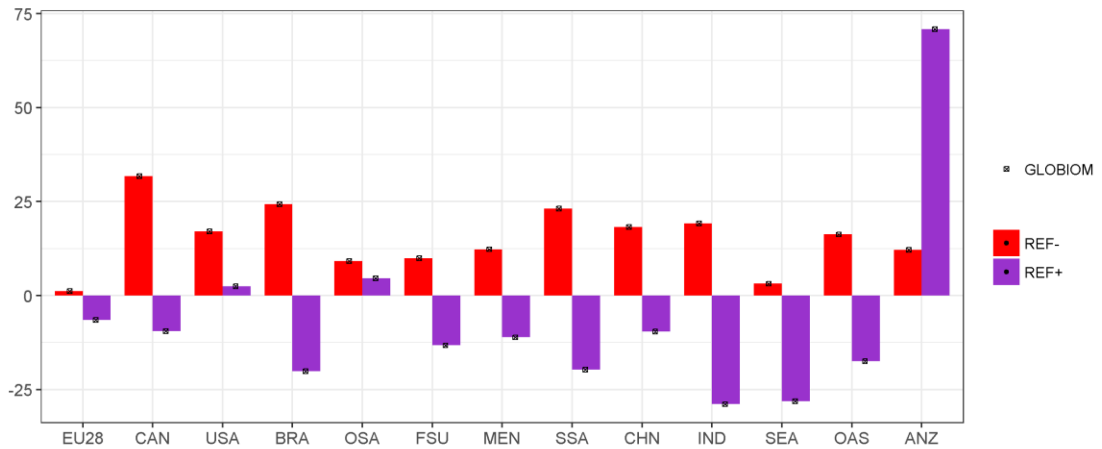

Figure 23. Relative change in nitrogen fertilizer use in GLOBIOM across contextual scenarios (REF-, REF+) compared to the baseline (REF0) scenario by 2050 [%] (EU28 – European Union, CAN – Canada, USA – United States, BRA – Brazil, OSA – Rest of Latin America, FSU – Former USSR, MEN – Middle East and North Africa, SSA – Sub-Saharan Africa, CHN – China, IND – India, SEA – South East Asia, OAS – Other Asia, ANZ – Australia and New Zealand).

At global scale, the contextual scenarios show more symmetric impacts across the REF+ and REF- scenarios as i.e. agricultural production is affected not only by population growth (as in the EU) but also by GDP growth which drives substantial food demand increases. Similarly as for the EU, technological change is a key driver for the reduction of environmental impacts (Figure 24) since despite significant gains in per capita calorie consumption and increase in agricultural production in the REF+ scenario, GHG emissions and fertilizer use can be most likely reduced as compared to the REF0 scenario.

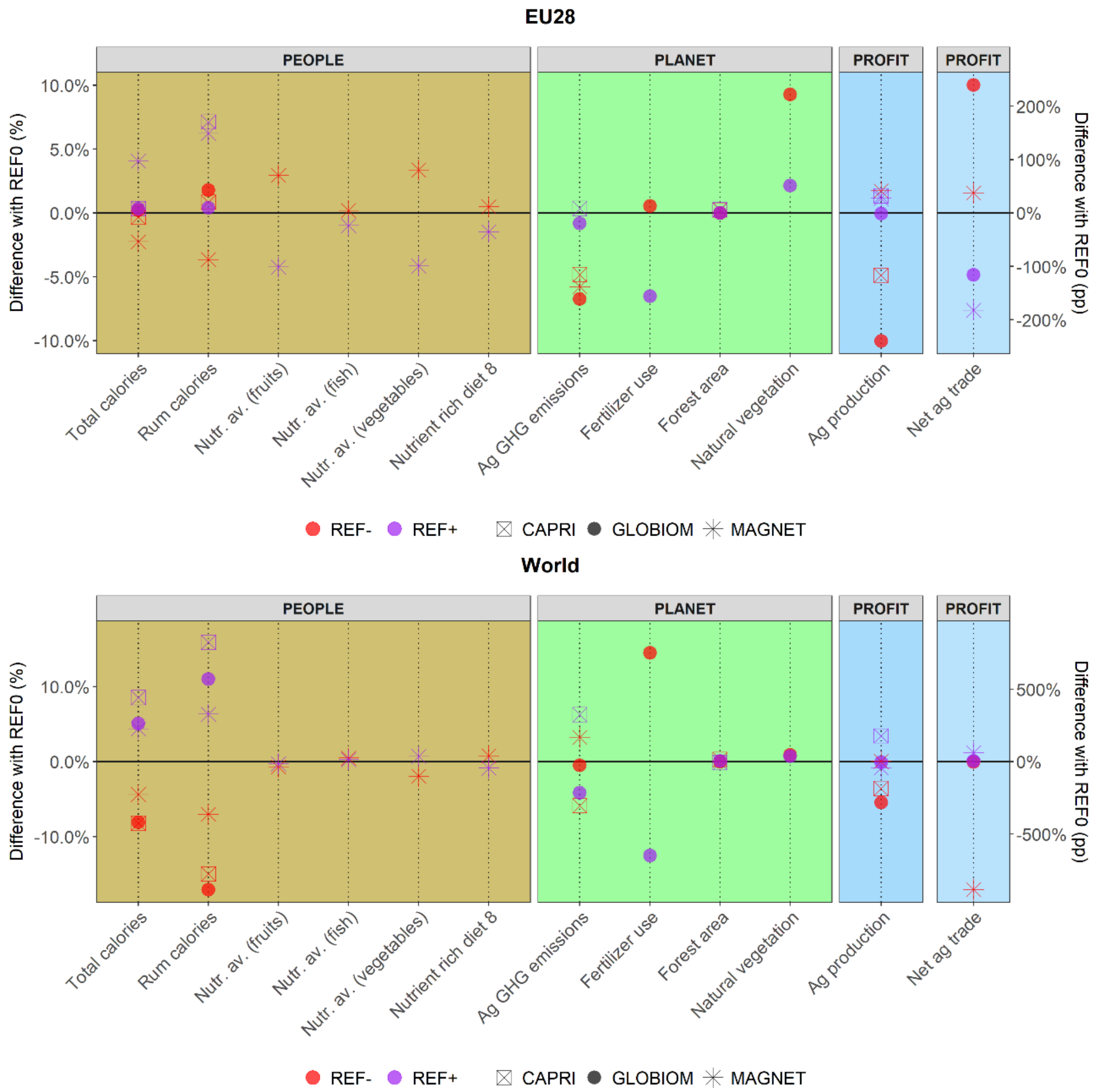

Figure 24. Relative change for people, planet, and profit indicators across contextual scenarios (REF-, REF+) compared to the baseline (REF0) scenario by 2050.

CONCLUSIONS

This deliverable applied the SUSFANS modeling toolbox to assess challenges to the EU food and nutrition security resulting from medium and long term developments in macro drivers characterizing alternative contextual scenarios.

The projected baseline, REF0, developments represent for the EU continuation of the current levels of total food consumption with a slight decrease in the share of fruits and vegetables, stagnation in the share of fish and depending on the model stagnation or even slight increase in ruminant meat consumption. Therefore additional policies, in large sense, are required for EU consumers to transition to healthier and more nutritious diets. These findings are in line with the "Global Food" scenario representing the business as usual case in a recent assessment of challenges to food safety and nutrition in the EU by Mylona et al. (2016).

With respect to the sustainability of farm businesses, the stagnating domestic demand, and projected decreases in producer prices, by 25% for crop products and 8% for livestock products, the growth of farm income from agricultural produce is highly depend on the competitiveness of EU products on international markets. The models in the SUSFANS toolbox differ in their projections of the future EU export capacity. While CAPRI and MAGNET are rather optimistic in this sense, and increases in exports of both crop and livestock products are projected to drive further increase in EU agricultural production, by more than 20% between 2010 and 2050, GLOBIOM sees the EU export capacity decreasing over time, leading to stagnation of agricultural production at +3% compared to 2010. From this perspective, it seems that increased incomes for EU farmers should come in the future rather from increased quality than quantity. The domestic market saturated with conventional agricultural products but benefiting from affluent consumers, whose wealth is supposed to further increase over the coming decades, offers opportunities for high quality and specialty products. Similarly, maintenance of the excellent reputation of the safety of EU products, is necessary for their competitiveness on international markets, where based purely on cost competitiveness among standard products, they are in a difficult position already today and will be even more so in the future, when also the competitiveness of developing and transition countries is projected to rise.

The environment is projected to benefit from the stagnation or moderate increases in agricultural production. GHG emissions from agricultural production are projected to stay close to the current levels, or only slightly increase in the case of export opportunities driven production increases. Overall fertilizer use would slightly decrease, due to assumed continuous improvements in fertilizer use efficiency, which is well in line with recent trends (EC, 2017). Forest areas, as well as areas available for natural vegetation would slightly increase. These apparently positive trends raise also some considerations. First, they rely on the assumptions of continued improvements in agricultural sector productivity and input and resource use efficiency. However, the saturated demand and decreasing prices could create incentives for business and private sector to disinvest in research and development. Second, while the described developments do not represent deterioration compared to the current situation, they also do not go far enough to secure the desirable outcomes. For instance, while stagnating GHG emissions may seem as a good news, it is projected that they should decrease by 13% if the 1.5 degree target stipulated in the Paris Agreement should be achieved. Increasing consumer awareness and effective public policies will thus be necessary to provide a sustainable environment while supplying healthy and safe diets.

These developments are subject to uncertainties; on the one hand, uncertainties in the applied models, and on the other hand, uncertainties in the underlying scenario drivers. The model related uncertainties are partly covered by the multi-model set-up of the SUSFANS toolbox, where the individual models complement each other through sectorial, geographical or thematic coverage but at the same time all are able to report in a harmonized way a multitude of comparable parameters on which the uncertainty of the projections can be judged. With respect to driver uncertainties, we considered in particular: population and GDP development, speed of technological change, international trade policies, and climate change impacts and mitigation policies.

While in our baseline scenario, EU population growth by 4% and the population in the rest of the world by 35%, in our high challenge population scenario, we consider a 10% decline in EU population contrasting with a 49% increase in the population in the rest of the world by 2050. Decreasing EU population would lead to overall food consumption decrease by more than 10% compared to the baseline scenario which in turn would lead to lower prices and increased per capita consumption without any visible improvement in the diet composition. The pressures on the farmer income would be also further accentuated, the only potential beneficiary of such a development would thus be the environment, where decreasing demand could lead, depending on the model, to substantial decreases in agricultural production, -10%, and reduction of negative effects in terms of GHG emissions and synthetic fertilizer use, as well as potential increase in areas for natural vegetation.

In terms of economic development, the high challenge scenario, where EU GDP is by 23% lower than in the baseline scenario, and also GDP in the rest of the world is by more than 20% lower, still means substantial economic growth both in the EU and in the rest of the world compared to 2010. The simultaneous decrease in the EU and in the rest of the world, leads, on the one hand, to reduced purchasing power in the EU, but on the other hand, through reduced consumption in the rest of the world also to lower prices. Depending on which of these effects dominates, this development could lead to lower or higher EU food consumption. Overall, and across the models, these effects on average cancel out, hence our high challenge economic development scenario seems at least in the EU context not to represent a major problem for the food system sustainability.

Our results confirm, that continued technological improvement leading to higher resource and input use efficiency is key for sustainability of the EU food supply. Slowing down of the technological improvement would among other things lead to a more than 10% increase in fertilizer use and an almost 5% decrease in natural vegetation areas compared to the baseline scenario in 2050. Interestingly, the EU farmers could benefit from a global slowdown in technological change, as the rest of the world would be catching up slower with the EU productivity, and thus compared to the baseline, EU could further expand its exports and production.

Further increasing trade barriers from the side of EU would have limited effect on the key sustainability indicators. But in general, through reduced imports and the need to supply even larger part of EU consumption from domestic production, would lead to increased pressure on the environment.

In terms of climate change impacts, and impacts of climate change mitigation policies our results are very much in line with the findings of Hasegawa et al. (2018) and van Meijl et al. (2018) in the major conclusion that the gradual climate change impacts will have much smaller effect on the agro-food system than the climate change mitigation policies by 2050. While climate change impacts would have only limited effect on food consumption in the EU, climate change policies compatible with Paris Agreement climate stabilization targets, when implemented in the form of a carbon tax, would lead to food consumption reduction, most pronounced in the case of ruminant meat, -10%. This decrease is relatively small compared with the global reduction of ruminant consumption, which would reach -20%. The agricultural emissions in the EU would be reduced by 13%, while the emissions globally would go down by almost 40%. The effects on the EU production, would be a reduction by 5% only, as the exports from the EU would increase substantially. These developments are due to higher GHG emission efficiency of EU production compared with the rest of the world, as well as due to the lower price sensitivity of EU demand. Indeed, coordinated global efforts for GHG emissions reductions could represent an opportunity for the efficient EU food system. However, if such policies were implemented only in a very limited number of regions, incl. EU, depending on the policy instrument, the domestic agricultural sector could lose competitiveness on the global markets. Such unilateral policies would need to take form of support to new GHG efficient technologies and their adoption by farmers rather than restrictive measures or even financial penalties.

To conclude, the future macro drivers developments do not substantially increase the sustainability challenges of the EU food and nutrition security compared to today. They provide even signs of opportunities in terms of the mix of further increasing the already high level of safety and efficiency of the EU food system together with saturated stagnating demand. But on their own, they are not enough to reach the desirable targets in terms of healthy nutrition, environment and agro-food businesses. Additional policies, in large sense, are required for EU consumers to transition to healthier and more nutritious diets (Mylona et al. 2016). As conceptualized in SUSFANS, such policies may stem from a range of actors in the food system, both public and private (Rutten et al. 2018; Zurek et al. 2017). Under SUSFANS a set of policy scenarios on European government policy strategies will be explored; either to assess the impact of food and nutrition policies in a food systems setting, or to assess environmental and agricultural policies with regard their potential impact on dietary patterns in the EU (report D10.3, Heckelei et al. 2018). A key area of research is the interplay of policy options with the contextual drivers in the EU food system, which may effect both the political economy around policy design, and the effectiveness of proposed instruments vis-à-vis contributions to sustainable food and nutrition security in Europe.

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