Simulating stakeholder-driven food and climate scenarios for policy development in Africa, Asia and Latin America: A multi-regional synthesis

Working Paper No. 109

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Abstract

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) engaged stakeholders in Africa, Asia and Latin America in the development of regional socio-economic scenarios for policy development. These scenarios were framed and outlined by regional experts and then quantified using the IMPACT and GLOBIOM models. The scenarios were used in a number of policy design processes at national and regional levels. The model results show that investment in agriculture is essential to close yield gaps needed for growing demand, and that increases in production costs increases these yield gaps. However, even under high agricultural investments, regional production is unlikely to meet regional demand. In many cases, the socio-economic assumptions of the scenarios are more impactful than climate effects on yields. Increased yields can lead to crop area expansion, and the protection and enforcement of forests and biodiversity is essential, especially with increased investment in agriculture. The CCAFS scenarios process show the need to combine socio-economic and climate scenarios, to base these scenarios in regional expertise, and ways to make scenarios useful for policy design.

Keywords

Scenarios, climate change, socio-economic development, model simulation, yields, demand

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Contents

Introduction

Decision-makers around the world are looking to engage more meaningfully with an uncertain future. To develop robust policies, they have to explore contexts where many stressors including climate change, the challenges of socio-economic development, environmental degradation and political instability interact (Vervoort et al. 2014). Various methods exist for the development and use of scenarios as a way to develop diverse, plausible narratives (in words, numbers and images) about future contexts for decision-making.

This working paper provides insights into the quantitative results of a series of scenario processes led by the CGIAR Climate Change, Agriculture and Food Security program together with UNEP WCMC and FAO. These processes consisted of stakeholder-driven and model-driven scenario development, aimed at scenario-guided policy analysis and improvement in close collaboration with national governments and regional partners.

Overview of scenario development methods

In each of the CCAFS scenario processes, regional stakeholders identified a large number of change factors and selected the factors they considered to be most uncertain, and most relevant for the scope of the process. Participants identified multiple states for each change factor. The stakeholders evaluated all combinations of states for a range of factors in terms of compatibility. In the initial regions, East Africa and West Africa, a two-axis scenario approach was used to structure these uncertainties. OLDFAR, a software program designed for this process, was used in the most recent regions (South Asia, Southeast Asia, the Andes and Central America) to construct diverse scenarios out of compatible factor state combinations. A novel aspect of OLDFAR is its use of robust optimization to maximise the diversity between scenarios according to a wide range of possibilities of what participant's might consider diversity in states and factors. Once presented with diverse sets of scenarios, the participants assessed and developed the resulting scenarios into full narratives using explorative back-casting. All other factors that had been identified by participants were then examined in the context of each scenario to further ensure that the scenarios had sufficient scope to be relevant to the concerns of the decision-makers.

Quantifying stakeholder scenarios

As a next step, the stakeholder-generated scenarios were quantified using two agricultural economic models, each with different assumptions – GLOBIOM (Havlík et al. 2014), developed by the International Institute for Applied Systems Analysis (IIASA) and IMPACT (Rosegrant and Team 2012), developed by the International Food Policy Research Institute (IFPRI). To provide inputs for this quantification, drivers like population, GDP, technology impacts on yields, farm input costs and others were discussed with the developers of each scenario, in terms of scenario logic, direction of change (using a semi-quantitative scale), discussing volatility, and in addition discussing a number of qualifying statements (agreement/disagreement, need for external sources of expertise). These semi-quantitative results where then linked to the global Shared Socio-economic Pathways (O'Neill et al. 2014) for each region and a critical comparison between the stakeholder-generated scenarios and the SSPs was made to generate quantitative scenario inputs.

The partial equilibrium models provide the stakeholders with more than just the regional scenarios. They also offer insights in how the region will be affected by forces outside its sphere of control, such as global markets, and climate change. These factors can have profound effects on regional outcomes. For example, the negative effects of climate change

on rice yields is about equal to the positive effects of several of the regional scenarios, meaning that some of the assumptions behind the regional scenarios (such as high public and private investment in agriculture) are able to offset the negative effects of climate change. The models also highlight how the region will interact with the rest of the world through trade, and how countries in the region can become more or less vulnerable to global price shocks due to changes in levels of importing and exporting. For example, in Buffalo, Buffalo, a scenario for Southeast Asia representing slow economic growth and lower agricultural productivity the region will become a smaller exporter in many key commodities like rice, while becoming larger importers of other important commodities like dairy. This future was used to test the robustness of regional policies as stakeholders consider a future with lower incomes and greater reliance on imported foods. In the Tigers on the Train scenario, for Southeast Asia, where there is less economic growth and increasingly protected markets, crop production increases to meet demand but the expansion of crop area is also highest. This future could be used to test examine regional policies that consider trade-offs of between self-sufficient food production and the protection of ecosystems and environment.

The scenarios were further quantified using the land use change model LANDSHIFT (Schaldach et al. 2013) in Southeast Asia, East Africa and Latin America, which simulated land use change, change in ecosystem services and changes in biodiversity, presented as maps which were critically examined and edited by regional stakeholders. GLOBIOM, IMPACT and LANDSHIFT generated further diversity in scenario results, based on the multi-dimensional stakeholder inputs.

Scenarios as effective policy development tools

These scenario results were adapted, reinterpreted and used to guide a number of specific policies and investment plans in all regions, through carefully managed participatory processes of close collaboration between researchers and the developers of these policies and investments. Examples are the development and finalization of the Cambodian Ministry of Agriculture, Forestry and Fisheries' Climate Change Priorities Action Plan, the development of the Bangladesh 7th 5 year socio-economic development plan, changes and additions to the Honduras Secretariat for Agriculture and Livestock's climate adaptation plan, the Colombian agricultural adaptation plan and similar policies in other countries.

In terms of process, preparation, timing, trust and close collaboration between partners were crucial. In terms of the scenario content, the attributes of the developed scenarios – which are multi-state, multi-factor, multi-model, qualitative and quantitative and generated by regional

stakeholders – greatly increased their credibility, legitimacy, usefulness and adaptability. We argue that a multidimensionality of change factors and states, as well as a diversity of models through which to interpret and explore the scenarios is crucial for scenarios which are meant to be and adapted for a wide range of decision-contexts and levels.

Toward a global synthesis

This working paper provides selected insight from the quantification of the CCAFS scenarios in all regions, using the GLOBIOM model results as examples. The next step in this element of the CCAFS scenarios research program is to create a global synthesis that examines the differences and similarities between regional scenarios, and how these scenarios would potentially interact if they were to occur simultaneously.

Introduction to Quantification

The quantification process of the regional scenarios has two parts. The first process involves interpretation of the semi-quantitative indicators and factors of change in each scenario into number values to be used as drivers in the model. The second process involves including the factors of change for each scenario into GLOBIOM and solving the model over the time period. Finally the model quantification results are examined for consistency with the scenarios storylines as developed by the stakeholders.

Following the storyline developments in each region, several drivers which were given directional and magnitude of change by participants of the regional workshop were quantified over the timeline. The factors of change considered as exogenous drivers for modelling are GDP and population growth, technical crop yield growth, livestock yield growth, the share of crop area and for specific crop production systems, the share of area for pasture and for specific livestock production systems, and production costs. As production of agricultural and forest products in GLOBIOM is spatially explicit, the expansion of these sectors into pristine forest also spatially explicit. Included in the narratives for several of the regional scenarios were protection of forests and biodiversity hotspots. While not used for the main comparison and harmonization with the results from IFPRI's IMPACT model, the framework

for identifying biodiversity hotspots ensuring their protection from land use change consistent with the narrative storylines was included in additional scenarios runs.

Quantification has several benefits. Illustrating the narratives with numbers gives prospective users more definite information that can be applied in the testing of policies and research recommendations. In addition, the models represent a structured set of assumptions that can be used to challenge the ideas proposed by the narratives and to make each narrative more internally consistent. However, using existing quantitative models also has drawbacks in the fact that the models have been designed based on the present rather than qualitatively different futures, and therefore there are limits with regard to the degree to which models can capture these futures. Also, quantitative scenarios of the future can easily and wrongfully be interpreted as forecasts with predictive value. Therefore, the presentation of quantitative results from the CCAFS scenarios process involves highlighting the limitations and assumptions of the models and shows that depending on the model as well as the scenario, very different futures arise. In an iterative process, the regional stakeholders challenged the modelling results if they thought these were not plausible from a regional perspective. Furthermore, the scenarios created by the regional stakeholders ask questions about the future that might challenge the modelling framework to adapt, creating a two-way interaction between the narratives and the modelling results for further improvement of the scenarios.

Quantification of Drivers

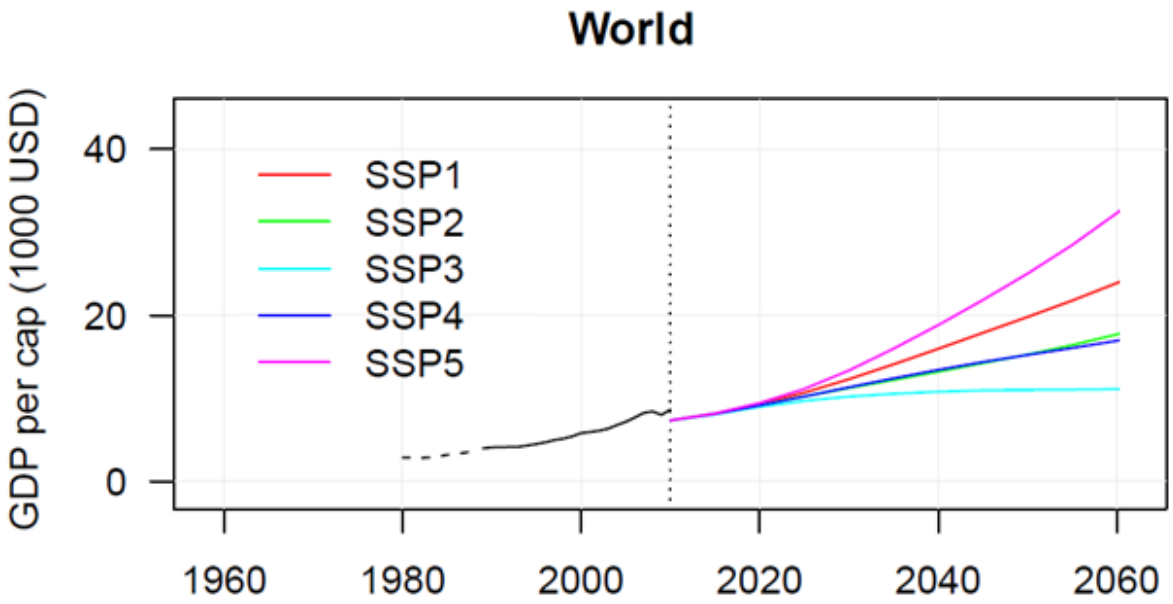
For the quantification of the scenarios each of the regions, the regional shared socio-economic pathways (SSPs) for drivers of the scenarios in each region. The SSPs define five possible futures worlds which were designed to improve interdisciplinary analysis and assessment of climate change impacts and mitigation and adaptation options until 2100 (O'Neill et al 2013). A brief definition of the SSPs and a graphical representation of the challenge spaces of each SSP can be found in the Appendix. IIASA has been a key contributor to the SSP development process, providing a set of plausible drivers of change. These include GDP, population, crop yields, livestock yields, producer input costs. The regional SSPs were used as a starting point for the quantification of drivers for the each of the regions. Examining the regional scenarios within the context of SSPs allows the regional stakeholder process to connect to the global framework improving the consistency as well as usefulness across scales as suggested by van Ruijven et al (2014). The narratives of the SSPs along with the narratives and semi-quantitative indicators for the CCAFS scenarios have been used to quantify the factors of

change in each region to 2050. The socioeconomic factors of change as well as the biophysical effects of climate change have been implemented in the GLOBIOM model. The results were organized and harmonized with IFPRI's IMPACT team and a subset of results were provided to the CCAFS team to be used to further develop CCAFS draft reports for each region.

Drivers: GDP per capita

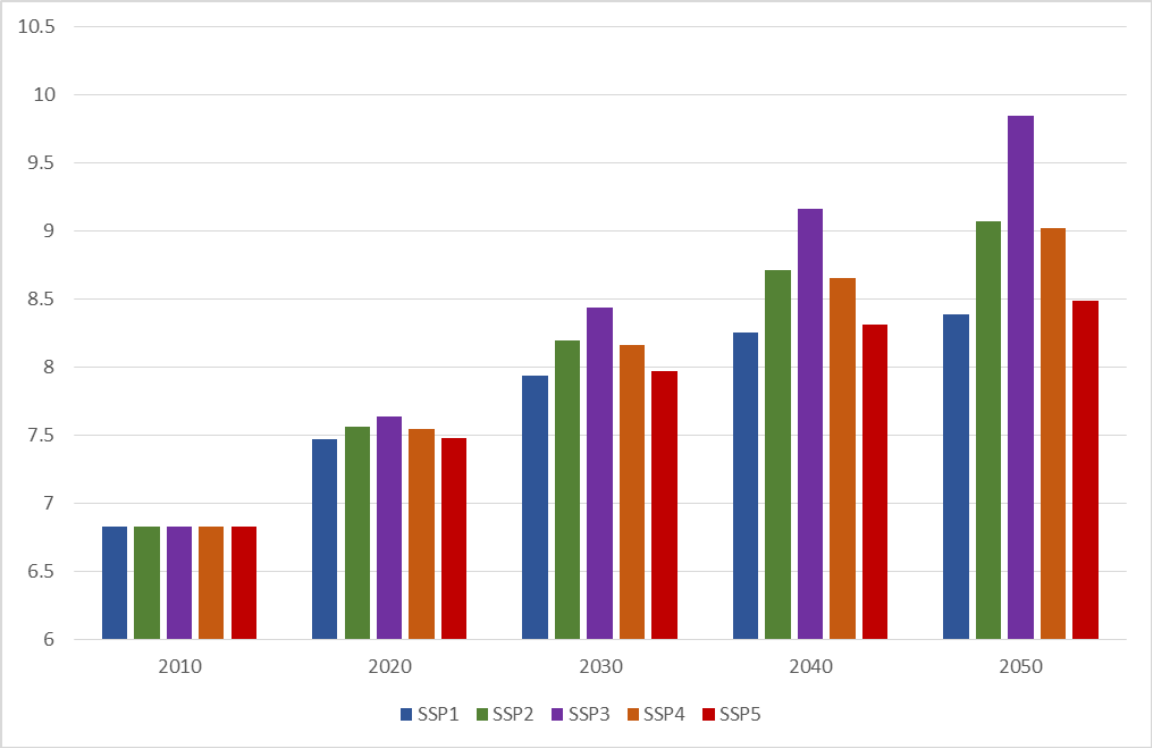
The growth of population as well as the growth of the GDP per capita significantly affect the future demand of agricultural products. The population growth and increase in GDP per capita as described in the regional scenarios narratives and through the semi-quantitative indicators were interpreted using the SSP projections of population growth and GDP growth as a starting point so that the regional scenario projections fall within the envelope of the SSPs. The global population grows from nearly 7 billion in 2010 to nearly 10 billion by 2050 in the SSP3 scenario (Figure 2).

Figure 1 GDP per capita projections (1000 USD)



Source: SSP database (https://secure.iiasa.ac.at/web-apps/ene/SspDb)

Figure 2 Population projections (billions of people



Source: SSP database (https://secure.iiasa.ac.at/web-apps/ene/SspDb)

Drivers: Crop and Livestock Yields

Technical progress in crop production is represented in GLOBIOM through an increase in crop yields and future projections of crop yields are based on the econometric estimate of the relationship between crop yields and GDP per capita assumptions of the SSPs (Herrero et al. 2014). Each of the regional scenarios has specific assumptions on the development of the agricultural sector. The crop yield projections for the SSPs have been used as a starting point and the scenario narratives on agricultural productivity have been translated into scenario specific crop yield projections as well as crop specific productivity when applicable from the storylines. The exogenous changes this would have on domestically produced calories are presented in Figure 3 for SSP2 for each of the regions, and in the following section for the regional scenarios. Globally, the average crop yields per hectare in 2000 were around 10 gigacalories and are projected to increase to 14 gigacalories per ha by 2050.

To present the current and future productivity of livestock, the conversion efficiency of livestock product per unit of feed is used. The projections of conversion efficiencies for livestock as presented in *African Livestock Futures* (Herrero et al. 2014) for the SSPs were used as a starting point for the regional scenarios. The exogenous changes in livestock

feeding efficiencies are presented in Figure 4 for SSP2 for each of the regions, and in the following section for the regional scenarios.

Figure 3 Aggregate Exogenous Crop Yields (gigacalories per ha)

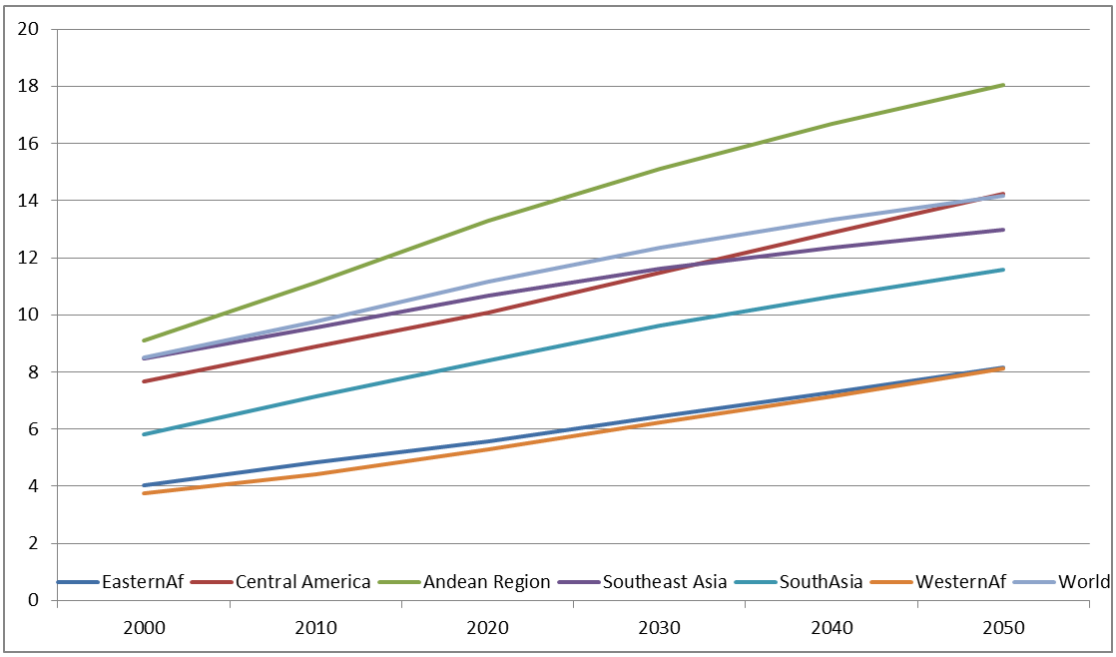
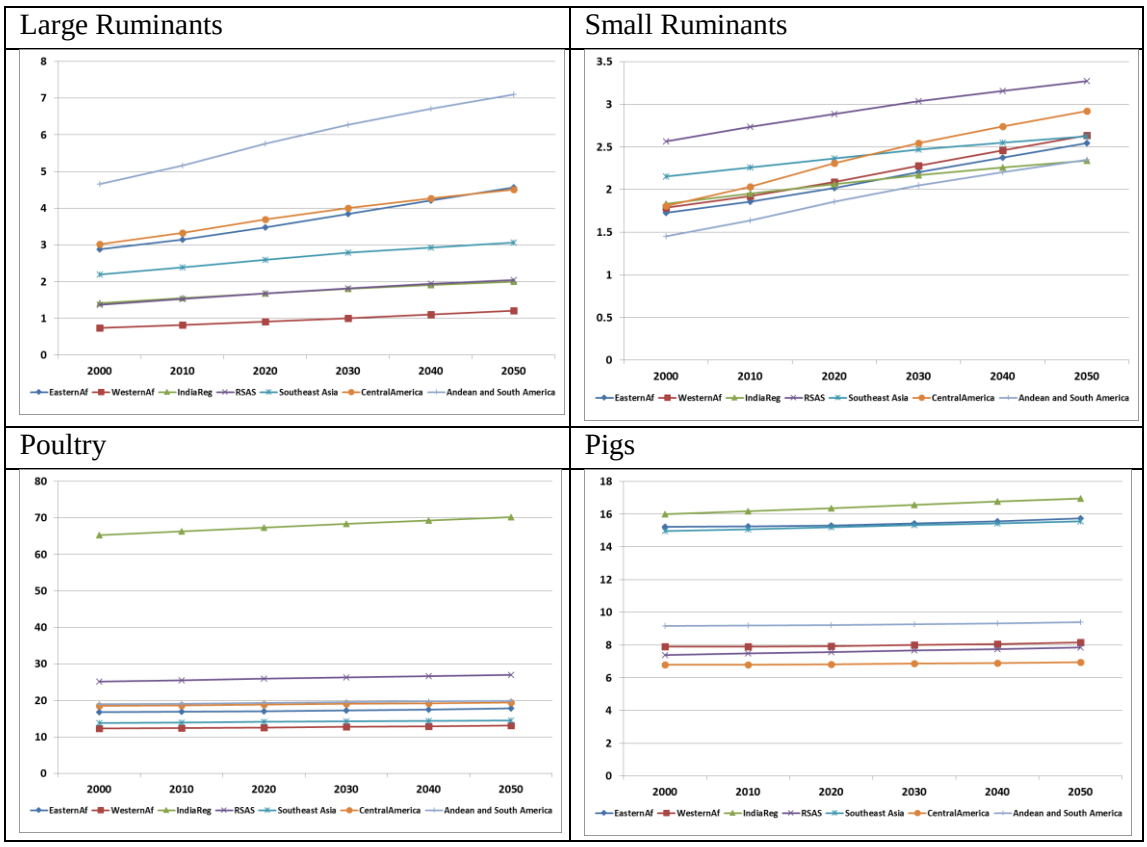


Figure 4 Exogenous Livestock Feeding Efficiencies (kg protein/t dm feed



Drivers: Biophysical Effects from Climate Change

For each of the regional scenarios, the impacts of a changing climate on the agricultural system were modeled by combining the climate projections for temperature and precipitation from general circulation models (GCMs) with the globally-gridded crop model EPIC to simulate the future impacts on crop yields, fertilizer needs, and irrigation requirements (Leclère et al. 2014). The representative concentrated pathway (RCP) 8.5 was used for four GCMs: HadGEM2-ES, GFDL-ESM2M, IPSL-CM5A-LR, MIROC-ESM-CHEM, and increasing CO2 effects on crops. These scenarios along with a no climate change scenario of constant present climate and CO2 levels were used.

Drivers: Protection and enforcement of biodiversity

As GLOBIOM is a land use model and considers the major uses of land, such as crop land, pasture, and forests, the quantification of the scenarios was able to consider the effect on food security as well as on the environment of protecting forests from land use changes such as conversion of forests to cropland or to managed forests. As the IMPACT is not a full land use model and does not represent land use change as an endogenous, the scenarios results presented here will present the results that are comparable with IMPACT, where the protection of forests from the storylines is not considered.

Drivers: Production Costs

Under the assumption that producers and consumers produce and consume goods at prices that maximize their welfare GLOBIOM, uses real production costs to calculate profitability production. For the regional scenarios, changes in production costs were used as a proxy for scenario-specific environments such as increased government taxes for inputs and poor infrastructure development.

Quantified Model Results

In the following sections the regional scenarios will be presented. We offer these brief highlights and insights into the scenarios and results as an overview of the quantification process. Each regional scenarios process will be presented more thoroughly in future working papers. The format of each section is as follows: the stakeholder defined regional scenarios as developed by the stakeholders will be presented including the factors of change used by the modelling team, and the results quantitative results of the scenarios from GLOBIOM will be examined.

Eastern Africa

Eastern Africa was the first region in which CCAFS engaged with stakeholders to develop regionally applicable scenarios for food security and development. The region of Eastern Africa includes Burundi, Ethiopia, Kenya, Rwanda, Tanzania, Uganda (Figure 5). The initial timeline for the scenarios was 2030 and has been presented previously (J M Vervoort et al. 2013) While these scenarios were useful in engaging with policy makers, they did not include the effects of climate change on agriculture, but instead considered socio-economic drivers that would affect Eastern Africa food security and regional development. To provide a better context for strategic planning, the scenarios were extended to 2050 and combined with climate scenarios. In four workshops, regional stakeholders outlined the four scenarios using narrative flowcharts, conceptual maps, storylines, and a range of semi-quantitative indicators including information on governance (investment, education, market liberalization or control), agriculture (yields, input prices), food security (dietary diversity, access to food) and livelihoods (rural employment, urbanization).

Two drivers were considered the most relevant and most uncertain to the future of food security, environments and livelihoods in Eastern Africa:

- *Regional Integration*: Will the countries of Eastern Africa integrate politically and economically, or will a fragmented status quo be maintained?
- *Mode of Governance*: Will governance – the rules, regulations, institutions and processes affecting the behavior of individuals and groups – be characterized by a reactive or proactive stance of governments, the private sector and civil society?

These two axes of uncertainty have structured the scenarios, though many other drivers play a key role in the scenario pathways (e.g.: population, GDP, investment in agriculture) assumed to occur in each scenario to allow for comparisons to be made between them.

From these two drivers, four socio-economic scenarios of Eastern Africa were developed (Table 1). The semi-quantitative indicators for each region were interpreted in the context around the SSPs. The SSPs were developed to offer plausible futures that are globally and regionally consistent. The drivers for scenarios were quantified, using the population and GDP futures developed in the SSP process as a starting point, the semi-quantitative changes from the workshops to add additional context, as well as feedback from stakeholders on plausibility. By using the regional assumptions of the SSPs as an envelope of possibilities this process was able to add consistency to the scenarios and usefulness of the SSPs themselves.

Figure 5 Eastern Africa Regional Definition

Table 1 Eastern Africa Scenarios: 2050 end state factors of change developed on two axes of uncertainty and relevance

	Mode of Governance	Regional Integration
Industrious Ants	Proactive government	Regionally integrated
Herd of Zebra	Reactive government	Regionally Integrated
Lone Leopards	Proactive government	Fragmented Status Quo
Sleeping Lions	Reactive government	Fragmented Status Quo

Drivers: GDP per capita

SSP 1 and SSP5 project high GDP per capita growth for the region of Eastern Africa by 2050, these two scenarios most closely fit with the narrative high economic growth of the Industrious Ants and Herd of Zebra scenario developed by the stakeholders. The narratives of Lone Leopards and Sleeping Lions scenario more closely with the GDP per capita growth of SSP2 (Middle of the Road) and SSP3 (Fragmentation), respectively, where there is higher population growth, especially in the Sleeping Lions scenario where population grows by 2.5 times before 2050 and there is overall less economic growth. The regional GDP per capita and population growth is presented in Figure 6 and Figure 7.

Figure 6 GDP per capita growth indexed to the year 2000 values

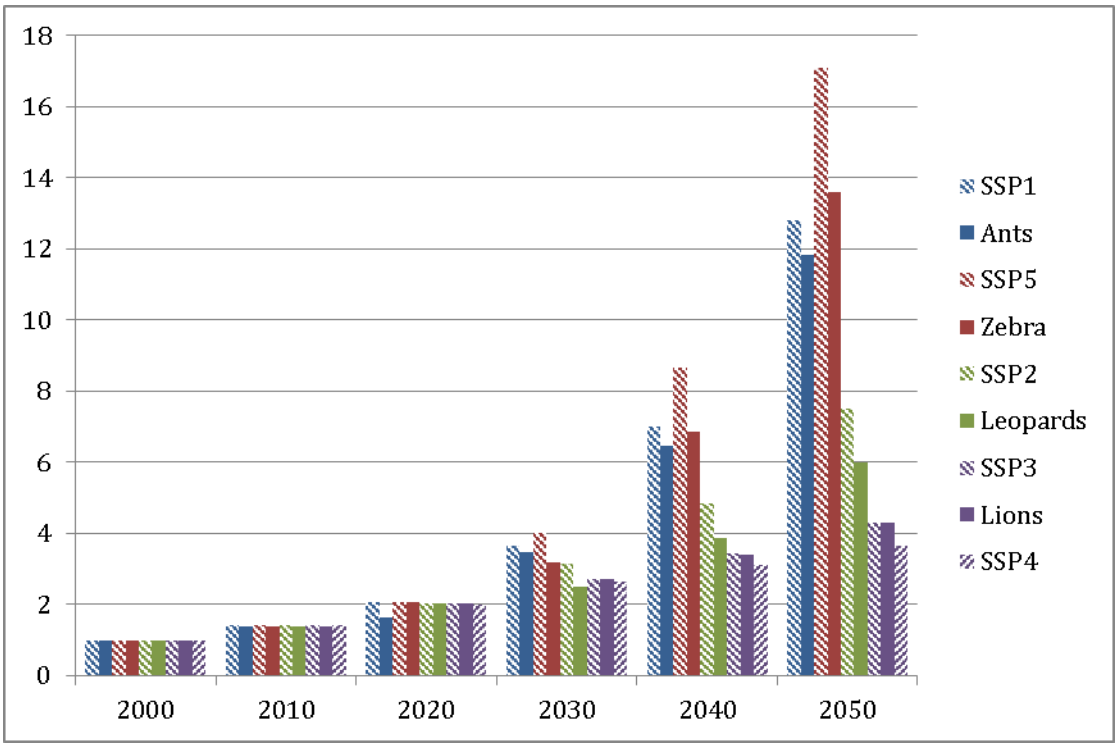
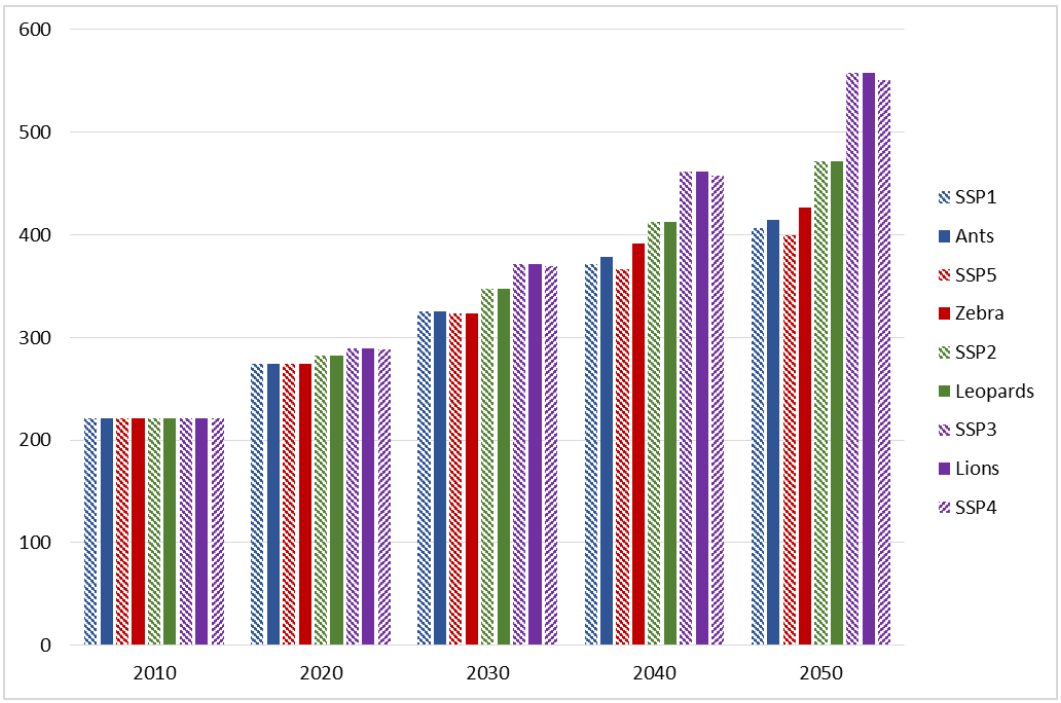


Figure 7 Population of Eastern Africa (millions of people)



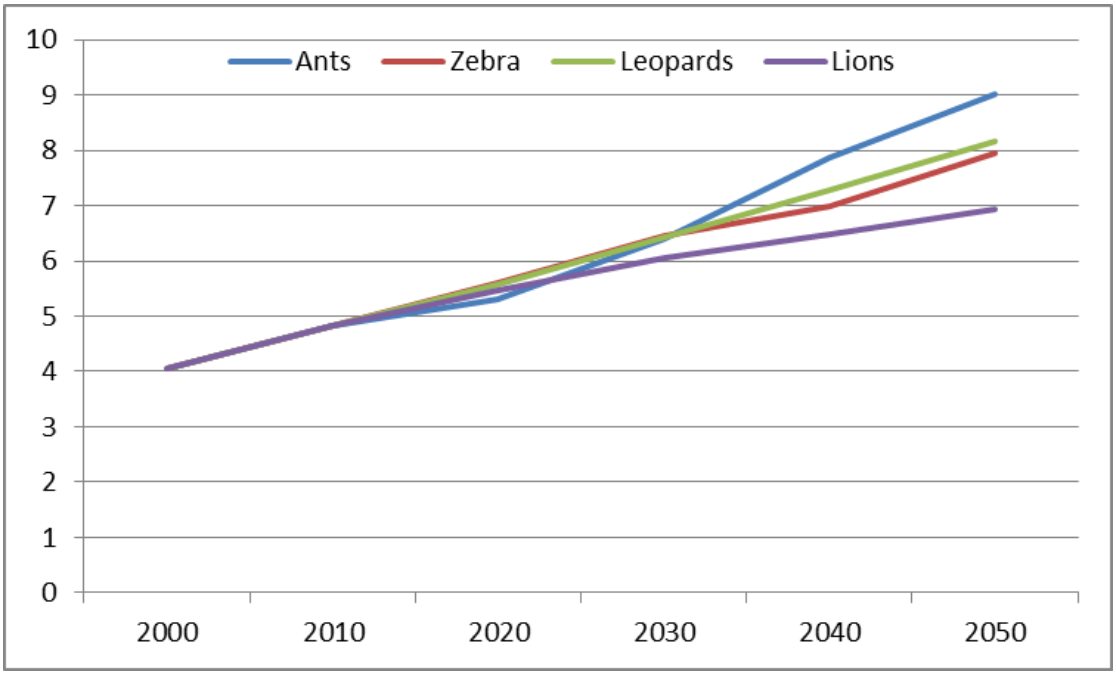
Drivers: Crop and Livestock Yields

As described in the section above, the exogenous growth in crop yields have been translated from the scenario storylines.

Figure 8 gives a summary of the changes assumed in the productivity of agricultural areas, as well as the potential effects it would have on the domestic supply (excluding imports) of calories for each of the scenarios, an important exogenous assumption on changes in food availability within the scenario narratives.

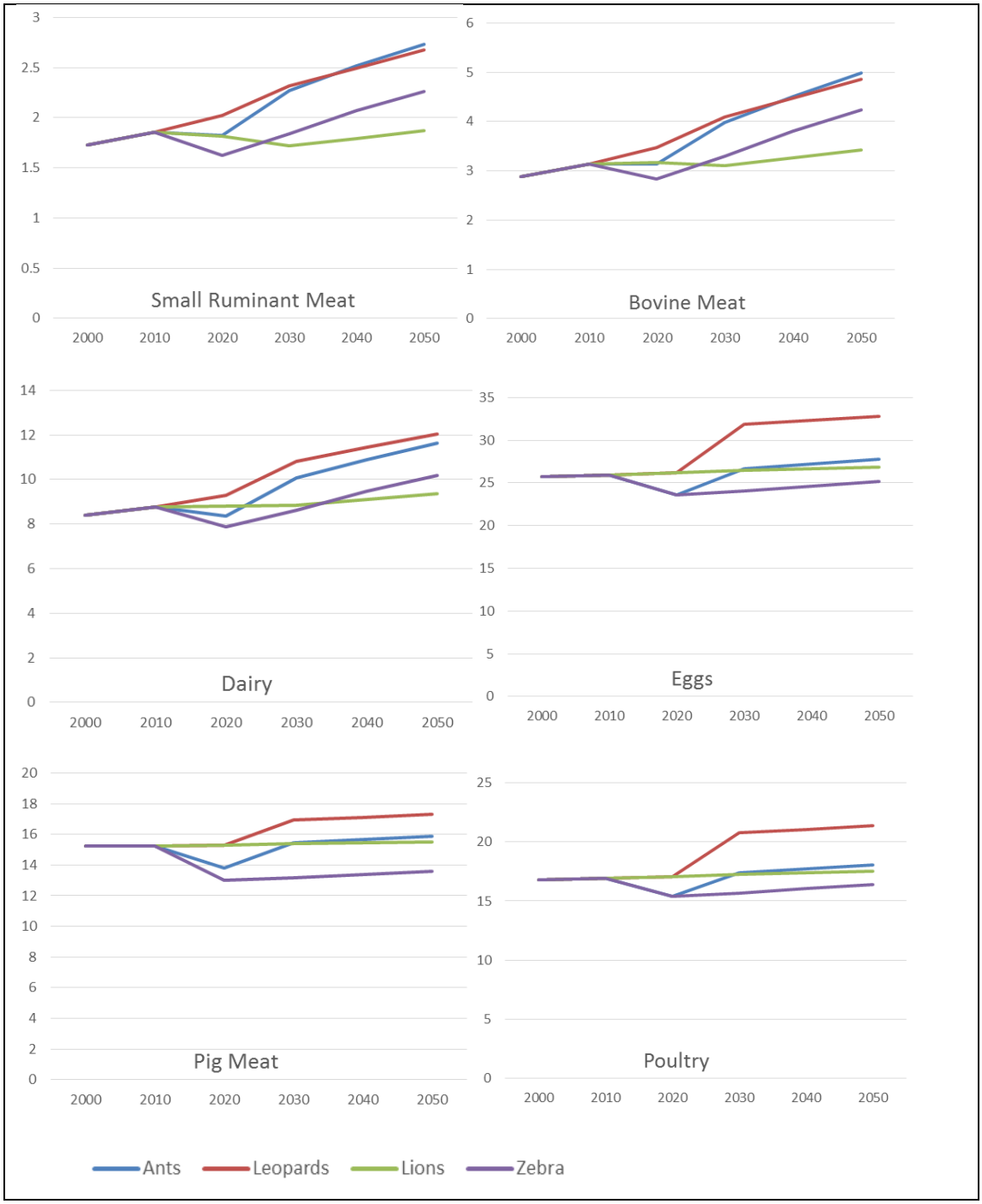
Crop yields are highest in Industrious Ants by the end of the period, more than doubling the calories per ha produced. Although these yields (being exogenous) do not represent the transitions between low input low yielding crop systems to high input high yield crop systems or reallocation of crop production to highly productive land or crop types, the yield gap for Eastern Africa will remain large even under the most proactive future.

Figure 8 Aggregate exogenous crop yield projections for Eastern Africa by scenario (gigacalories per ha)



To present the current and future productivity of livestock, the conversion efficiency of livestock product per unit of feed is used. The projections of conversion efficiencies for livestock as presented in *African Livestock Futures* (Herrero et al. 2014) for the SSPs were used as a starting point for the regional scenarios. Figure 9 represents the exogenous growth in livestock yields for each of the regional scenarios and for each livestock product. Investment in livestock feeding efficiencies as outlined in the scenario narratives are seen in the Industrious Ants and Lone Leopards scenario. The focus on monogastric production in the Lone Leopards scenario is highlighted as well.

Figure 9 Exogenous Growth in Livestock Feeding Conversion Efficiency (kg protein product/t dm feed)



Drivers: Production Costs

As part of the scenarios narratives, the costs of production for the Herd of Zebra scenario were increased by 15% to reflect the lengthy process by which the governments respond to

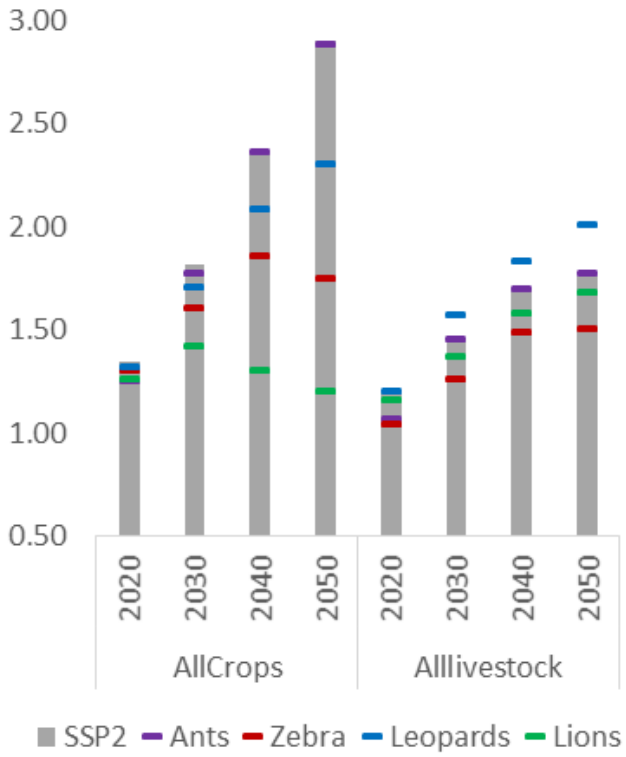
potential problems, although the Zebra scenario specifically considers a future of increased regional market integration. The costs to producers are also increased in the Lone Leopards scenario but by only 10%, due to the lack of market integration but proactive governance. In the Sleeping Lions scenario, where governments are slow to react and also fail to achieve regional market integration the costs of production increase by 25%.

Results

The following section presents the quantified results from GLOBIOM for agricultural production, food security, and land use and environmental impacts for the Eastern Africa scenarios. In these scenarios the growing regional demand for crop and livestock products, the supply of those products was modeled in GLOBIOM for period of the 2000-2050, while also considering the biophysical effects of climate change on crop production.

In Eastern Africa, crop and livestock production increase dramatically in the scenarios with where governments are proactive in making investments in agricultural as seen in Figure 10. For Industrious Ants crop production triples, and livestock production doubles in the Lone Leopard where the focus on monogastric production is the strongest. Increased crop production occurs not only through higher yields, but also through expansion of crop area as seen in Figure 11.

Figure 10 Eastern Africa Crop and Livestock Production Relative to 2010



Crop area expansion is highest for Industrious Ants, as higher crop yields encourage producers to expand. Crop area expands nearly 40% from 2010 in the Sleeping Lions scenario, where crop production only increases by 20% from 2010 highlighting the extensification of crop area needed for low yielding crops. Figure 12 presents the shares of area in 2000 and then in 2050, in this set of scenarios which do not include additional protection of forests and biodiversity hotspots. The largest increases in land use change takes place as conversion of pristine forests to managed forests, grassland, and cropland. In all the scenarios, forest area is converted and large portions of other natural lands, such as savannahs and shrublands are converted as well. The environmental impacts, in thousand tons of CO2 GHG emissions, of this deforestation are highest for the Lone Leopards scenario, where conversion to grassland accounts for more than half the CO2 emissions.

Figure 11 Eastern Africa Crop Area Expansion Relative to 2010 Area

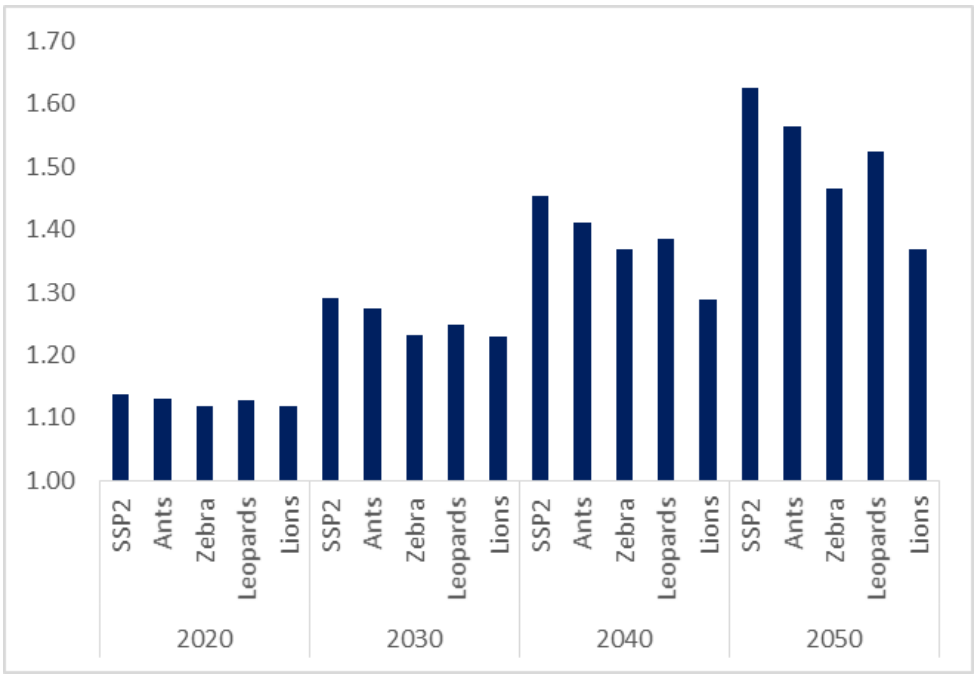
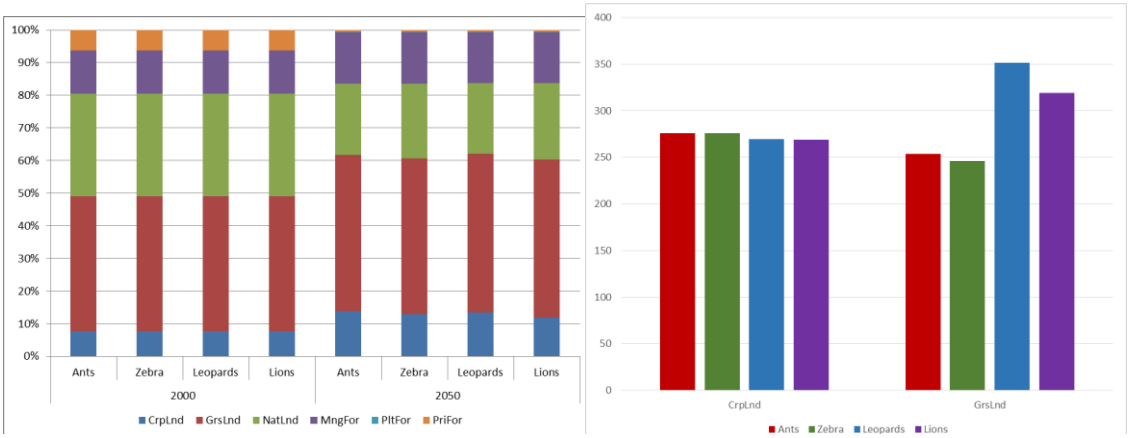


Figure 12 Eastern Africa share of land use by land use types (2000 and 2050) and 000 t CO2 emissions from deforestation from 2000-2050



The yields for two of the most important crops for Eastern Africa, cassava and maize are presented over the time period from 2010-2050 in Figure 15 along with the biophysical effects from climate change in 2050 compared to crop yields in 2010. These increase over time for maize and cassava for all scenarios except the Sleeping Lions scenarios which faces higher production costs as well as little investment in agriculture. The effects of climate change on maize and cassava are not dramatically different from the no climate change scenario for the region, suggesting that investment in agriculture could have an impact on adaptation to climate change. However, only regional yields have been presented; the local effects from climate change could be significant. Because the model maximizes producer surplus, it assumes that there is flexibility of farmers to change production to different crops. GLOBIOM has been used to examine fixed investment adaptation strategies in the face of

climate change (Leclère et al. 2014) but these adaptation and maladaptation scenarios are outside the scope of this socioeconomic scenarios analysis.

Food security in the region improves throughout the period for all scenarios.

Figure **13** presents one measure of food security, available kilocalories per capita per day. Calorie consumption is highest for the Industrious Ants and Herd of Zebra scenario due to the increase in GDP per capita. Investment in livestock production in the Lone Leopards scenario increases the production of and lowers the price of livestock products, specifically monogastric meat. Consumption per capita of monogastrics increases in this scenario even under significantly lower GDP per capita assumptions. The food demand per capita relative to 2010 also provide a measure of change in food consumption as incomes change (Figure 14).

Figure 13 Eastern Africa Calories per capita per day

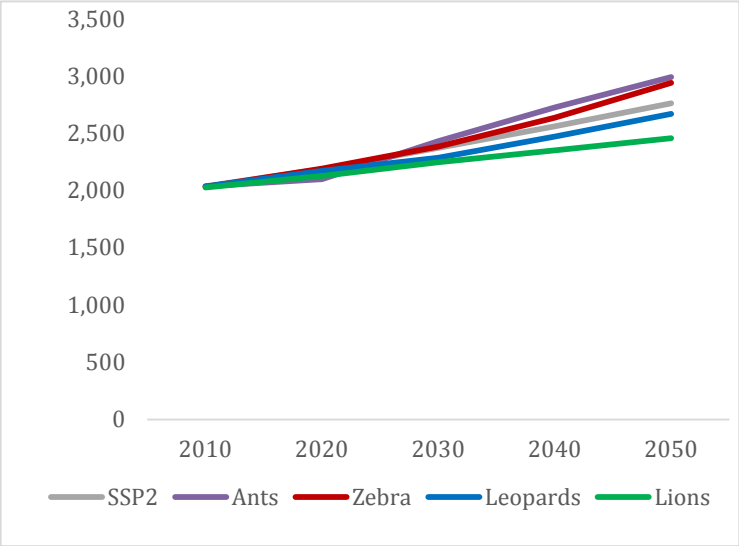


Figure 14 Eastern Africa per capita food demand by product indexed to 2010 food demand per capita

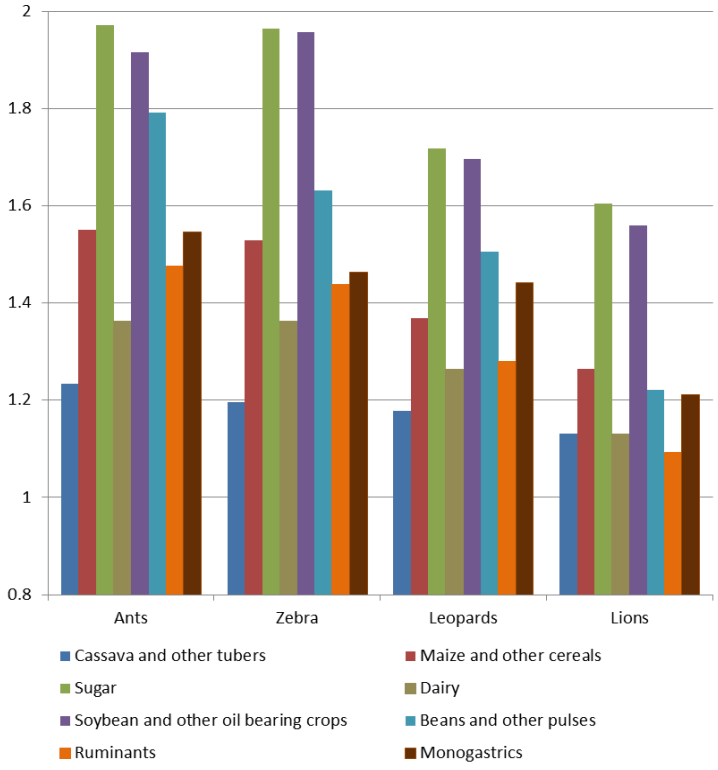
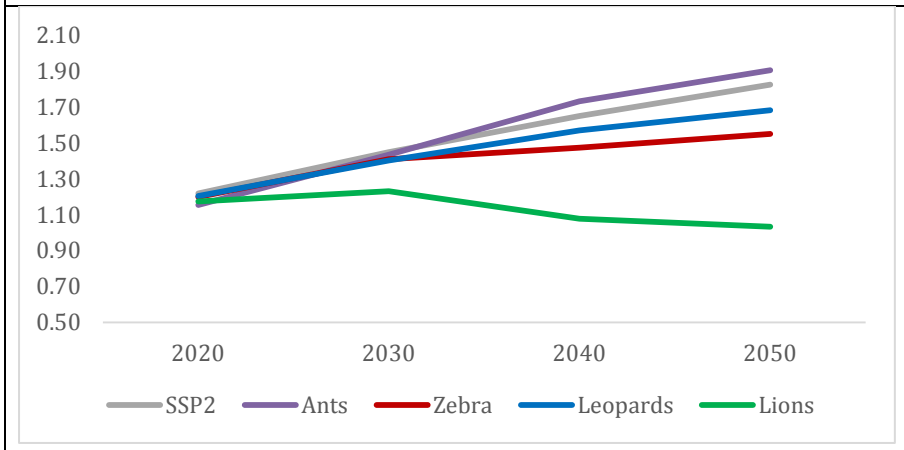
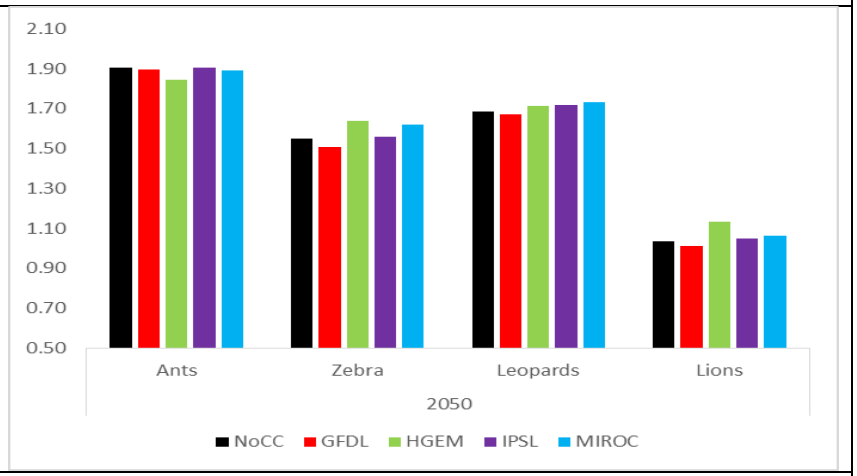

2
1.8
1.6
1.4
1.2
1
0.8
Ants
Zebra
Leopards
Lions
Cassava and other tubers
Maize and other cereals
Sugar
Dairy
Soybean and other oil bearing crops
Beans and other pulses
Ruminants
Monogastrics

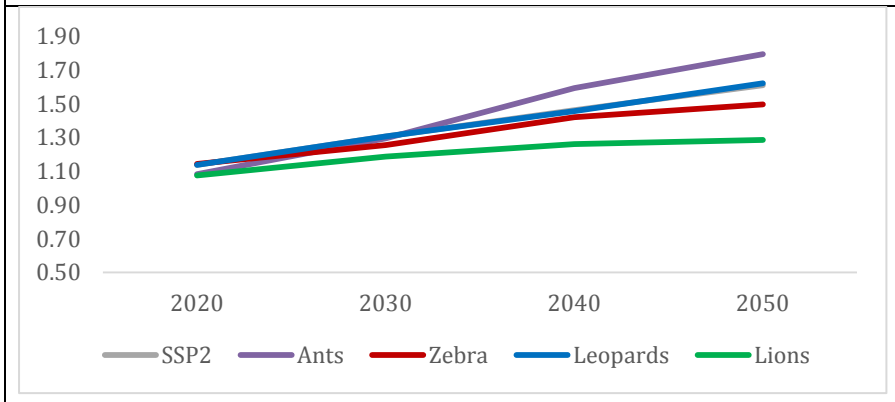
Figure 15 Crop Yield Growth Relative to 2010 levels and climate change effects on crop yields

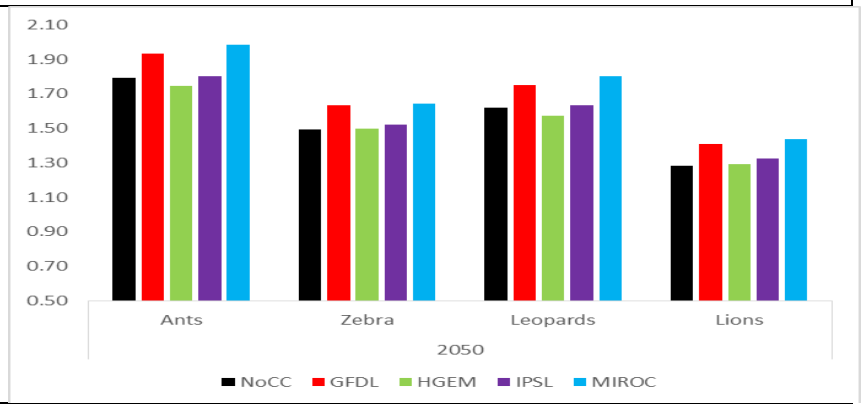
Maize





Cassava





Western Africa

In Western Africa, regional stakeholders outlined four scenarios using narrative flowcharts, conceptual maps, storylines, and a range of semi-quantitative indicators including information on governance (investment, education, market liberalization or control), agriculture (yields, input prices), food security (dietary diversity, access to food) and livelihoods (rural employment, urbanization). The region of Western Africa includes Benin, Burkina Faso, Cape Verde, Ivory Coast, Gambia, Ghana, Guinne, Guinne Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo.

The scenarios have been structured along two axes of uncertainty: a) whether short-term or long-term priorities dominate in regional governance and b) whether state or non-state actors are the driving force of change in the region. These two axes of uncertainty have structured the scenarios, though many other drivers play a key role in the scenario pathways (e.g.: population, GDP, political stability).assumed to occur in each scenario to allow for comparisons to be made between them (Table 2 Western Africa Scenarios: 2050 end state factors of change developed on two axes of uncertainty and relevance.

The four socio-economic scenarios of Western Africa are as follows:

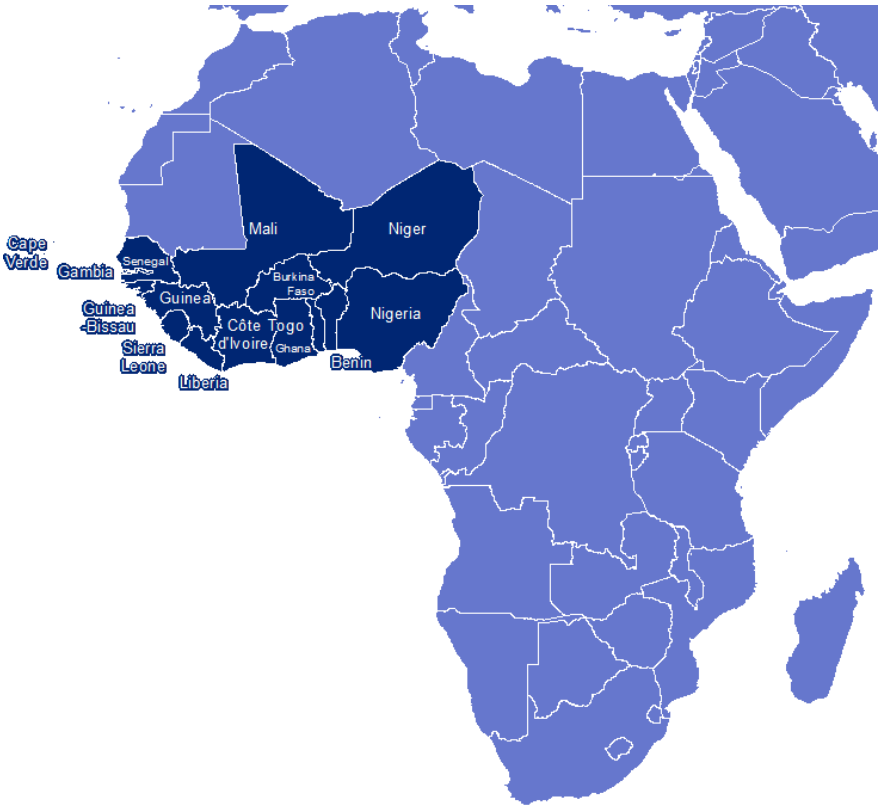
- *Cash, Control and Calories* (CCC): A scenario about short-term priorities with state actors as the dominant force in West Africa to 2050
- *Self-Determination* (SelfDet): A scenario where state actors are dominant and long-term priorities prevail in West Africa up to 2050
- *Civil Society to the Rescue?* (CivilSociety): A scenario where non-state actors are dominant and long-term issues have priority.
- *Save Yourself* (SaveYourself): A scenario where non-state actors are the driving force and short-term priorities dominate in West Africa by 2050

Table 2 Western Africa Scenarios: 2050 end state factors of change developed on two axes of uncertainty and relevance

	Driving Force	**Policy Driver**
Cash, Control and Calories (CCC)	State Actors Dominate	Short-term Issues

Self-Determination (SelfDet)	State Actors Dominate	Long-term Issues
Civil Society to the Rescue? (CivilSociety)	Non-State Actors Dominate	Long-term Issues
Save Yourself (SaveYourself)	Non-State Actors	Short-term Issues

Figure 16 Western Africa Regional Definition



Drivers: GDP per capita

GDP per capita increases dramatically after 2030 across all scenarios. Cash, Control and Calories (CCC) undergoes the largest increase, but begins to taper off and actually declines slightly after 2040 – a reflection of the short-termism of the scenario. Self-Determination experiences both the largest and most consistent increase up to 2050. The other two scenarios both follow these patterns albeit on much smaller scales. Civil Society to the Rescue? (CivilSociety) also experiences a steady and consistent increase, albeit not a particularly large one over time (Figure 17). SaveYourself increases gradually until following off after 2040. Population grows from 300 million in 2010 to between almost 600 million (SelfDet) and 800 million (SaveYourself) (Figure 18).

Figure 17 Western Afria GDP per capita for regional scenarios indexed to 2000 values

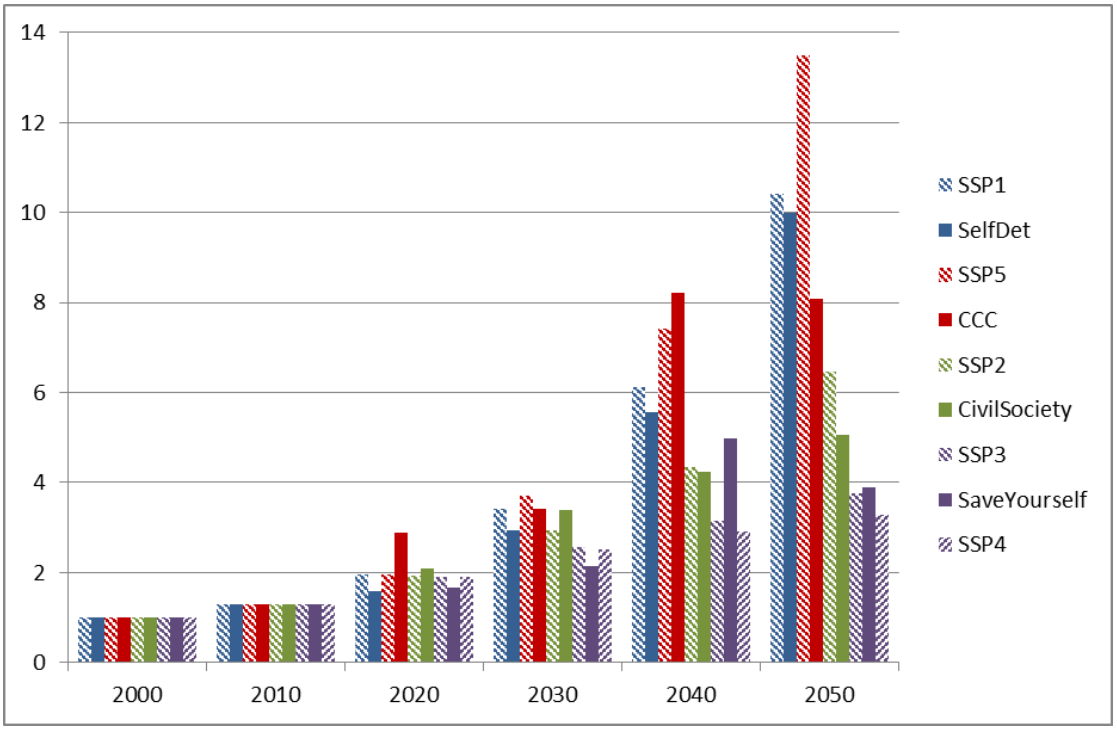
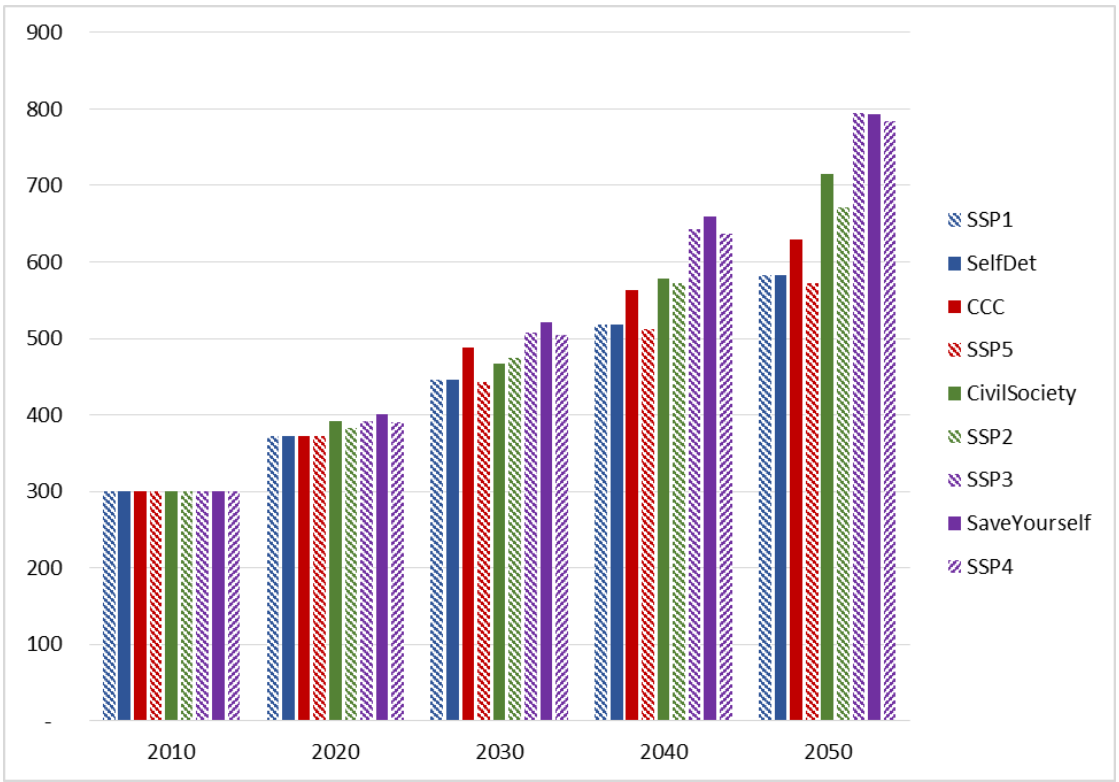


Figure 18 Population of Western Africa (millions of people)

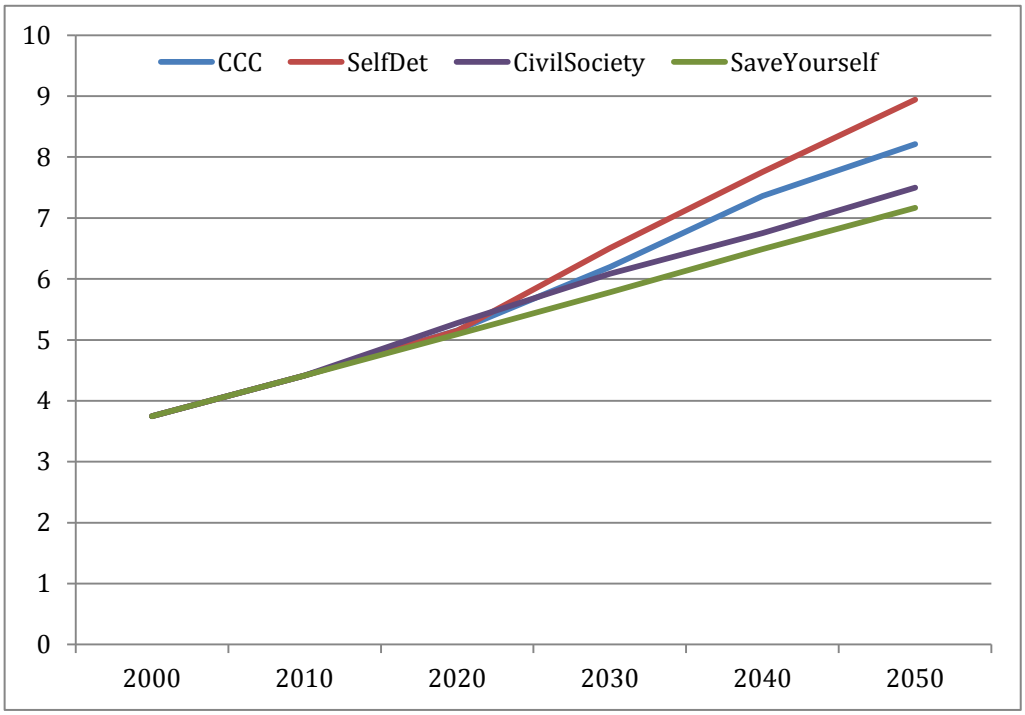


Drivers: Crop and Livestock Yields

As described in the section above, the exogenous growth in crop yields have been translated from the scenario storylines.
Figure 19 gives a summary of the changes assumed in the productivity of agricultural areas, as well as the potential effects it would have on the domestic supply (excluding imports) of calories for each of the scenarios, an important exogenous assumption on changes in food availability within the scenario narratives.

Crop yields are highest in Self-Determination scenario by the end of the period, increasing nearly 2.5 times. Yields in the Save Yourself scenario increase the least, representing the challenging environment where short-term issues take priority and change is left only in the hands of non-state actors. Although these yields (being exogenous) do not represent the transitions between low input low yielding crop systems to high input high yield crop systems or reallocation of crop production to highly productive land or crop types, the yield gap for Western Africa will remain a challenge for the agricultural system.

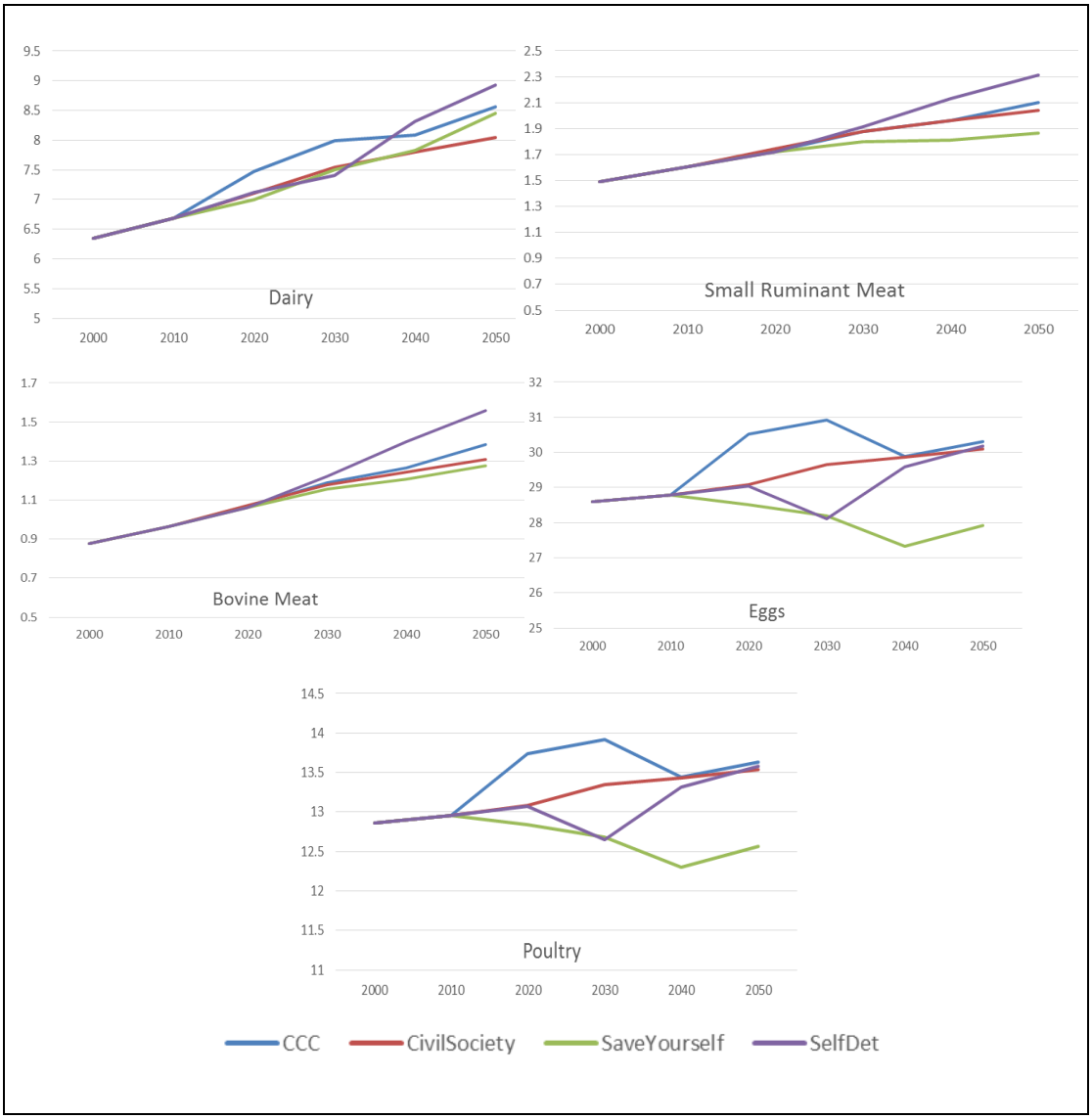
Figure 19 Aggregate exogenous crop yield projections for Western Africa by scenario (gigacalories per ha)



To present the current and future productivity of livestock, the conversion efficiency of livestock product per unit of feed is used. The projections of conversion efficiencies for livestock as presented in *African Livestock Futures* (Herrero et al 2014) for the SSPs were

used as a starting point for the regional scenarios. Figure 9 represents the exogenous growth in livestock yields for each of the regional scenarios and for each livestock product. Investment in ruminiant production as outlined in the scenario narratives are seen in the SelfDet scenario, while the focus of dairy production in the early decades of CCC is considered. Little investment is made in the SaveYourself scenario for livestock.

Figure 20 Exogenous Growth in Livestock Feeding Conversion Efficiency (kg protein product/t dm feed)



Drivers: Production Costs

As part of the scenarios narratives, the costs of production for the CCC scenario were increased by 15% to reflect the patchwork and myopic response by governments respond to

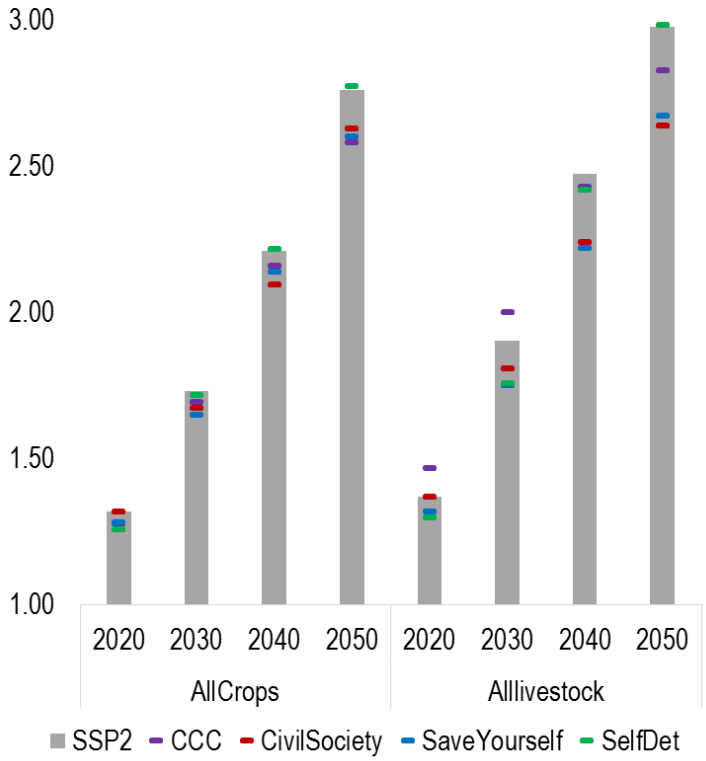
potential problems. For CivilSociety, costs of production were increased by 15% , and in SaveYourself, where non-state actors are driving change with a short term priority setting agenda the costs of production increase by 25%.

Results

The following section presents the quantified results from GLOBIOM for agricultural production, food security, and land use and environmental impacts for the Western Africa scenarios. The regional demand for crop and livestock products, using the context of the socioeconomic drivers from the storyline, and the supply of agricultural products was modeled in GLOBIOM for period of the 2000-2050, while also considering the biophysical effects of climate change on crop production.

CCC and SelfDet both have the highest investment in agriculture, as the exogenous growth in crop yields highlighted in the earlier section, only SelfDet has a long term priority setting that also keeps production costs from increasing for producers creates an environment where production of livestock triples by the end of the period and nearly triples for crops (Figure 21).

Figure 21 Western Africa Crop and Livestock Production Relative to 2010



Crop area expansion is highest, 60% from 2010 to 2050, for the Save Yourself scenario highlighting the extensification of crop area needed for low yielding crops (Figure 22). In the scenario where investments in agriculture area a priority, SelfDet, crop area expansion is far less than even the SSP2 scenario (where crop production grows nearly the same). This land-sparing intensification of agriculture can be seen in Figure 23, which shows the relative change in land types from 2000 to 2050. While conversion of pristine forest area for crop production is less in CCC (24% of pristine forest conversion), more than three-quarters of the forest is converted to other uses. Nearly half of the forest converted goes into livestock production while the other 30% is converted to managed forests. SaveYourself retains the least forest coverage of all the scenarios and converts the most to cropland and grassland, causing between 10- 25% more CO2 emissions than the other scenarios (Figure 23).

Figure 22 Western Africa Crop Area Expansion Relative to 2010 Area

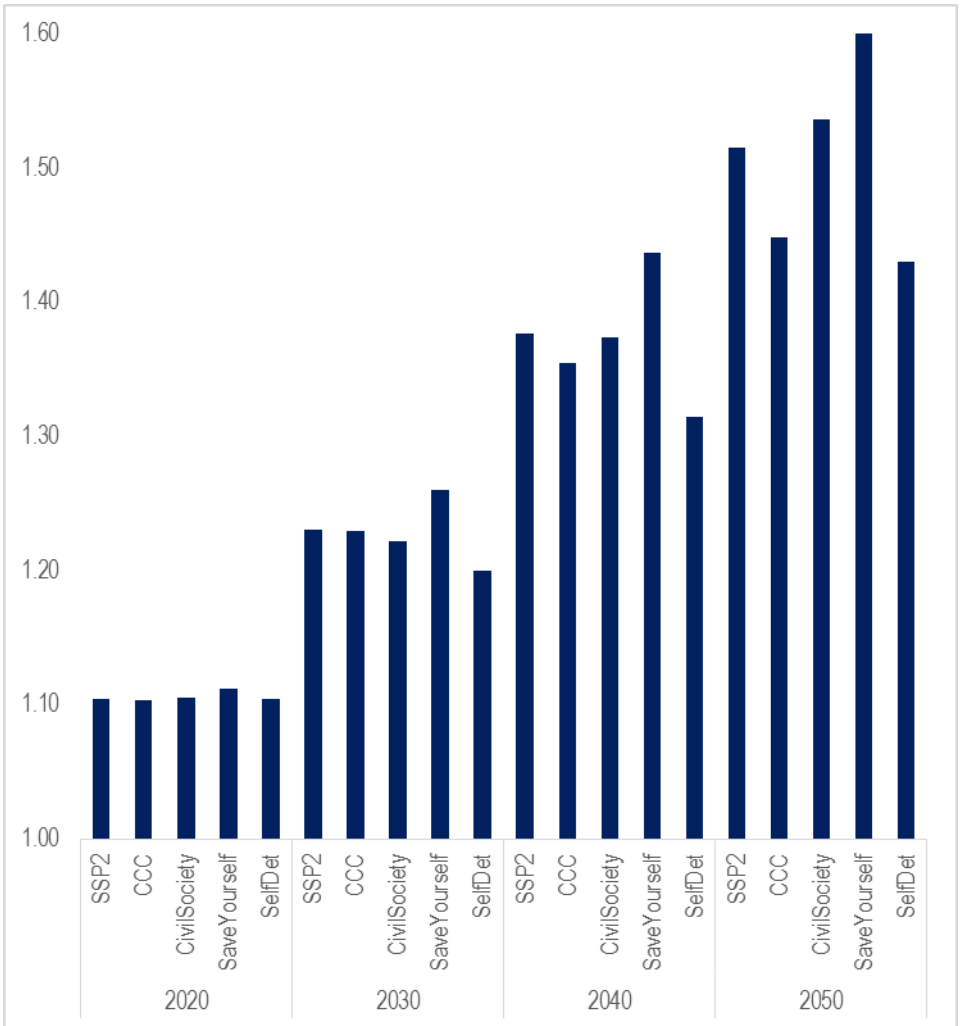
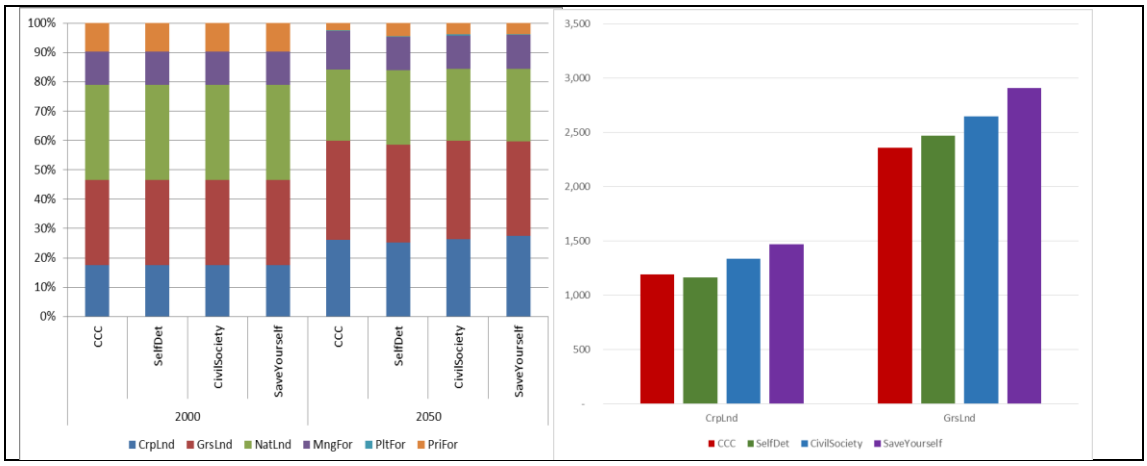


Figure 23 Western Africa share of land use by land use types (2000 and 2050) and 000 t CO2 emissions from deforestation from 2000-2050



Yields for two of most important crops for Western Africa, cassava and maize increase over the time period from 2010-2050, and for maize are highest for the CCC scenario reflecting the storyline of investment only in staple crops with a larger market (Figure 15). The effects of climate change on maize are not dramatically different from the no climate change scenario for the region, suggesting that investment in agriculture could have an impact on adaptation to climate change. The climate effects on cassava yields are much more negative and although these scenarios do not represent "absolute futures," the importance of cassava to food security in the region should be taken under consideration. Additionally, only the regional yields have been presented here; the local effects from climate change could be more or less dramatic. Because the model maximizes producer surplus, it assumes that there is flexibility of farmers to change production to different crops. GLOBIOM has been used to examine fixed investment adaptation strategies in the face of climate change (Leclère et al. 2014) but these adaptation and maladaptation scenarios are outside the scope of this socioeconomic scenarios analysis.

Food security in the region improves throughout the period for all scenarios, and presents one measure of food security, available kilocalories per capita per day. SelfDet and CCC see the highest growth in calorie availability, while SaveYourself and CivilSociety have less growth. The per capita demand for livestock products grows significantly (more than 30%) for SelfDet. The growth in demand for staple goods and also livestock products is lowest for CivilSociety and SaveYourself, reflecting the low economic growth as well as the increase in prices (30% increase from 2000 for livestock products in SaveYourself).

Figure 24 Western Africa Calories per capita per day

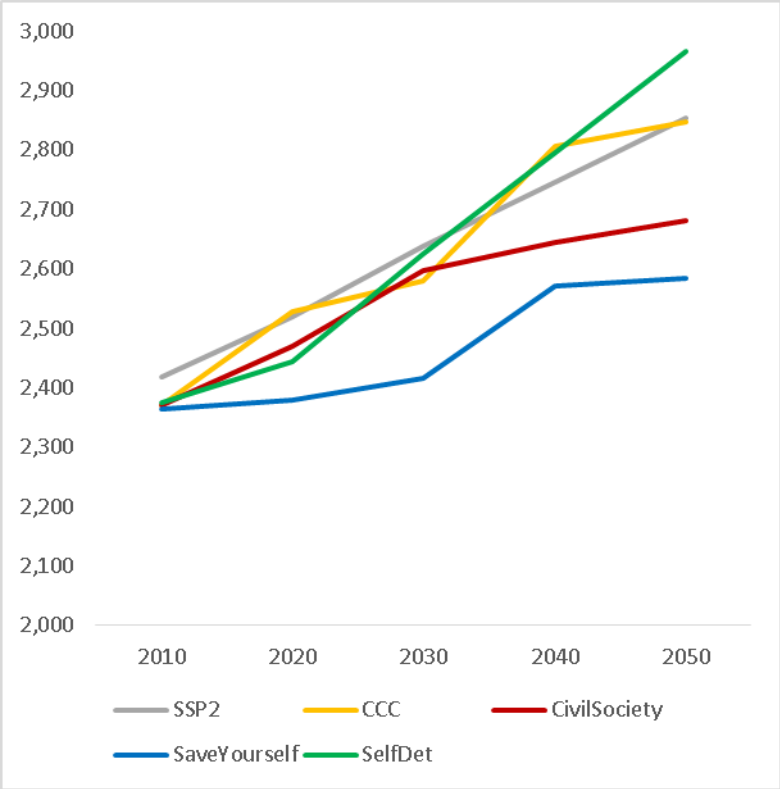


Figure 25 Western Africa per capita food demand by product indexed to 2010 food demand per capita

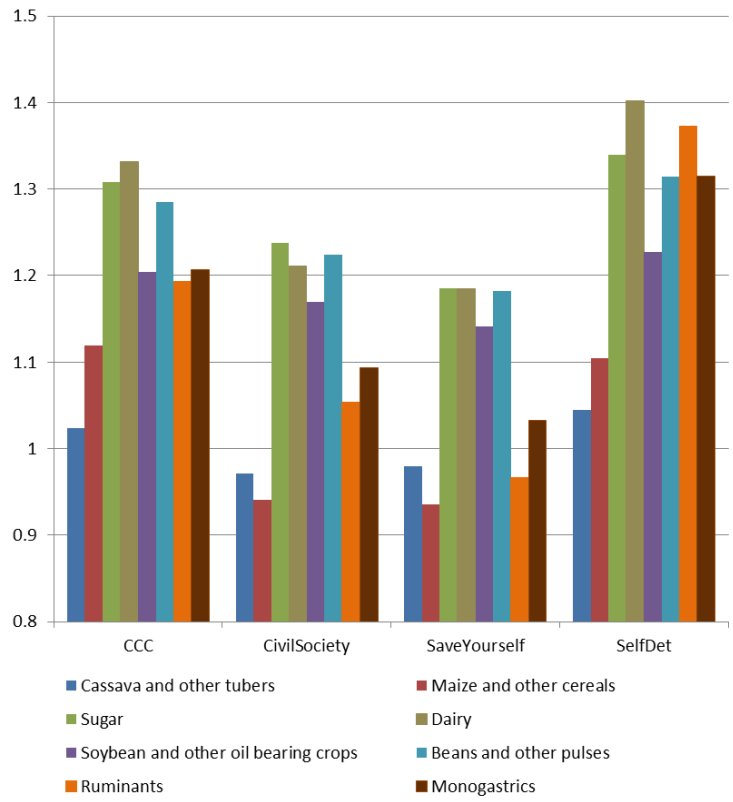
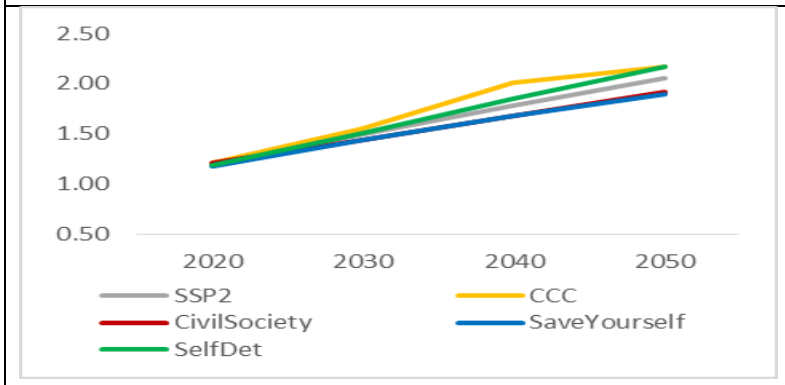
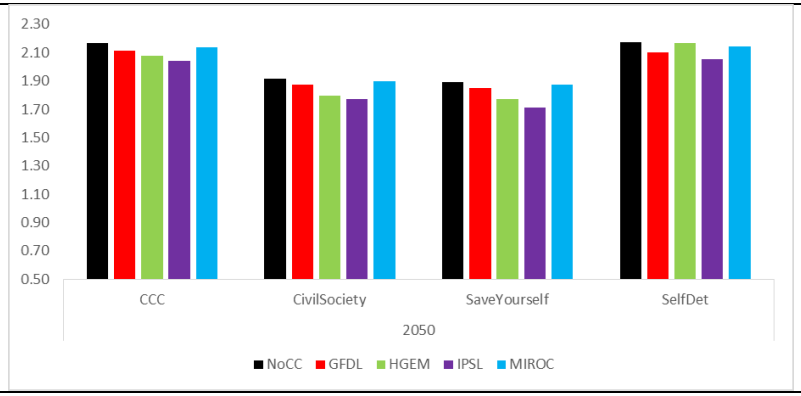


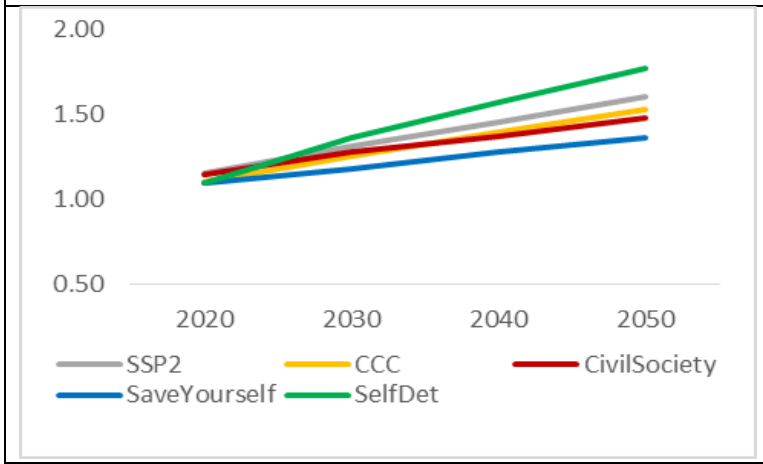
Figure 26 Crop Yield Growth Relative to 2010 levels and climate change effects on crop yields

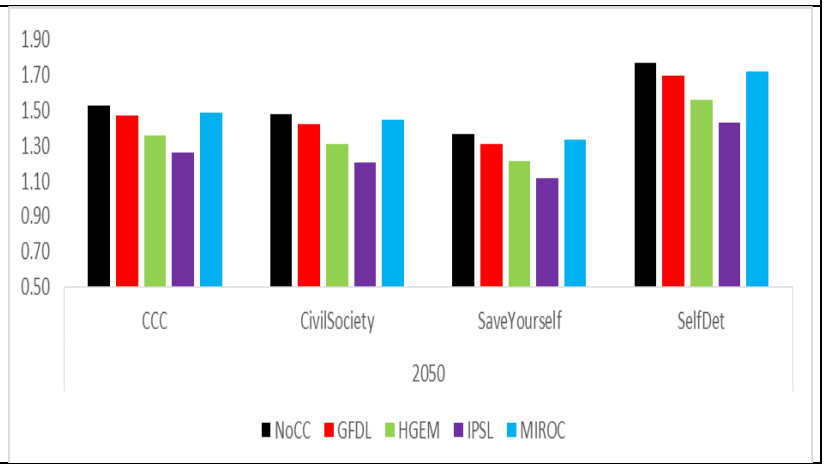
Maize





Cassava





South Asia

In South Asia, the process developed by Vervoort et al. (2014) was first used to create diverse scenarios that considered multiple factors of change and multiple end states. Regional stakeholders began the development of scenarios by identifying challenges to future food security, rural livelihoods, and the environment and ranking these challenges by relevance for food security for the region and whether the future of that challenge was uncertain. This allowed the stakeholders to create highly diverse and relevant scenarios. The scenarios developed for South Asia considered six factors of change: Knowledge, education, information (human capital); Governance and Institutions; Science, Technology, and Innovation; Political Stability and conflict; Economic Structure; and Demographics. In in the initial and subsequent stakeholder workshops, five plausible socio-economic scenarios were chosen and storylines were developed using narrative flowcharts, conceptual maps, and semi-quantified indicator. The scenarios are defined by the end state, or world in 2050, for each factor of change displayed Table 3. The region of South Asia includes Bangladesh, India, Pakistan, Sri Lanka, Nepal (

Figure 27).

The semi-quantitative indicators for each region were interpreted in the context around the SSPs. The SSPs were developed to offer plausible futures that are globally and regionally consistent. The drivers for scenarios were quantified, using the population and GDP futures developed in the SSP process as a starting point, the semi-quantitative changes from the workshops to add additional context, as well as feedback from stakeholders on plausibility. By using the regional assumptions of the SSPs as an envelope of possibilities this process was able to add consistency to the scenarios and usefulness of the SSPs themselves.

Figure 27 South Asia Regional Definition

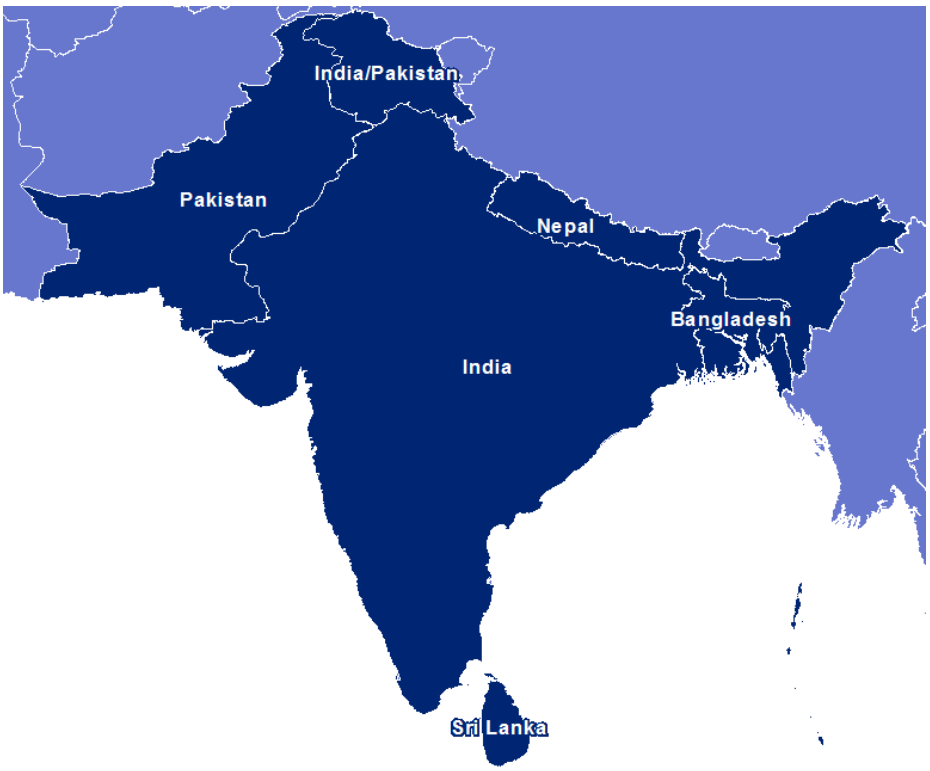


Table 3 South Asia scenario definitions: 2050 end states for each factor of change

	Knowledge, education, information (human capital) (K)	**Governance and Institutions** (I)	**Science, Technology, and Innovation** (S)	**Political Stability and Conflict** (S)	**Economic Structure** (E)	**Demographics** (D)
The New Union of South Asia (USA)	Aware, Informed, educated population	High institutional capacity and high coordination across agencies	High transfer and availability of science and technology	Political stability in the region	Agricultural sector is not dominant	low population growth and medium urbanization
Jugaad	Unaware, uninformed, uneducated population	Low institutional capacity and low coordination across agencies	Low transfer and availability of science and technology	Political instability and conflict in the region	Agricultural sector is dominant	high population growth and high urbanization
Unstable Flourishing	Aware, Informed, educated population	High institutional capacity and high coordination across agencies	High transfer and availability of science and technology	Political instability and conflict in the region	Agricultural sector is dominant	low population growth and medium urbanization
People Power	Aware, Informed, educated population	Low institutional capacity and low coordination across agencies	High transfer and availability of science and technology	Political instability and conflict in the region	Agricultural sector is not dominant	low population growth and medium urbanization
Precipice	Aware, Informed, educated population	Low institutional capacity and low coordination across agencies	Low transfer and availability of science and technology	Political instability and conflict in the region	Agricultural sector is dominant	high population growth and high urbanization

Drivers: GDP per capita

GDP per capita for the NewUSA scenario follows closely with the GDP per capita for SSP1 the sustainability scenario. Precipice follows the SSP5 (conventional development) scenario initially and until 2030 and then falls to the SSP3 (fragmentation), which is the scenario most closely associated with the Jugaad scenario. People Power and Unstable Flourishing GDP per capita follows with SSP2 the Middle of the Road scenario (Figure 28 GDP per capita growth relative to year 2000 values). Population grows in all scenarios, from 1.6 billion in 2010 to nearly 2.6 billion in the Jugaad scenario and 2 billion in NewUSA.

Figure 28 GDP per capita growth relative to year 2000 values

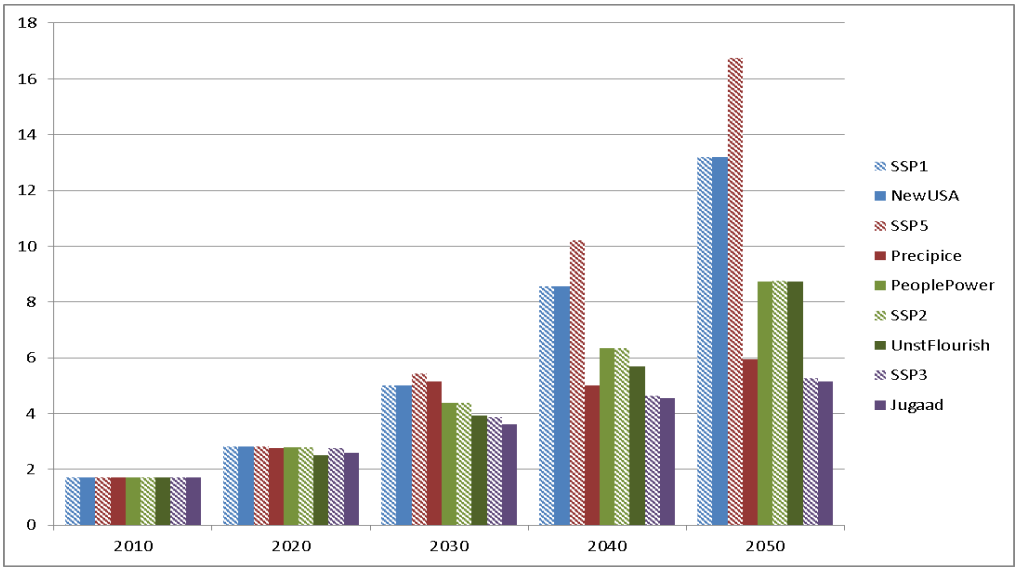
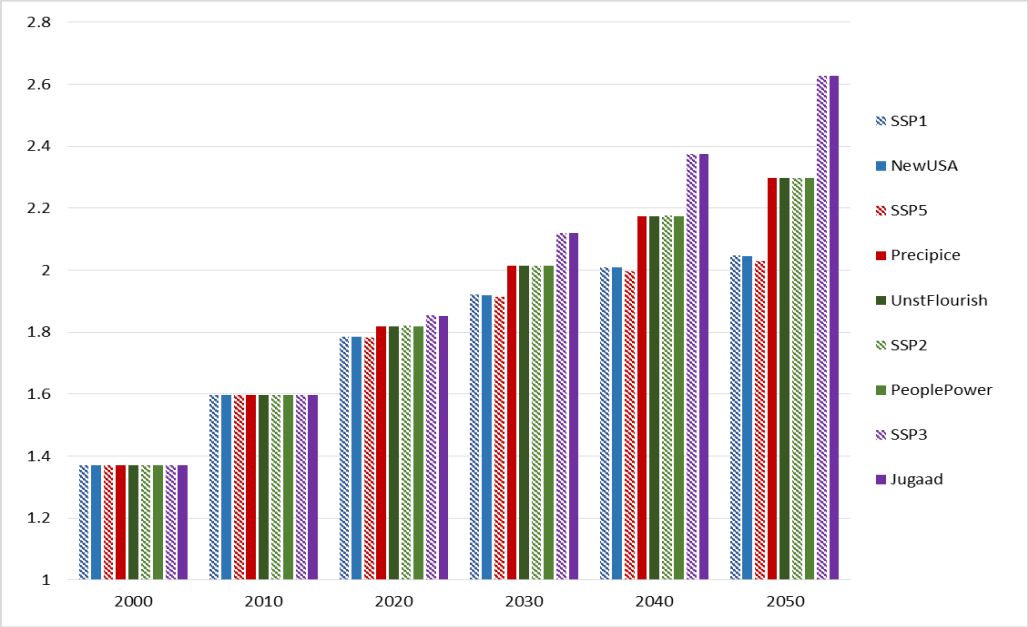


Figure 29 Population of South Asia (billions of people)

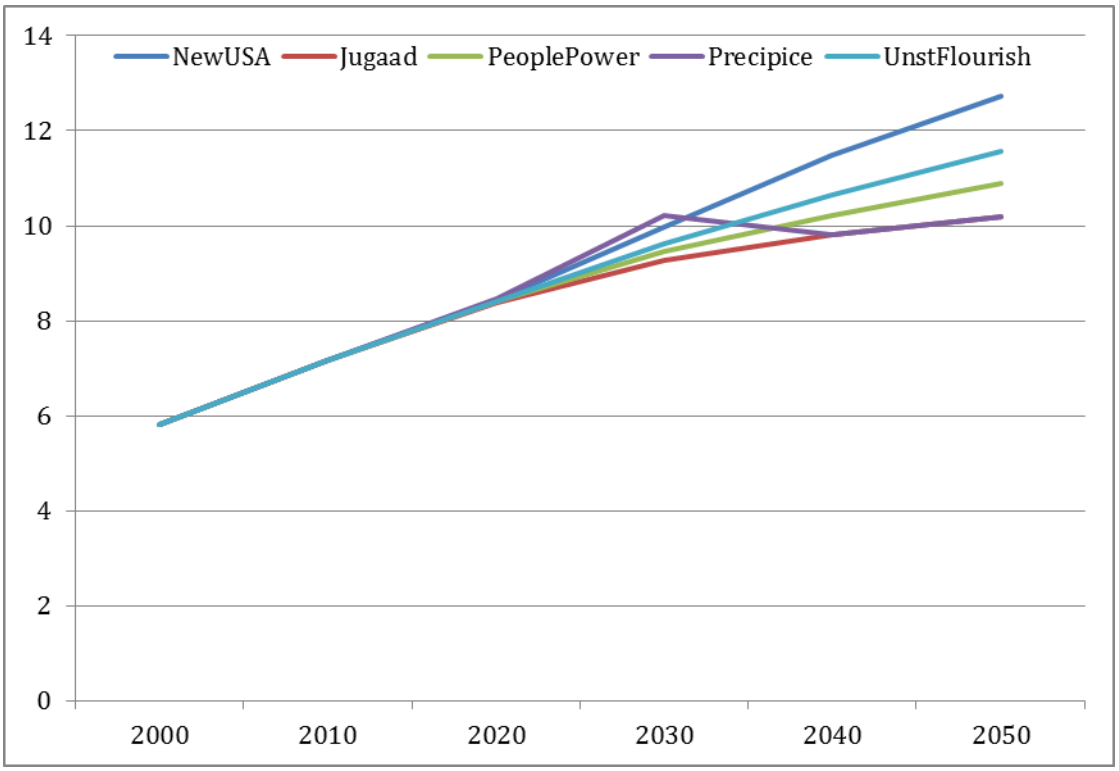


Drivers: Crop and Livestock Yields

As described in the section above, the exogenous growth in crop yields have been translated from the scenario storylines. Figure 30 gives a summary of the changes assumed in the productivity of agricultural areas, as well as the potential effects it would have on the domestic supply (excluding imports) of calories for each of the scenarios, an important exogenous assumption on changes in food availability within the scenario narratives.

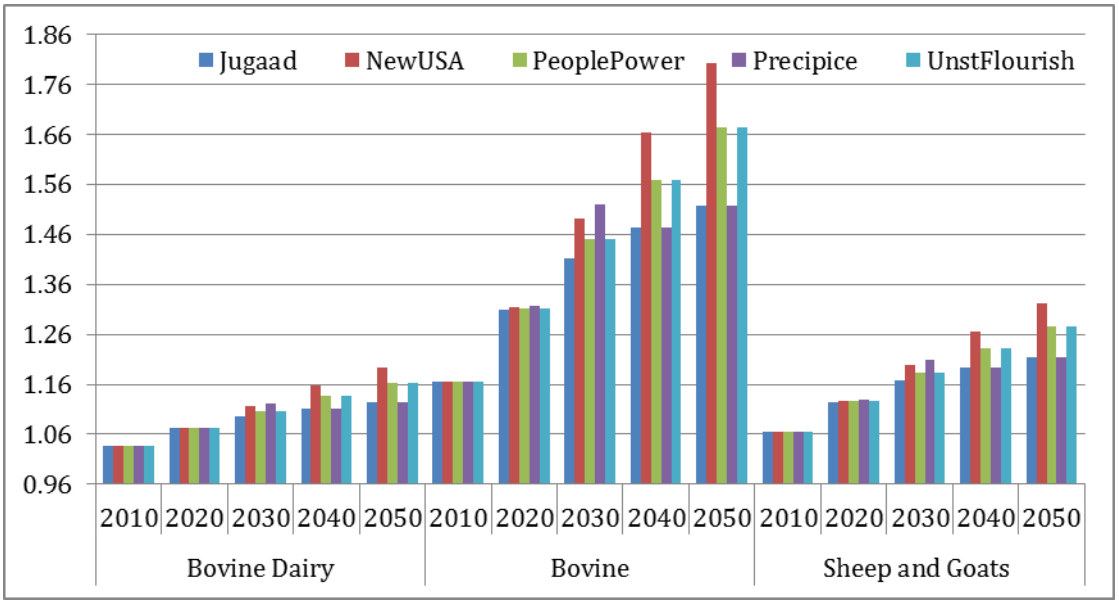
Crop yields are highest in NewUSA and Precipice in the early periods, but then the yields in the Precipice remain around 10 gigacalories per ha for the rest of the period. Yields, in terms of calories, double for New USA and nearly double for unstable flourishing, whereas Jugaad and Precipice fall short of this, representing the low institutional capacity and coordination among agencies as well as the lack of investment in extension services to transfer knowledge. These yields (being exogenous) do not represent the transitions between low input low yielding crop systems to high input high yield crop systems or reallocation of crop production to highly productive land or crop types.

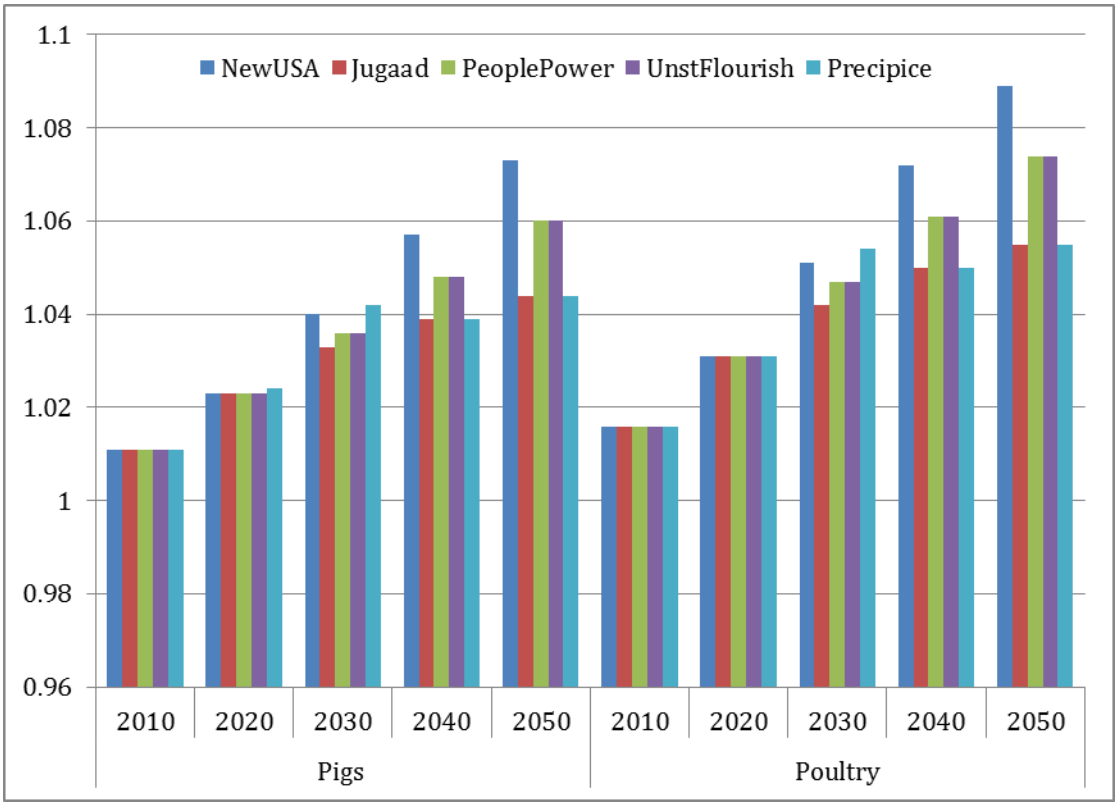
Figure 30 Aggregate exogenous crop yield projections by scenario (gigacalories per ha)



Livestock yields are highest for NewUSA, and while the livestock yields for People Power and UnstableFlourish are the second highest, the underlying assumption for how these yields are achieved are unique to the narrative. Although the exogenous yield growth for bovine and other livestock products appear quite large, livestock production and demand in the region remains dominated by dairy products.

Figure 31 Livestock exogenous yield increases (Ruminants and Monogastrics)





Drivers: Production Costs

As part of the scenarios narratives, the costs of production for the Precipice and Jugaad scenarios were increased by 25% to represent the low transfer of knowledge and technology and poor institutional capacity and coordination of governmental agencies.

Results

The following section presents the quantified results from GLOBIOM for agricultural production, food security, and land use and environmental impacts for the South Asian scenarios. In these scenarios the growing regional demand for crop and livestock products, the supply of those products was modeled in GLOBIOM for period of the 2000-2050, while also considering the biophysical effects of climate change on crop production.

In South Asia, crop production increases by nearly 80% for most of the scenarios by 2050. Production is driven by increasing demand for products, and dairy production increases most significantly in the Jugaad scenario, where demand for dairy products doubles by 2050. Despite the growth in this sector, there remains unmet regional demand, met through imports. Dairy imports in the region are highest for Jugaad and Precipice and as a share of the regional production account for 11% and 12%, respectively. In crop production, the region is a net exporter for all scenarios except for Jugaad, where the region must import by 2050, due to the

growing population and an agricultural sector that is faces little innovation and transfer of technology, political instability, and poor governance. By 2050, Precipice shows signs of a failing agricultural sector and makes only marginal exports of crops.

In all scenarios over the time period, crop yields grow for four of the most produced crops in South Asia, rice, wheat, maize and sugar. Relative to the 2010 levels, yields are highest for the NewUSA reflecting the high institutional capacity and transfer of technologies for agriculture. This yield increase is especially noticeable for maize in NewUSA where yields more than double by 2050 (Figure 37). The climate change effects on crop yields are presented in Figure 38. For rice and wheat, the yields under climate change are lower than those under no climate change. These yields are aggregated to the regional level, which reflect the flexibility of farmers to produce different crops and switch from less to more productive land. However, the very local effects from climate change could have even lower yields. GLOBIOM has been used to examine fixed investment adaptation strategies in the face of climate change (Leclère et al. 2014) but these adaptation and maladaptation scenarios are outside the scope of this socioeconomic scenarios analysis.

Figure 32 South Asia Crop and Livestock Production Relative to 2010

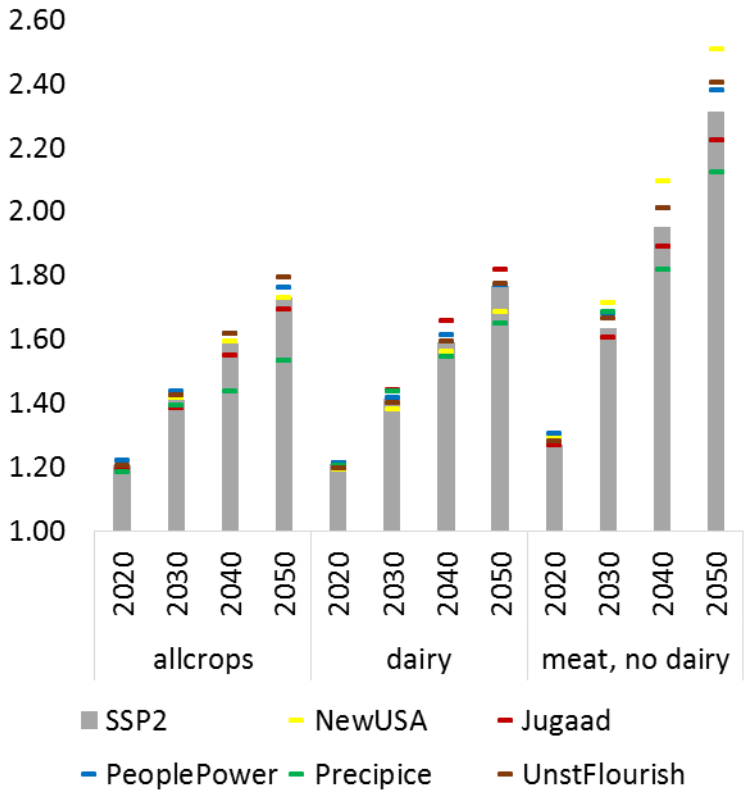
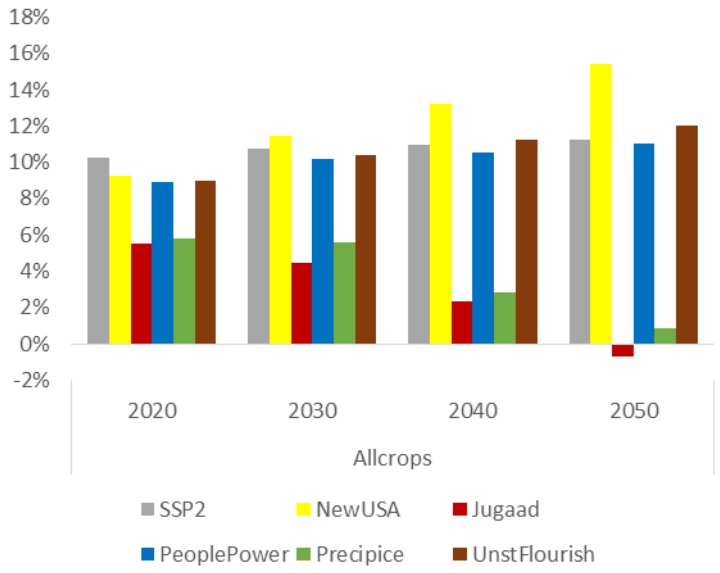


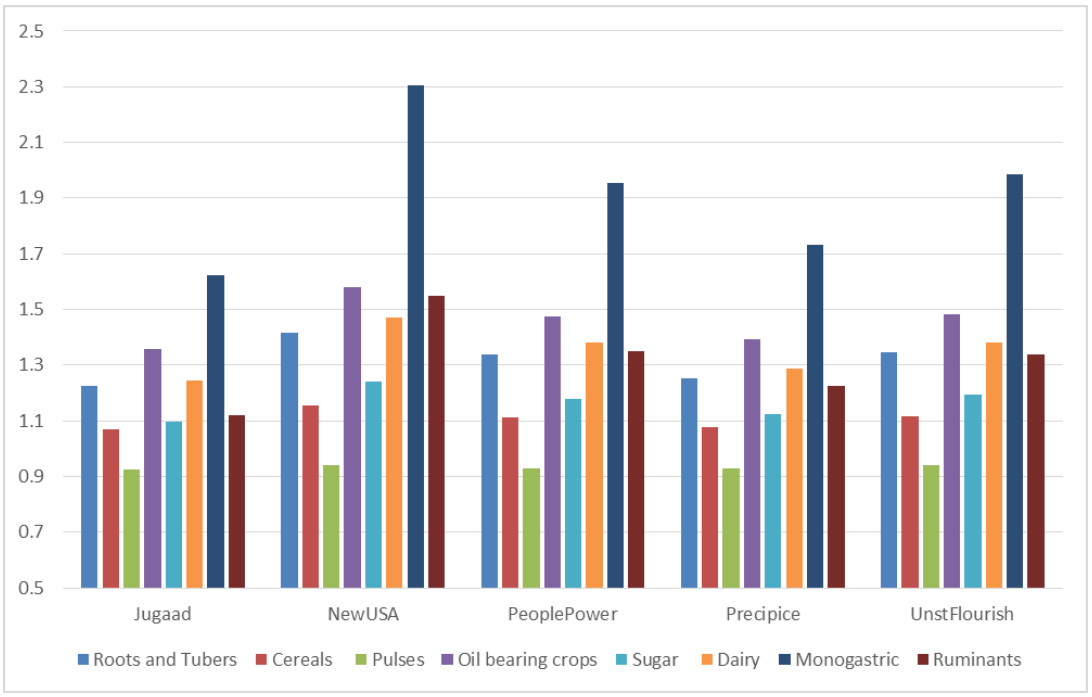
Figure 33 South Asia Crop Exports as a Percentage of Total Regional Production



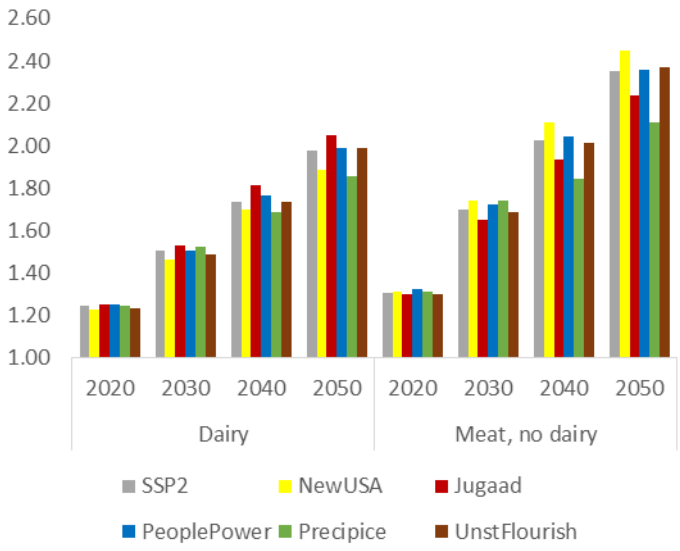
In South Asia, demand for crop and livestock product grows in all scenarios. Figure 34 presents the growth in per capita food demand by aggregate crop and livestock groups. While meat consumption is low in South Asia due to cultural reasons, there is some growth in meat consumption (monogastric meat in particular), especially in the scenarios with higher income per capita growth. Demand for all crop products as well as for dairy products grows most significantly over the time period for the Jugaad scenario, but with growing population, the demand per capita is the lowest for all products of all scenarios. As the demand per capita is lowest in Jugaad, it is unsurprising that kilocalorie availability, one measure of food security is lowest in for that scenario, increasing only 16% from 2000. Calories increase nearly 30% for NewUSA, PeoplePower, and UnstableFlourishing (Figure 35).

Figure 34 South Asia Food Demand per capita for all products (indexed to year 2010 levels of food demand per capita) (a); South Asia Total Food Demand for Dairy and Livestock and all crop products indexed to year 2010 levels (Ruminants and Monogastrics) (b)

a)


2.5
2.3
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
Jugaad
NewUSA
PeoplePower
Precipice
UnstFlourish
Roots and Tubers
Cereals
Pulses
Oil bearing crops
Sugar
Dairy
Monogastric
Ruminants

b)


2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
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2020
2030
2040
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Dairy
Meat, no dairy
SSP2
NewUSA
Jugaad
PeoplePower
Precipice
UnstFlourish

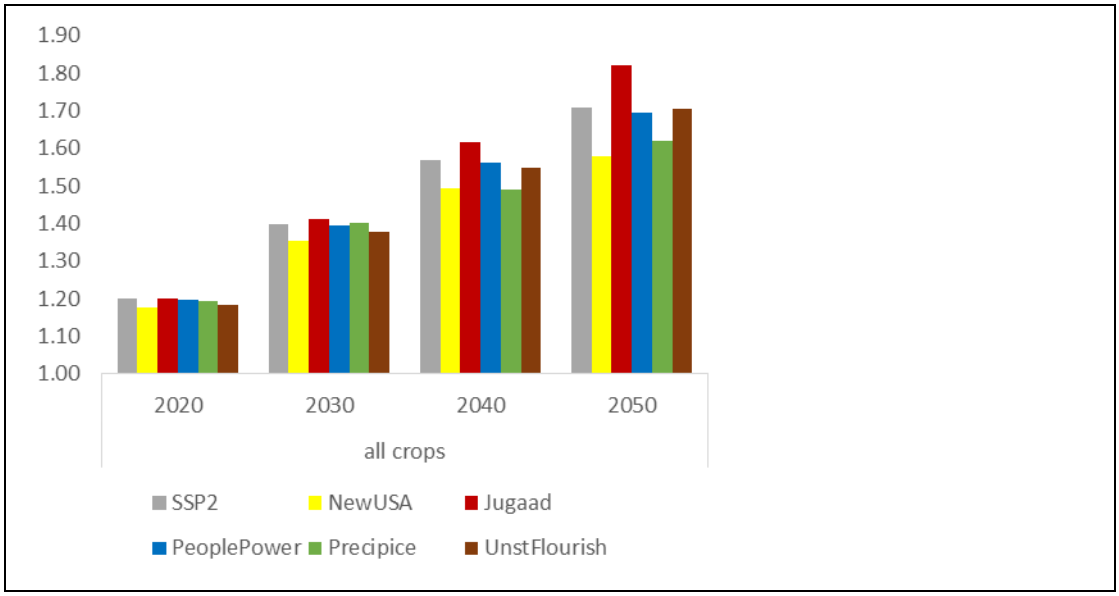
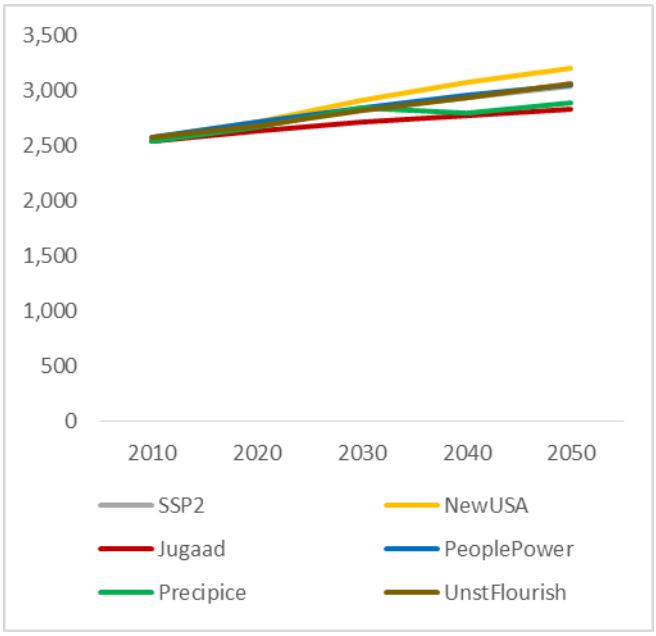


Figure 35 South Asia Available Kilocalorie per capita per day



Over the time period GHG emissions from the major users of land increase by nearly 100 million mt of CO2, more than half of which comes from livestock production, nearly 40 % from crop production and 5% comes from land use change (Figure 36). Emissions are nearly the same for each scenario, but lowest for NewUSA, as the growth of the agricultural sector for the PeoplePower and UnstableFlourishing, due to the increase in demand coming from a larger population.

Figure 36 Greenhouse gas emissions for South Asia (million tons CO2 eq)

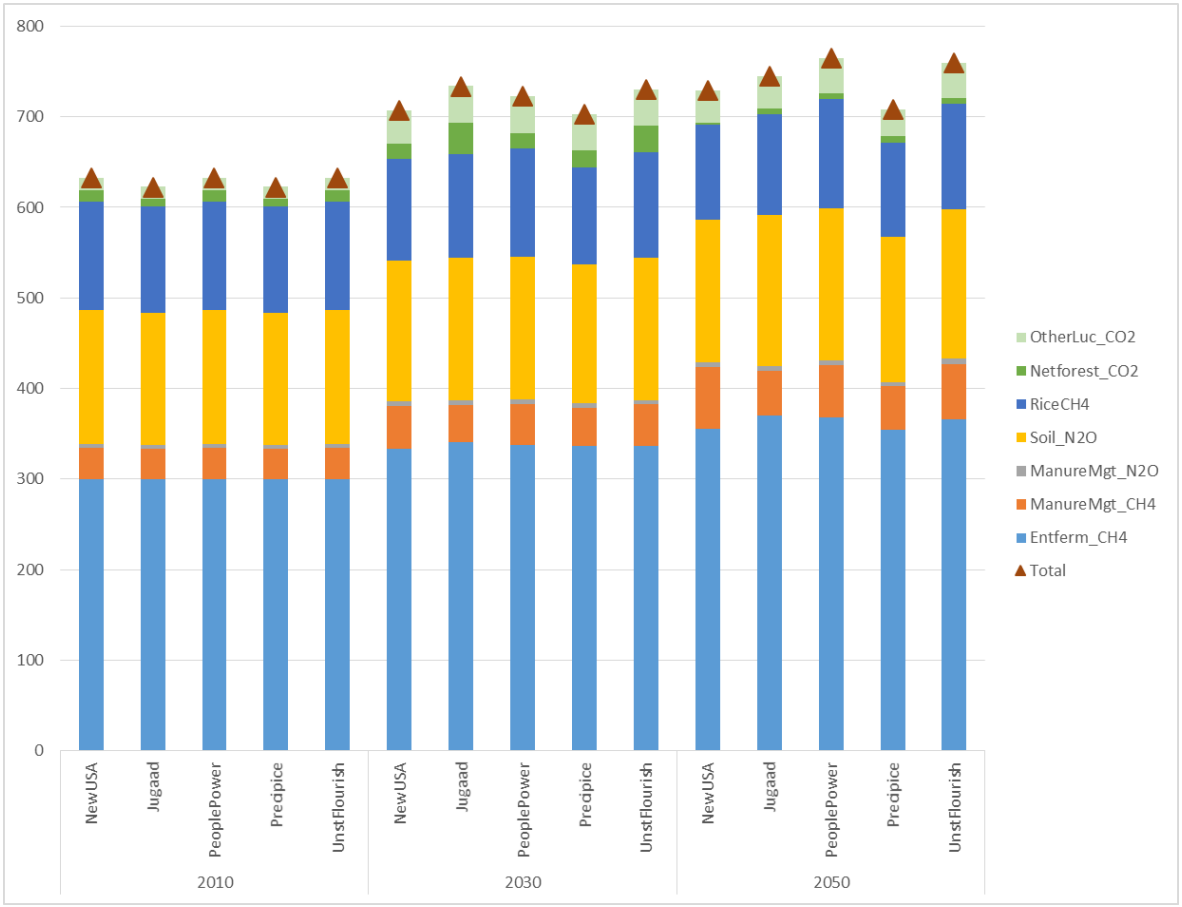


Figure 37 South Asia Crop Yield Growth Relative to 2010 levels

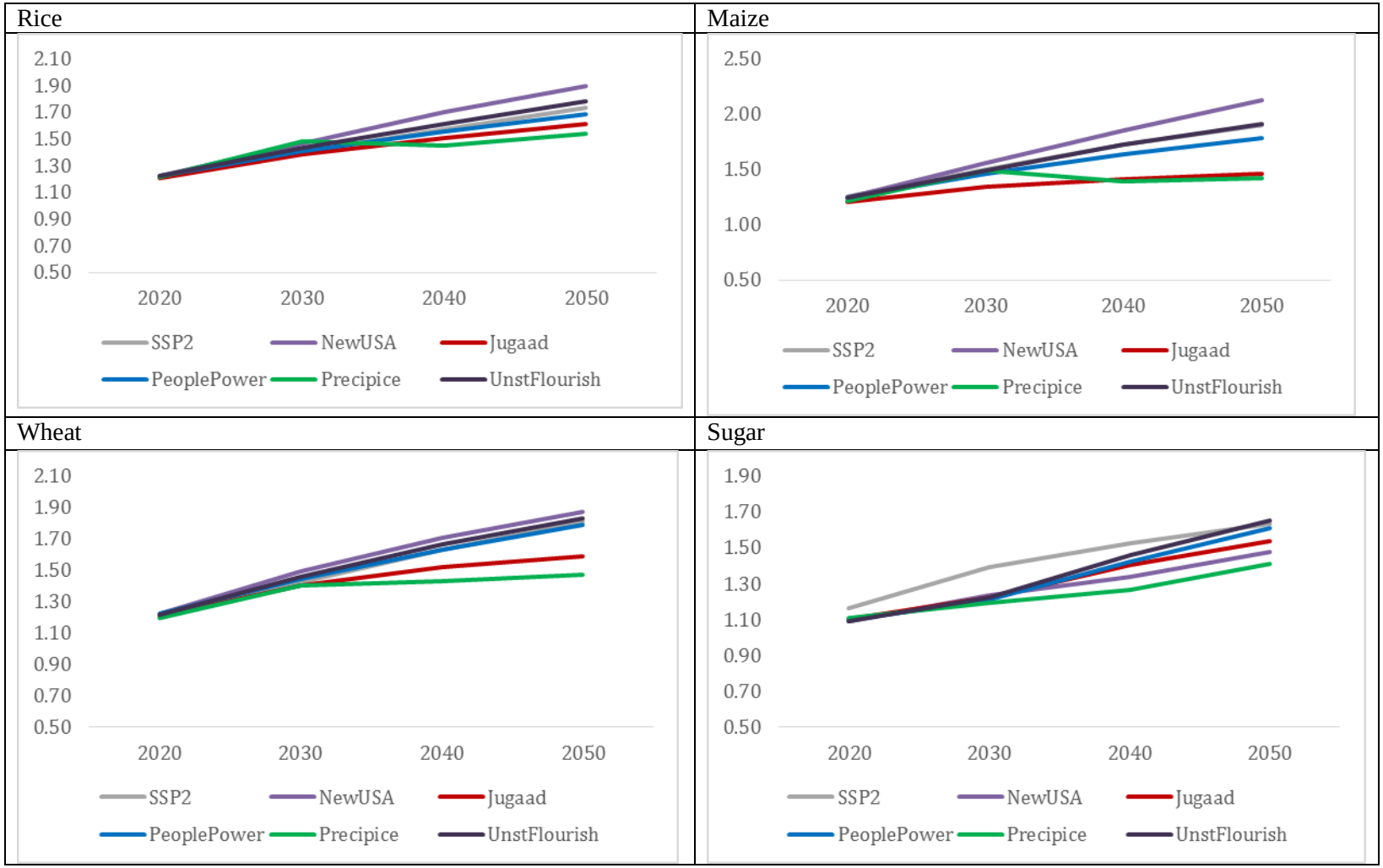
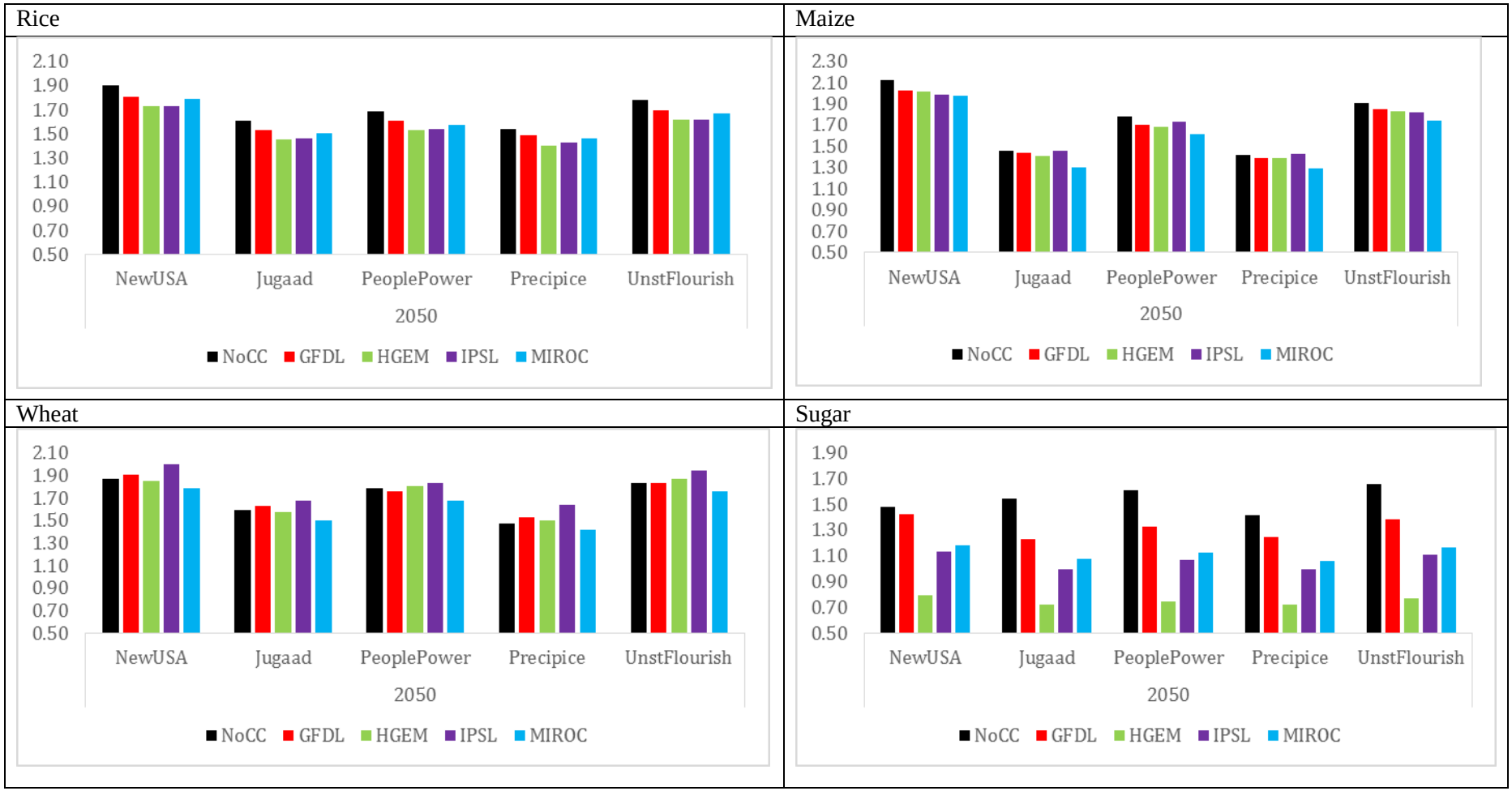


Figure 38 Climate change effects on crop yields indexed to year 2010 values for South Asia



Southeast Asia

Under a methodology similar to the one used in South Asia, scenarios were developed for Southeast Asia. Details from the process can be found in the Workshop Report (CCAFS 2014a). The region of Southeast Asia includes Vietnam, Cambodia, and Laos as show in

Figure 39. Stakeholders identified the most relevant and most uncertain factors of change they believed could transform or significantly affect agriculture and food security. For stakeholders in Southeast Asia, markets, the enforcement capacity and regional collaboration, investment in agriculture, and overall land degradation, were chosen as the most relevant and uncertain, presented in Table 4 Southeast Asia Scenario definitions: 2050 end states for each factor of change. For each of these factors, plausible states of being in 2050 were determined and combined with the other factor end states to create possible scenarios for the future. Stakeholders developed narratives of each scenario, which included qualitative storylines for how the region reached the end states in 2050. Developing the scenarios also included semi-quantitative indicators for other factors of change such as population growth, economic growth, and yields of agricultural crops. The scenarios narratives as well as semi-quantitative indicators developed for the Southeast Asia can be found in the workshop report (CCAFS 2014a).

The semi-quantitative indicators for each region were interpreted in the context around the SSPs. The SSPs were developed to offer plausible futures that are globally and regionally consistent. The drivers for scenarios were quantified, using the population and GDP futures developed in the SSP process as a starting point, the semi-quantitative changes from the workshops to add additional context, as well as feedback from stakeholders on plausibility. By using the regional assumptions of the SSPs as an envelope of possibilities this process was able to add consistency to the scenarios and usefulness of the SSPs themselves.

Figure 39 Southeast Asia Regional Definition

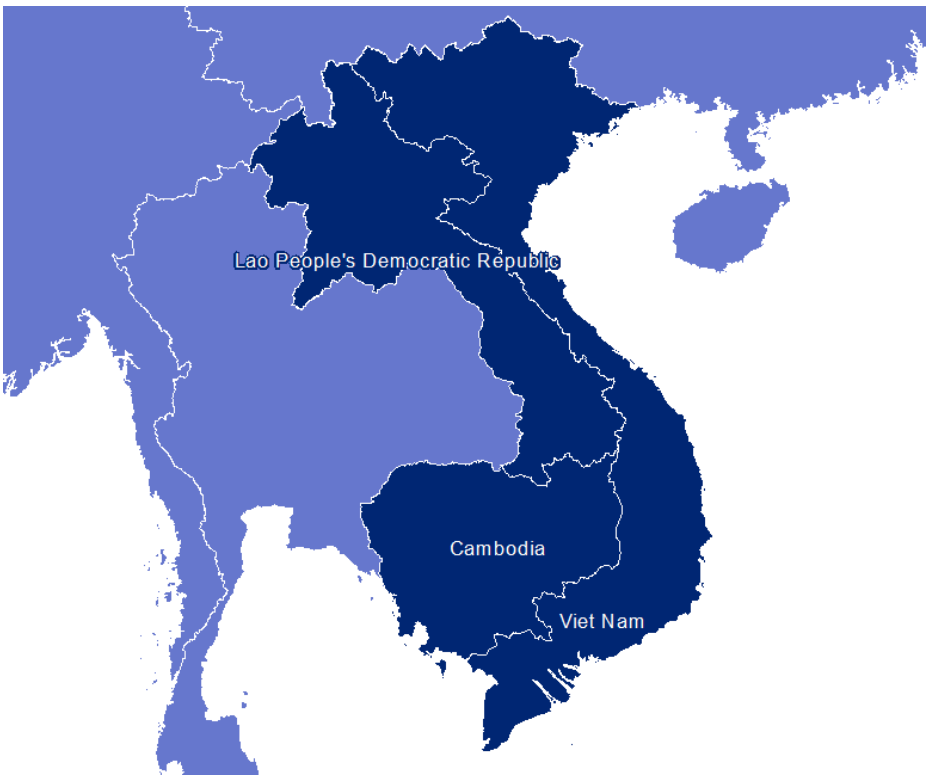


Table 4 Southeast Asia Scenario definitions: 2050 end states for each factor of change

Factors of change/Scenario	Markets	Enforcement capacity and regional collaboration	Agricultural Investment	Land degradation through land use change
Land of the Golden Mekong	Common Regulated Market	Strong Enforcement and Strong Regional collaboration	High public and private	Low
Buffalo, Buffalo	Unregulated	Weak enforcement and	Unbalanced: high private	High

		weak regional collaboration	investment in business and research	
The DoReKi Dragon	Common Regulated Market	Strong Enforcement and Strong Regional collaboration	Unbalanced: high private investment in business and research	High
Tigers on the Train	Protectionism and Closed Markets	Strong Enforcement and Strong Regional Collaboration	Low public and private	Low

Drivers: GDP per capita

The Land of the Golden Mekong (GoldenMekong) scenario, for example is a relatively optimistic scenario where the region develops in a sustainable and coordinated way from investments in agriculture from both the public and private sector. This scenario is similar to the SSP1 story line, and the population and GDP growth assumptions for GoldenMekong are similar with population growing 20% to reach 120 million by 2050 (Figure 40. Similarly, the more pessimistic Buffalo, Buffalo scenario, which reflects a world of private investment but unfavourable market conditions we see population and GDP growth assumptions similar to the SSP3 global scenario, with rapid population growth reaching over 140 million accompanied with stagnate economic growth by 2050. The other two regional scenarios fall somewhere in between, with the DoReKi Dragon and Tiger on a Train (TigerTrain) scenarios have medium population growth assumptions (130 million by 2050), but with very different economic growth assumptions with TigerTrain facing slower economic growth due to lack of investment from both private and public sector and protected market conditions, and the DorekiDragon scenario which has the highest GDP growth of all scenarios by 2050 reflecting the better market conditions and high investment from the private sector in agriculture (Figure 40 and Figure 41).

Figure 40 GDP per capita for Southeast Asia indexed to the year 2000 values

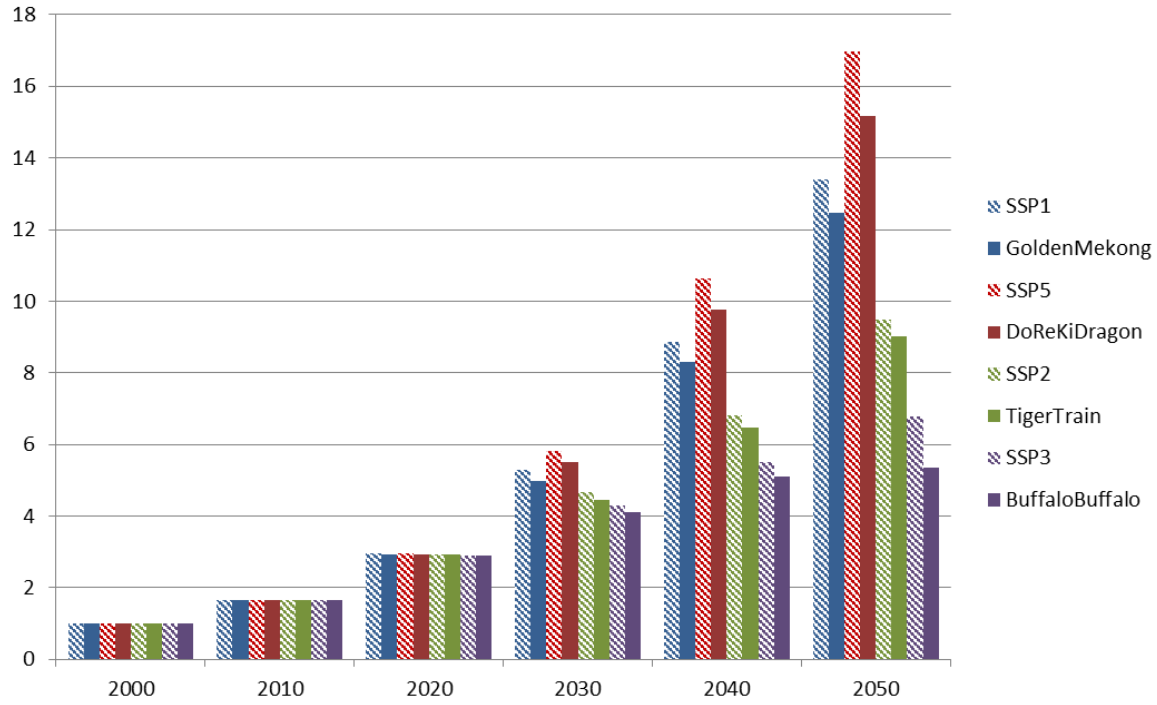
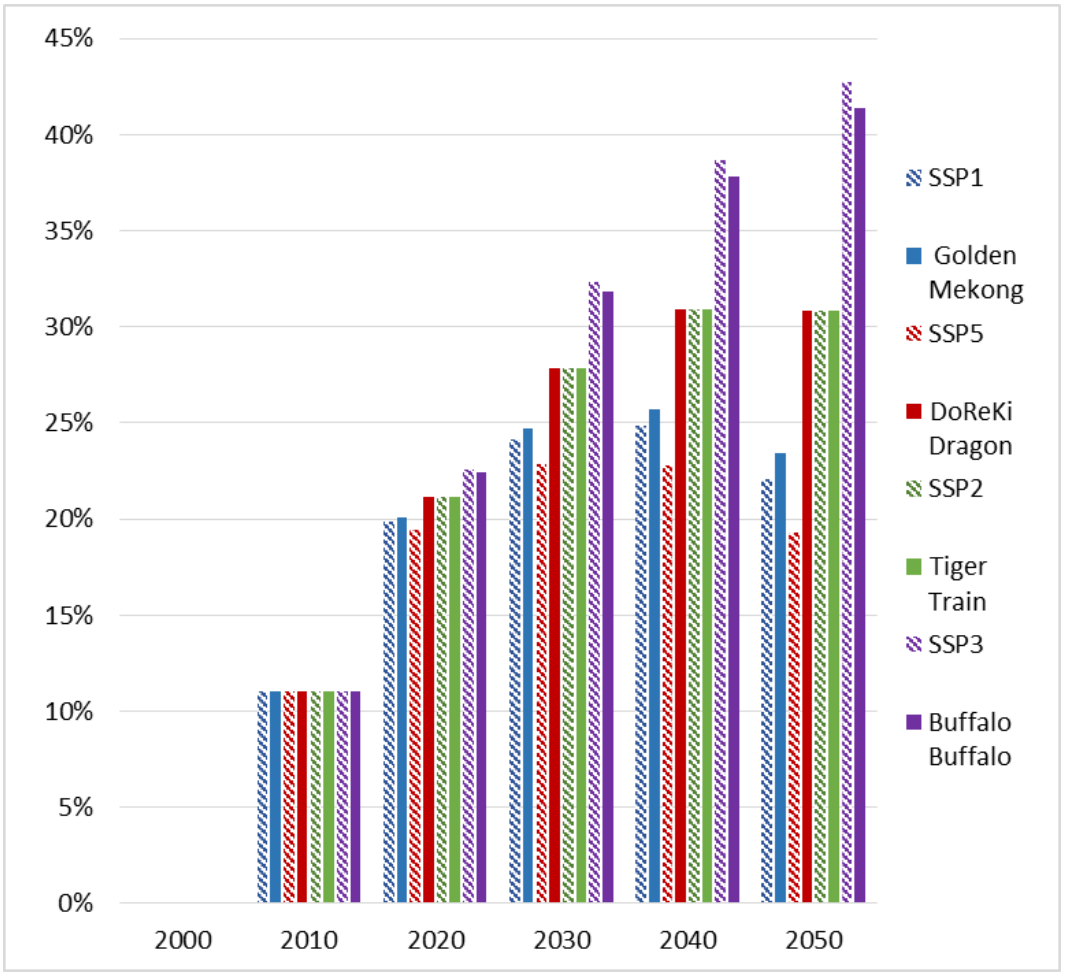


Figure 41 Percent growth in population for Southeast Asia over the period (from year 2000)

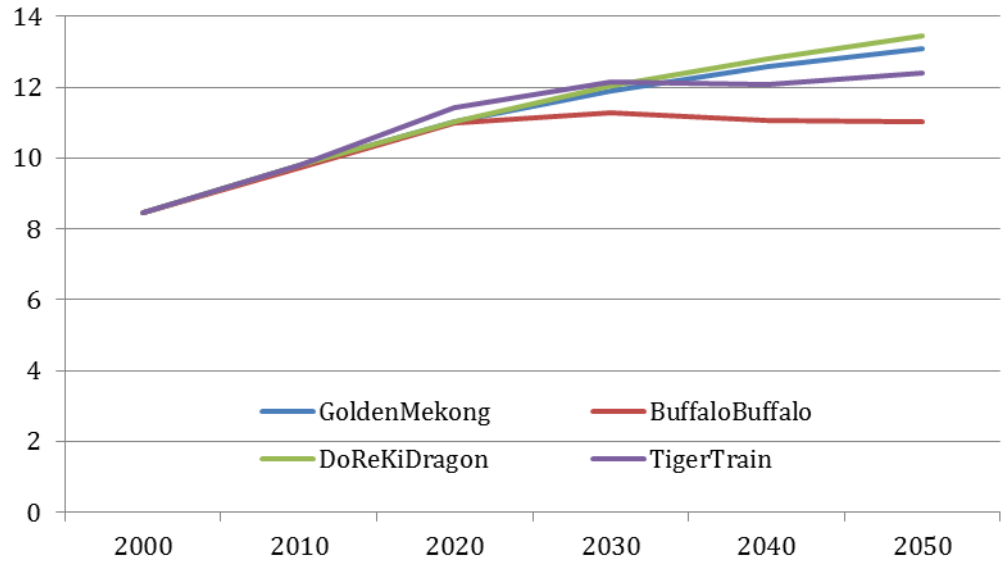


Drivers: Crop and Livestock Yields

As described in the section above, the exogenous growth in crop yields have been translated from the scenario storylines and semi-quantitative drivers. Figure 42 gives a summary of the changes assumed in the productivity of agricultural areas, as well as the potential effects it would have on the domestic supply (excluding imports) of calories for each of the scenarios, an important exogenous assumption on changes in food availability within the scenario narratives.

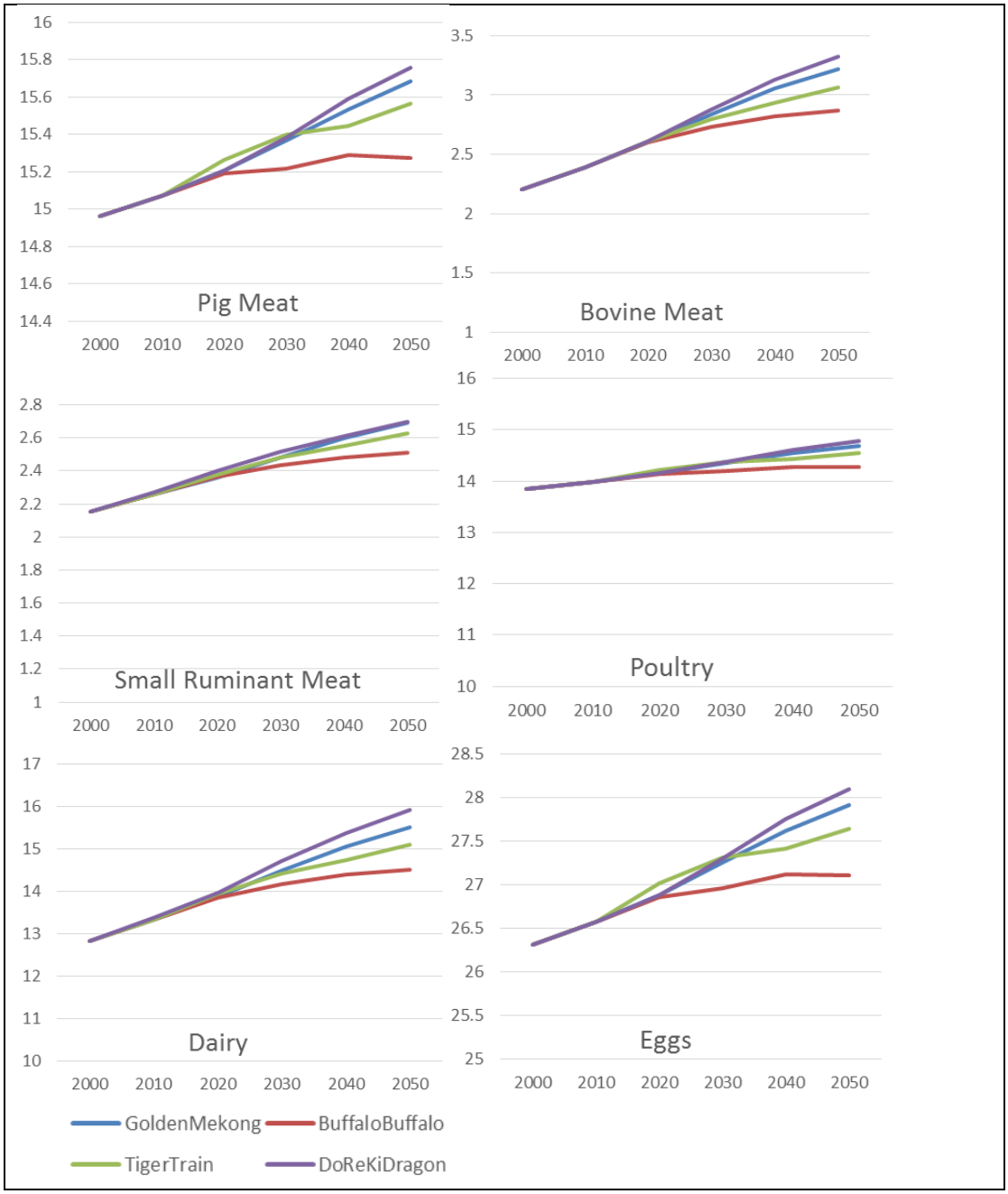
Yields in Southeast Asia, in terms of calories per ha, are, in 2000, nearly the same as the world yield. Over the time period, the productivity is expected to increase most in DoReKiDragon and GoldenMekong, keeping pace with the global averages, but for BuffaloBuffalo and TigerTrain, the exogenous yields for all crops are between 10-15% less than the global average. For rice specifically, the yield growth for BuffaloBuffalo and TigerTrain by 2050 falls 20% below the global average.

Figure 42 Aggregate exogenous crop yield projections for Southeast Asia by scenario (gigacalories per ha)



To present the current and future productivity of livestock, the conversion efficiency of livestock product per unit of feed is used. The projections of conversion efficiencies for livestock as presented in African Livestock Futures (Herrero et al. 2014) for the SSPs were used as a starting point for the regional scenarios. Figure 43 represents the exogenous growth in livestock yields for each of the regional scenarios and for each livestock product. Investment in livestock feeding efficiencies from the private sector are responsible for the exogenous growth in livestock yields for the DoReKiDragon scenario. Yields are also high for GoldenMekong due to the public and private investment. For all livestock products, TigerTrain and BuffaloBuffalo have the lowest yield growth.

Figure 43 Exogenous Livestock Feeding Efficiencies (kg protein/t dm feed)



Drivers: Production Costs

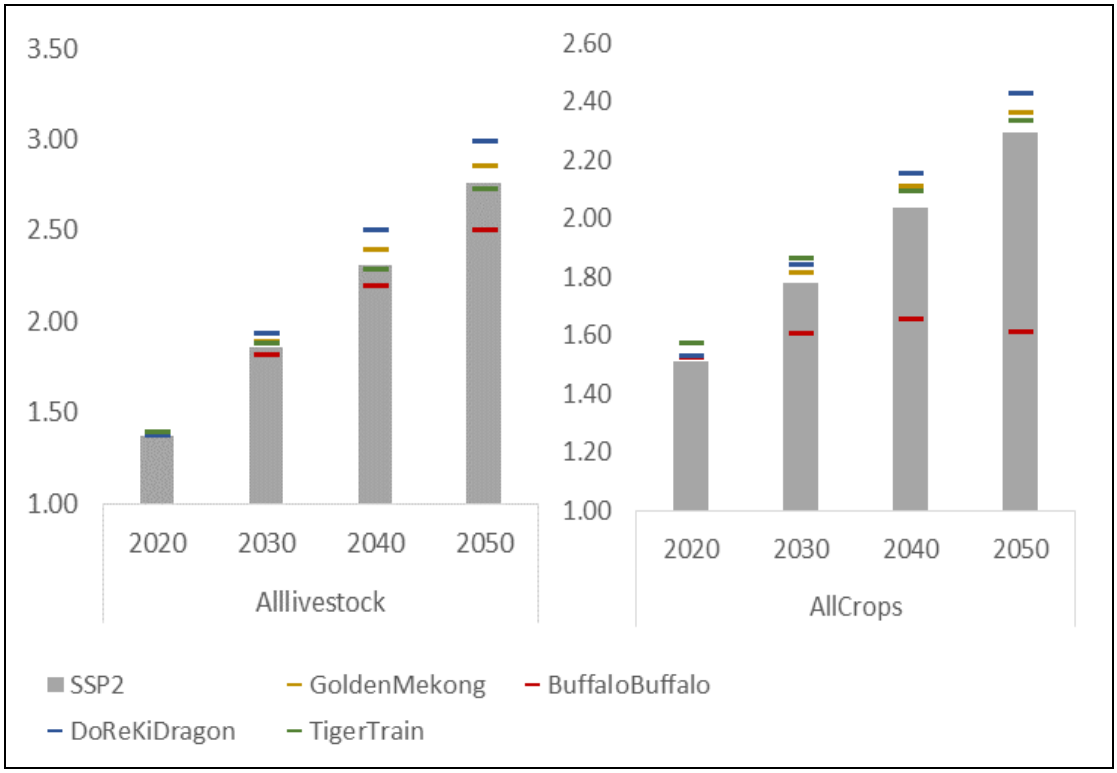
As part of the scenarios narratives, the producer costs for the BuffaloBuffalo scenario were increased 25% to capture the challenges producers would face in an unregulated marketplace. All other scenarios saw no increase or decrease in costs to producers.

Results

The following section presents the quantified results from GLOBIOM for agricultural production, food security, and land use and environmental impacts for the Southeast Asian scenarios. In these scenarios the growing regional demand for crop and livestock products, the supply of those products was modeled in GLOBIOM for period of the 2000-2050, while also considering the biophysical effects of climate change on crop production.

In Southeast Asia, crop production expands dramatically in the scenarios where there is investment in cash crops such as rice, sugar, maize, and cassava. GoldenMekong and DoReKiDragon, which specifically propose the yield increases for cash cops due to investments from the private sector. Growth in crop production for BuffaloBuffalo grows from 2010-2030 but then remains relatively flat, and the production in 2050 is far less than the in other scenarios, due the poor market conditions as well as the effects from land degradation. Although Southeast Asia is a relatively small producer of livestock products compared with most of the world, production nearly triples for DoRekiDragon and GoldenMekong, with monogastrics accounting for almost 60% of the livestock products.

Figure 44 Southeast Asia Crop and Livestock Production Relative to 2010



Crop area expands more than 50% in all of the scenarios except BuffaloBuffalo, where crop area expands only 30% over the time period. While the other scenarios see around 30% of the all forest area deforested and only 40-50% of the pristine forests preserved by 2050,

BuffaloBuffalo due to the poor market conditions for agricultural production, sees only 25% of forest are cut, and nearly 60% of the pristine forests preserved (Figure 46). Area under maize cultivation in BuffaloBuffalo decreases over the time period and when compared with the other scenarios. Due to the increase in costs of production, maize production of the region, cultivated under high-input or irrigated agriculture, declines dramatically over the time period. While the failing of agriculture sector in BuffaloBuffalo to meet the growing demand for products, has implications for protecting the region from deforestation, the region loses its competitiveness, and by 2050, imports of crop products are around 40% of the total regional crop production.

Figure 45 Crop share of total crop area production

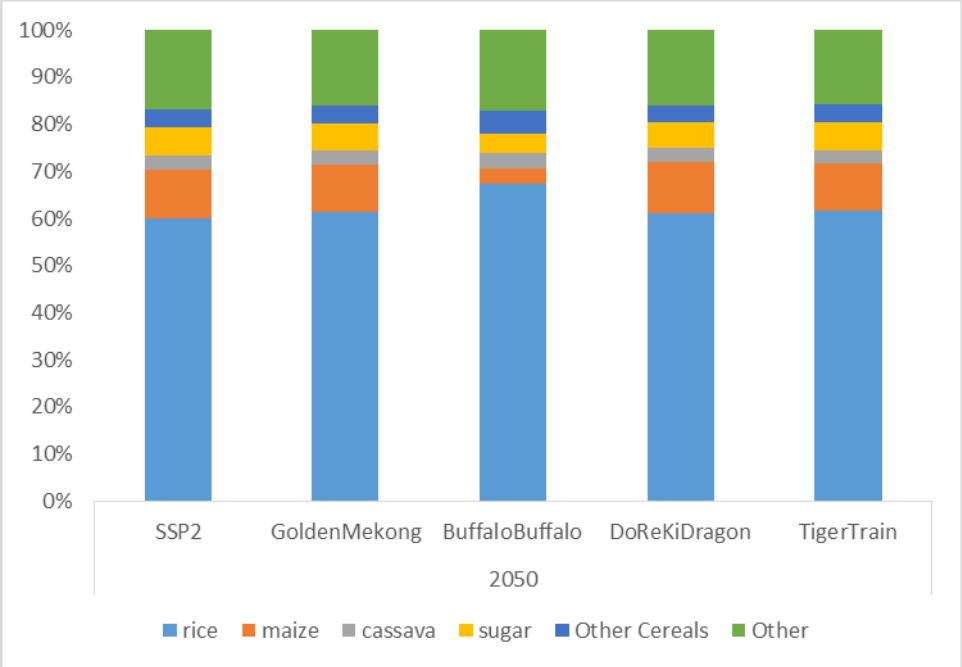
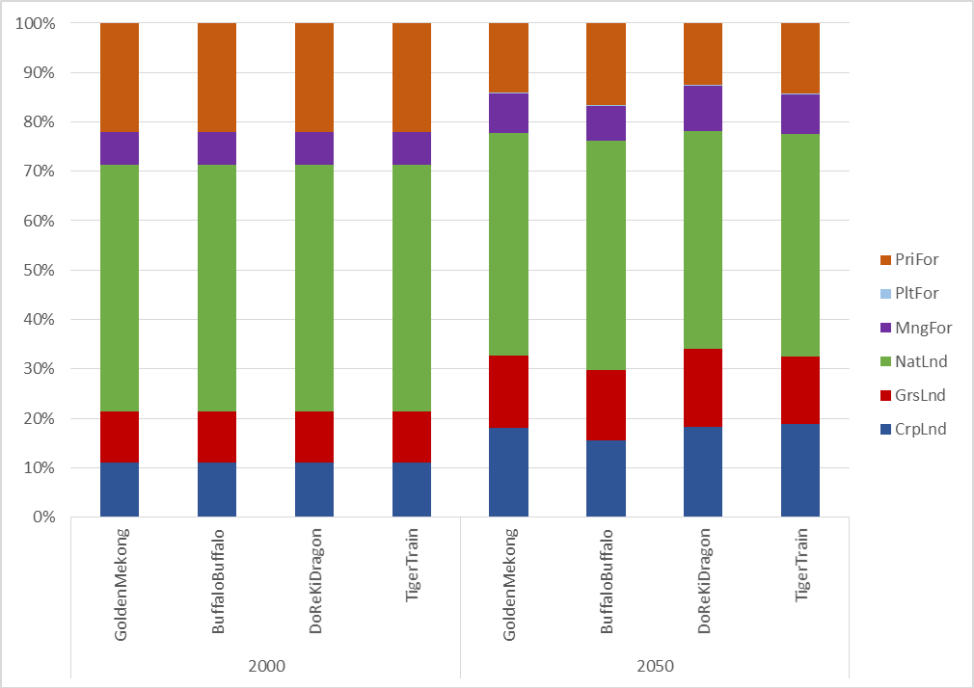


Figure 46 Southeast Asia hare of land use by land use types (2000 and 2050)



In the region of Southeast Asia, rice, sugar, maize, and cassava are the most produced crop products. Crop yields improve over the time period except for maize in the BuffaloBuffalo scenario, where the high costs for inputs shift production to less productive land. The effects of climate change on crop yields are negative and larger for cassava and sugar. For rice and maize, the effects do not depart from the no climate change scenario dramatically for the region, suggesting that investment in agriculture could have an impact on adaptation to climate change. However, only regional yields have been presented; the local effects from climate change could be significant. Because the model maximizes producer surplus, it assumes that there is flexibility of farmers to change production to different crops. GLOBIOM has been used to examine fixed investment adaptation strategies in the face of climate change (Leclère et al. 2014) but these adaptation and maladaptation scenarios are outside the scope of this socioeconomic scenarios analysis.

Food security in the region improves throughout the period for all scenarios. Figure 47 presents one measure of food security, available kilocalories per capita per day. Calorie consumption is highest for the GoldenMekong and DoReKiDragon due to the large increase in GDP per capita. The food demand per capita relative to 2010 also provides another measure of change in food consumption as incomes change (Figure 48). Calorie per capita consumption is lowest in BuffaloBuffalo, where the livestock product demand per capita is also lowest. In BuffaloBuffalo, prices are highest for most products, and although DoReKiDragon also faces high product prices, a population with higher incomes can afford to increase consumption.

Figure 47 Southeast Asia Calories per Capita per day

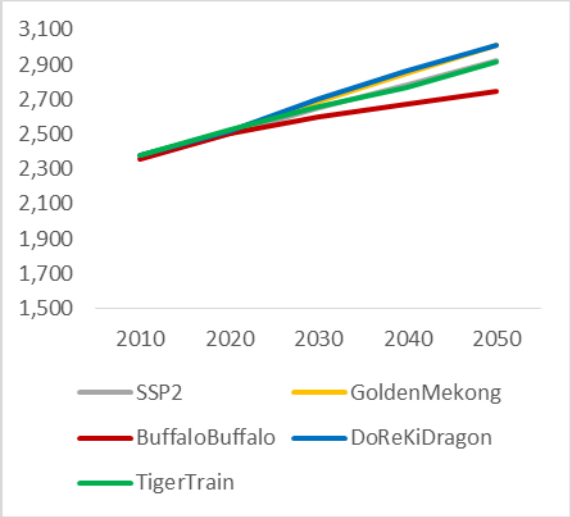


Figure 48 Southeast Asia **per capita food demand by product indexed to 2010 food demand per capita**

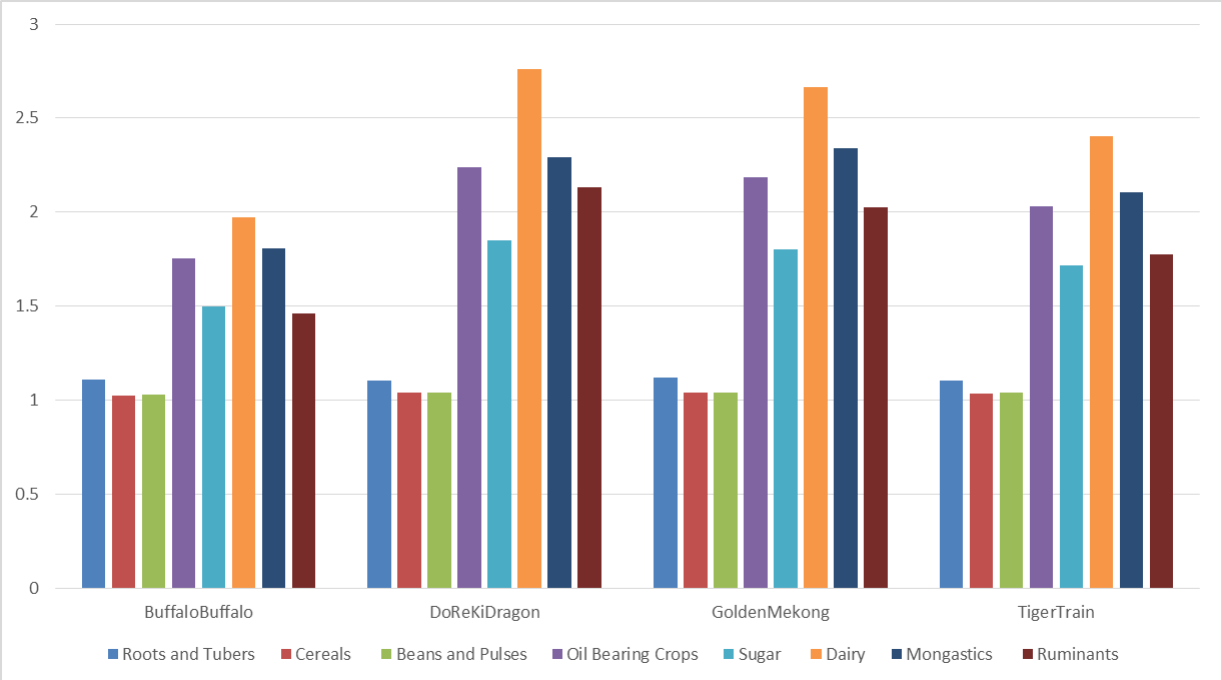
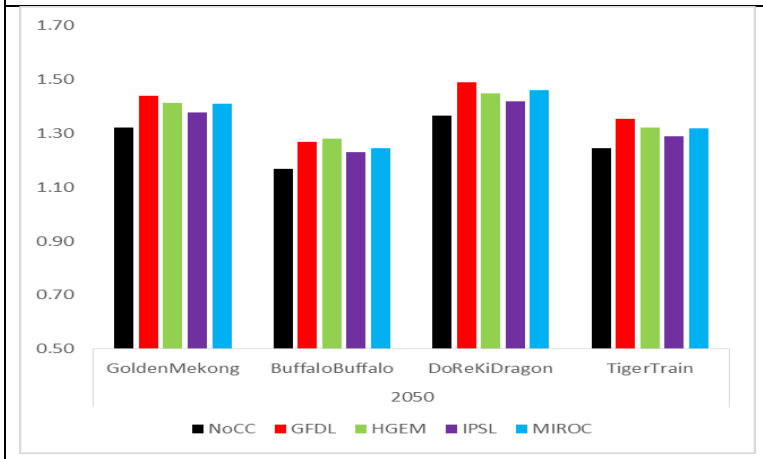
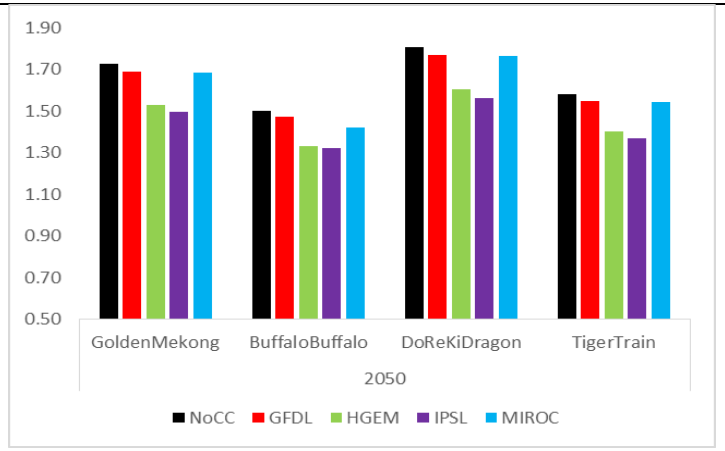


Figure 49 Crop Yield Growth with and without climate change effects relative to 2010 levels

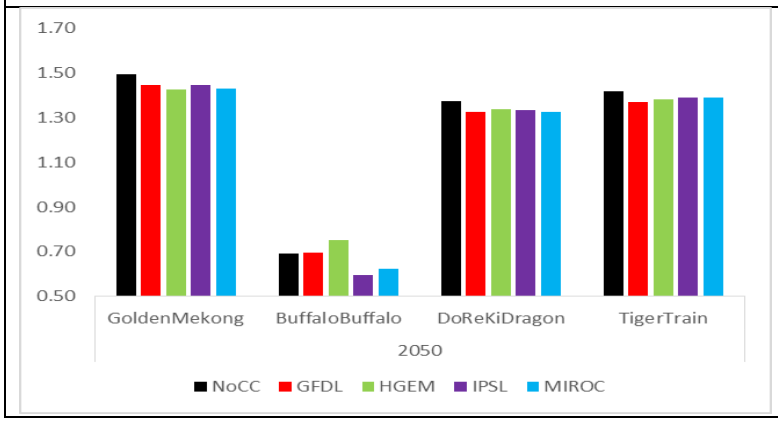
Rice



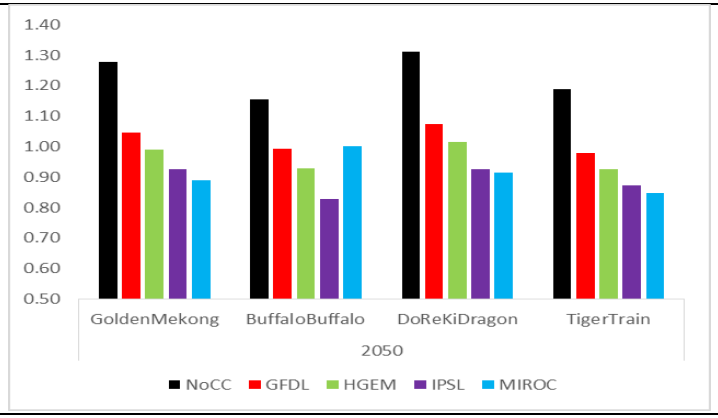
Cassava



Maize



Sugar



Central America

Stakeholders in Central America developed scenarios in a process similar to the one used in South Asia and Southeast Asia. Details from the process can be found in the Workshop Report (CCAFS 2014b). The region of Central America includes Belize, Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua as show in

Figure 50. Stakeholders identified the most relevant and most uncertain factors of change they believed could transform or significantly affect agriculture and food security. Institutional capacity, markets, distribution of wealth, and water resources were chosen by stakeholders as the most relevant and uncertain. For each of these factors, plausible states of being in 2050 presented in both Spanish and English in Table 5. The factors of change and possible end states were combined to create plausible scenarios for the future and storylines were developed by stakeholders using narrative flowcharts, conceptual maps, and semi-quantified indicators such as population growth, economic growth, and yields of agricultural crops. The scenarios are described in Table 6. Subsequent workshops have been held using the scenarios to develop priority setting for regional policies for the Trifinio area (Guatemala, Honduras, El Salvador) in October 2014. As the scenarios results were also quantified by the IFPRI's IMPACT model, and CCAFS has prioritized using their results for the Central American scenarios and their results were highlighted for this workshop.

The semi-quantitative indicators for each region were interpreted in the context around the SSPs. The scenario narratives and semi quantitative indicators are not presented in this Working Paper but have been presented in the workshop report and will presented in the forthcoming Central America Scenarios Working Paper (CCAFS 2014b). The SSPs were developed to offer plausible futures that are globally and regionally consistent. The drivers for scenarios were quantified, using the population and GDP futures developed in the SSP process as a starting point, the semi-quantitative changes from the workshops to add additional context, as well as feedback from stakeholders on plausibility. By using the regional assumptions of the SSPs as an envelope of possibilities this process was able to add consistency to the scenarios and usefulness of the SSPs themselves.

Figure 50 Central America Regional Definition

Table 5 Central America Factors of Change and Plausible 2050 End States

Factors of change	Factor states
Capacidad Institucional del Estado [institutional capacity]	Alta Capacidad institucional [high institutional capacity]
	Integración desigual, social y territorialmente [unequal, social and terrestrial]
	Baja Capacidad institucional [low institutional capactity]
Mercado [Markets]	Participativo regulado [Participatory, regulated]
	Participativo no regulado [Participatory, unregulated]
	No participativo-no regulado [Not Participatory, unregulated]
Distribución de la riqueza [Distribution of wealth]	Distribución equitativa – impulsado por el Estado [Equitable distribution – State driven]
	Distribución inequitativa - impulsado por el Mercado [Inequitable distribution - market driven]

	Distribución inequitativa – impulsado por el Estado [Inequitable distribution – State driven]
Recurso Hídrico **[water resources]**	Alta disponibilidad [high availability]
	Baja Disponibilidad [low availability]

Table 6: Central America scenario definitions: 2050 end states for each factor of change

Escenario [Scenario]	Mercados [Market]	Capacidad Institucional Del Estado [Institutional Capacity]	Distribucion de la Riqueza [Distribution of Wealth]	Recursos Hidricos [water availability]
Apiñados [Crowded]	Participativo, no regulado	Desigual	Disponibilidad Inequitativa, impulsado por el estado	Alta
14 Baktún: El inicio de la profecía Maya [14 Baktun: the beginning of the Mayan Prophecy]	Participativo, regulado	Alta	Disponibilidad Equitativa, impulsado por el estado	Alta
Libertarios sin Libertad [Freedom Fighters without Freedom]	Participativo, no regulado	Baja	Disponibilidad Inequitativa, impulsado por el mercado	Baja
El Nuevo colapso Maya	No participativo, no regulado	Desigual	Disponibilidad Inequitativa, impulsado por el mercado	Baja

Drivers: GDP per capita

The population of Central America is expected grow 30-70% by 2050 in the scenarios (Figure 52). In the scenarios where population increases the most, LibertariosSinLibertad (Freedom Fighters without Freedom) and ElNuevoColapsoMaya (The New Mayan Collapse) face widely different economic futures resulting in GDP per capita growth that is relatively high for LibertariosSinLibertad and low for ElNuevoColapsMaya (Figure 51). Baktun14 (14 Baktun: The Beginning of the Myan Prophecy) sees lower population growth and relatively high GDP growth, and the most equal distribution of wealth according to the narrative, making it the scenario with the highest growth GDP per capita. Apinados (Crowded), facing a

growing population and unequal wealth distribution, faces the second lowest GDP per capita growth of all the scenarios.

Figure 51 GDP per capita for Central America indexed to the year 2000 values

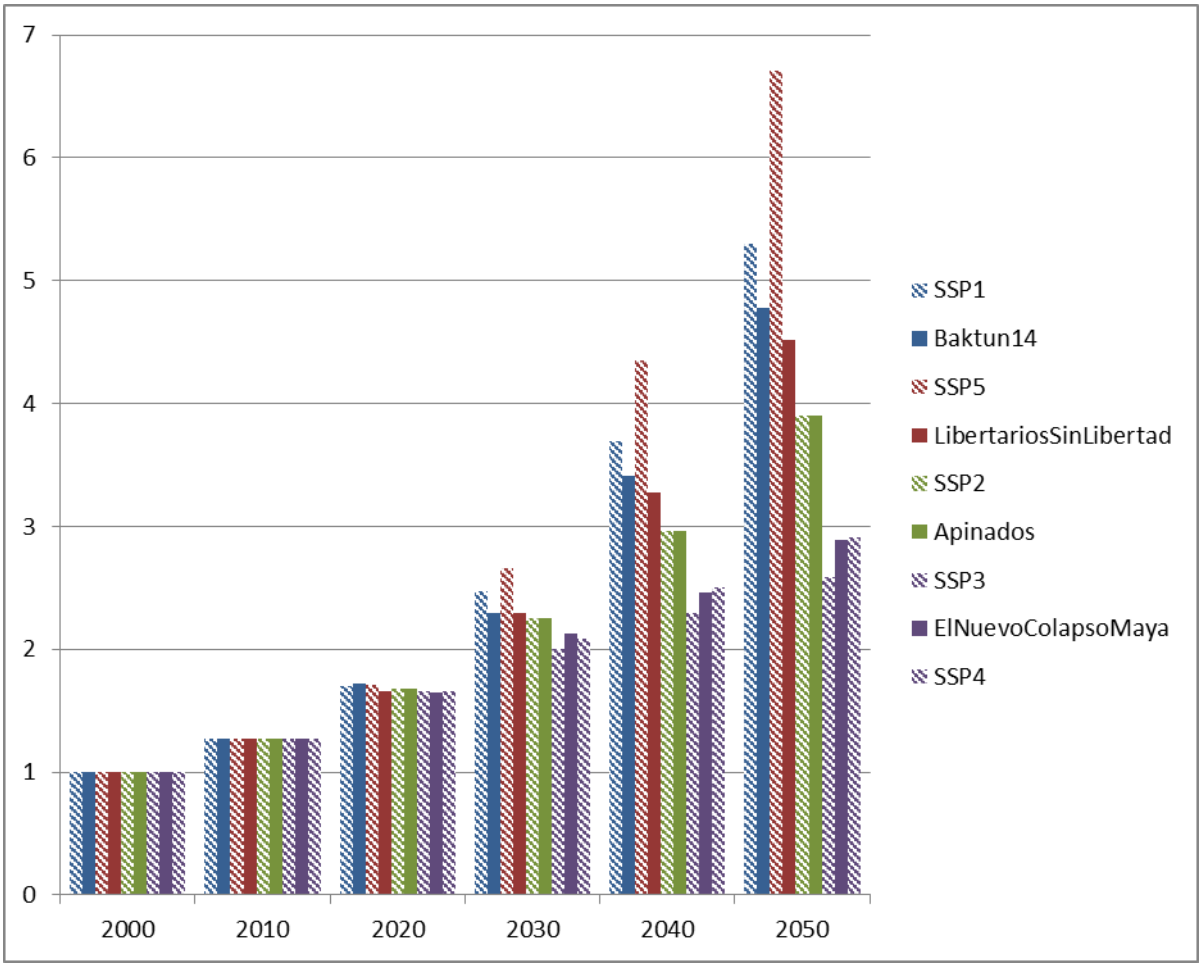
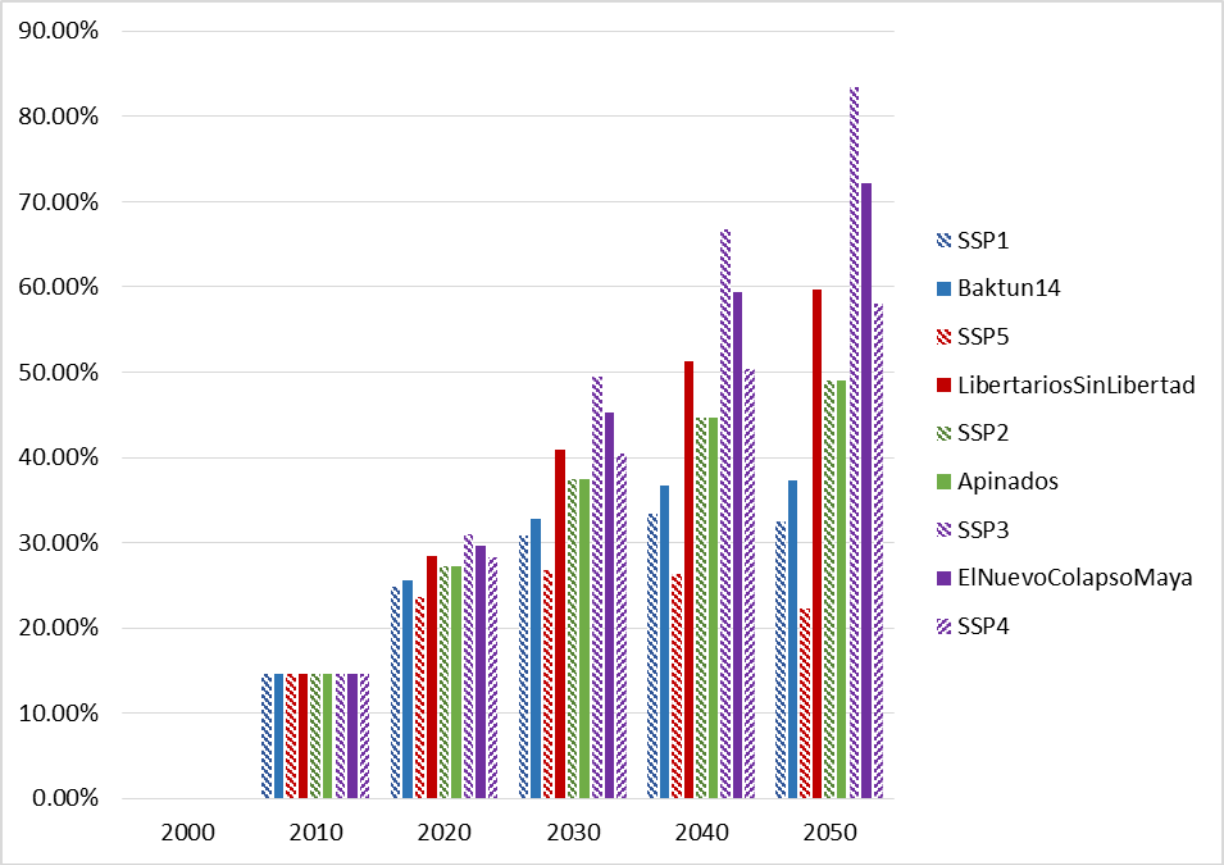


Figure 52 Population Growth of Central America (% growth from year 2000)



Drivers: Crop and Livestock Yields

As described in the section above, the exogenous growth in crop yields have been translated from the scenario storylines.

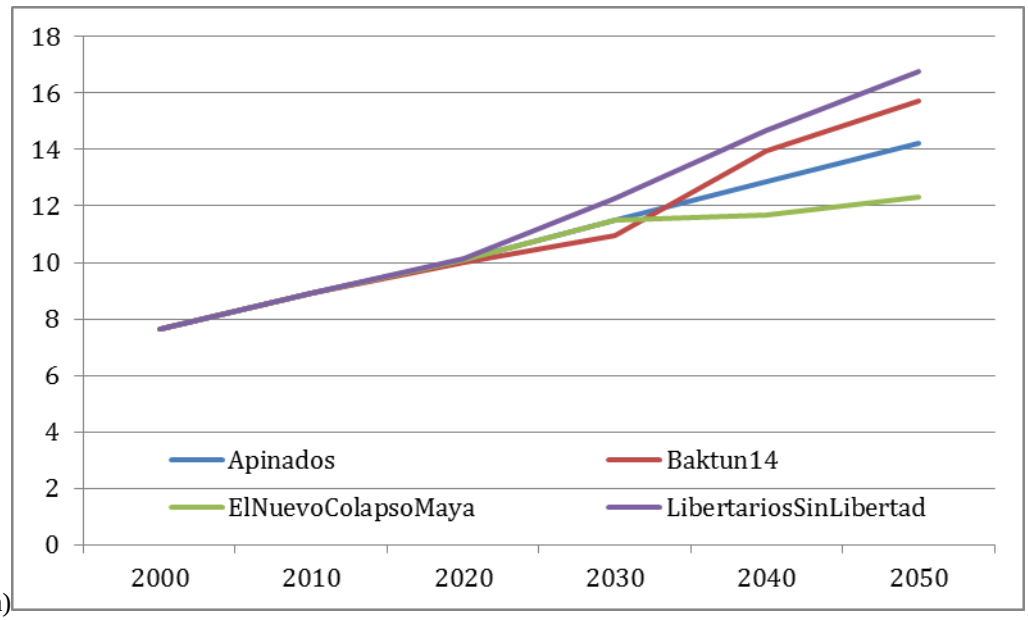
Figure 53 gives a summary of the changes assumed in the productivity of agricultural areas, as well as the potential effects it would have on the domestic supply (excluding imports) of calories for each of the scenarios, an important exogenous assumption on changes in food availability within the scenario narratives.

Yields in terms of calories produced per ha, are relatively high when compared with other CCAFS regions. The global average crop yield for SSP2 is projected to grow from around 10 gigacalories per ha in 2010 to 14, and regionally, the yields for Central America grow from around 9 gigacalories per ha in 2010 to around 12 to 17 in the scenarios. The highest growth in yields comes in the LibertariosSinLibertad scenario, as the narrative storyline focuses on an increase in the use of GMO technology to improve crop yields, as is also the case in Apindados. Baktun14, a scenario that exogenously projects the second highest crop yields by 2050, but only to reverse the trends of low yield growth caused by political insecurity, degradation of natural resources, corruption, and social crisis. Baktun14 highlights the

importance of the narrative and storyline of how an end state in 2050 is reached for a scenario. The lowest crop yield growth is expected in the ElNuevoColapsoMaya scenario, as the narrative outlines that water scarcity and low investment in agriculture will hinder the potential for crop yield growth.

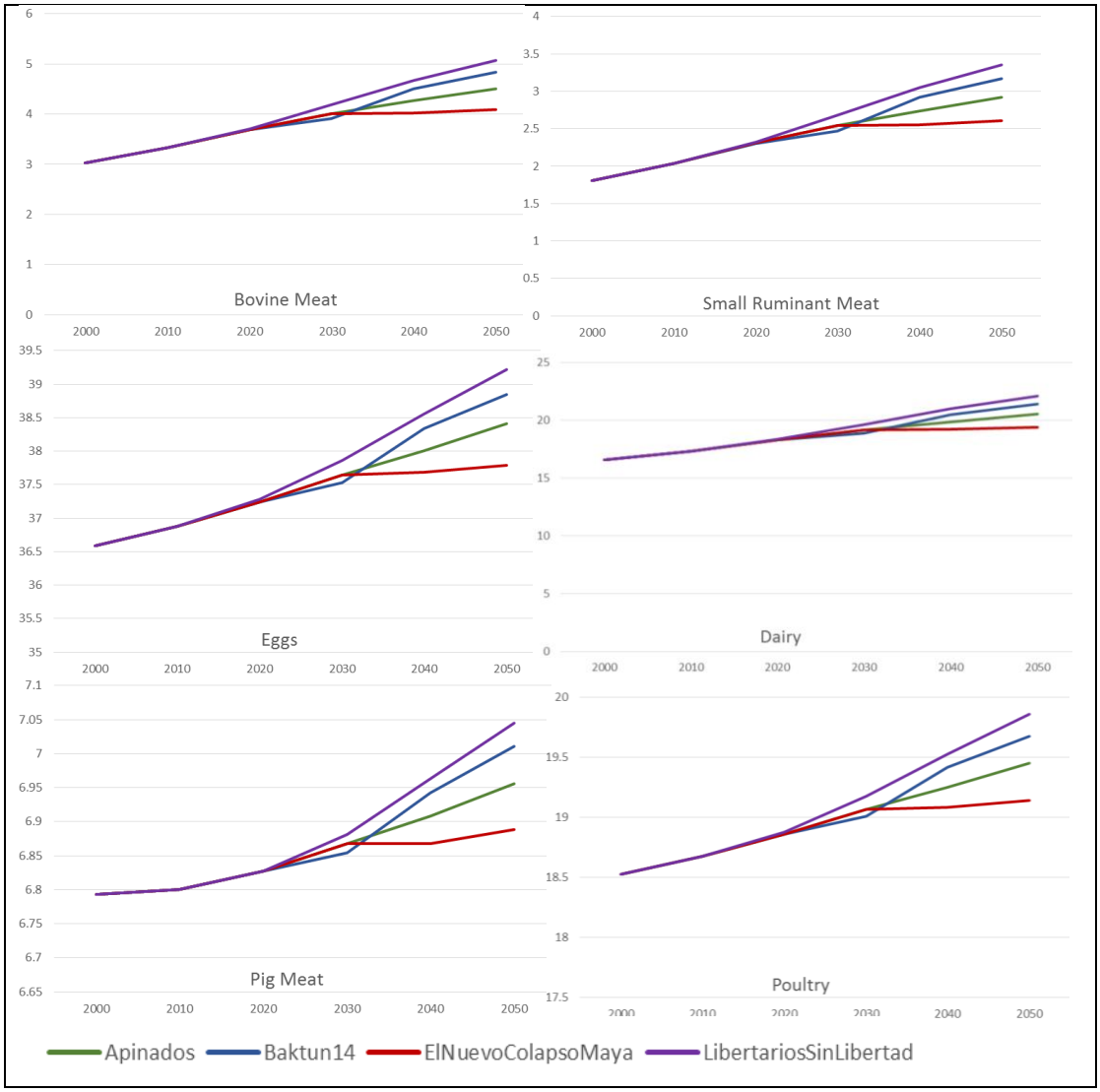
This yield growth, being exogenous, does not represent the transitions between low input, low yielding crop systems to high input, high yield crop systems or reallocation of crop production to highly productive land or crop types, but instead offer a glimpse of how much priority is giving to agriculture, for example, through investment in new technologies.

Figure 53 Aggregate exogenous crop yield projections for Central America by scenario (gigacalories per ha)



To present the current and future productivity of livestock, the conversion efficiency of livestock product per unit of feed is used. The projections of conversion efficiencies for livestock as presented in *African Livestock Futures* (Herrero et al 2014) for the SSPs were used as a starting point for the regional scenarios. Figure 64 represents the exogenous growth in livestock yields for each of the regional scenarios and for each livestock product.

Figure 54 Exogenous Livestock Feeding Efficiencies (kg protein/t dm feed)



Drivers: Production Costs

As part of the scenarios narratives, the costs of production for the ElNuevoColapsoMaya scenario were increased by 15% to reflect the mismanagement of state economies, lack of access to financial resources, and an unregulated marketplace.

Results

The following section presents the quantified results from GLOBIOM for agricultural production, food security, and land use and environmental impacts for the Central American scenarios. In these scenarios the growing regional demand for crop and livestock products, the supply of those products was modeled in GLOBIOM for period of the 2000-2050, while also considering the biophysical effects of climate change on crop production.

Crop production and livestock production grow throughout the period in all scenarios, most significantly in LiberariosSinLibertad. Due to the growing demand for livestock products from a growing population, the production in ElNuevoColapsoMaya and LibertariosSinLibertad increases, but at a large environmental cost. Agricultural area, crop areas and grasslands for livestock rearing, expand almost 80% in the region by 2050. To meet this demand for land and expand production, nearly 25% of the forest area is converted in LibertariosSinLibertad, and the GHG emissions from this land use conversion is 15% higher than in the other scenarios (Figure 56).

Figure 55 Central America Crop and Livestock Production Relative to 2010

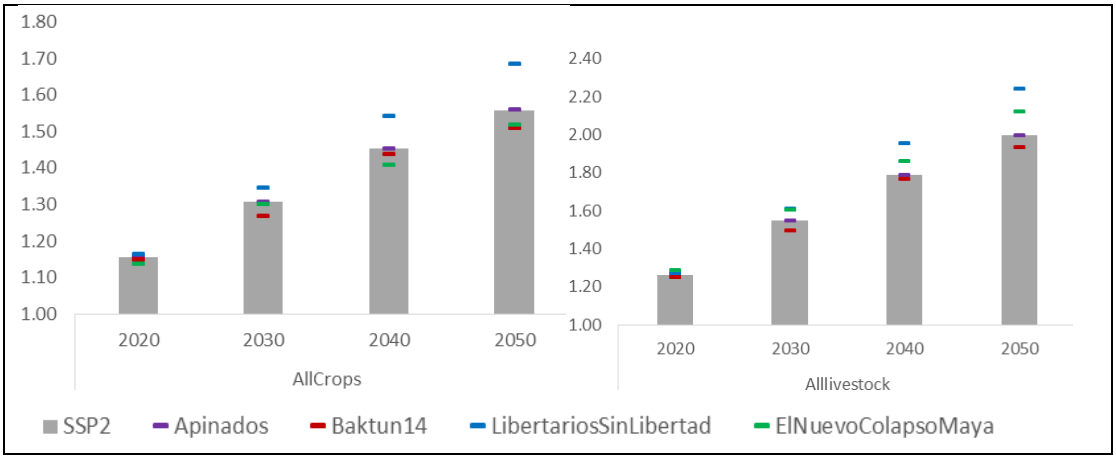
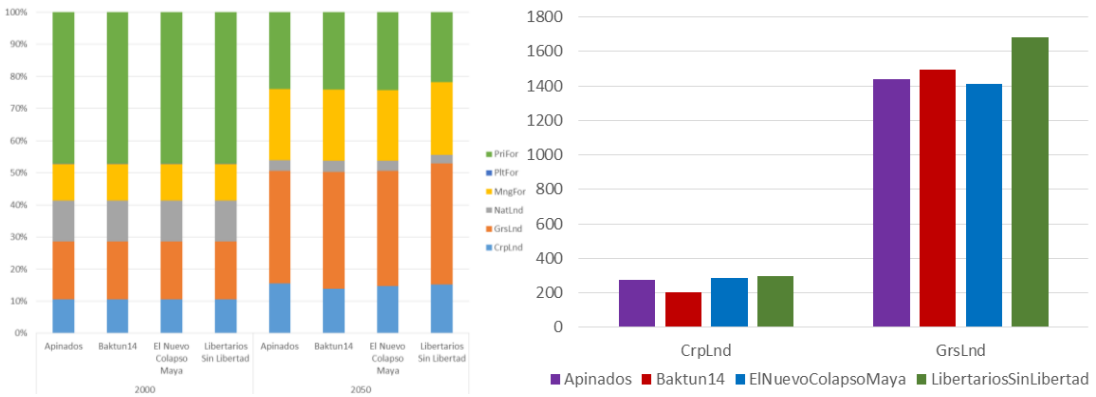


Figure 56 Central America share of land use by land use types (2000 and 2050) and 000 t CO2 emissions from deforestation from 2000-2050



In the region of Central America, maize, rice, sugar, maize, and beans are the most produced crop products. Crop yields improve over the time period, but far less for ElNuevoColapsoMaya due to the poor of institutional capacity and market conditions. The

effects of climate change on crop yields are negative for sugar and beans. For rice and maize, the effects do not depart from the no climate change scenario dramatically for the region. However, only regional yields have been presented; the local effects from climate change could be significant. Because the model maximizes producer surplus, it assumes that there is flexibility of farmers to change production to different crops. GLOBIOM has been used to examine fixed investment adaptation strategies in the face of climate change (Leclère et al. 2014) but these adaptation and maladaptation scenarios are outside the scope of this socioeconomic scenarios analysis.

Food security, measured in available kilocalories per capita per day, increases over the time period (Figure 58). Kilocalories available per capita is lowest for ElNuevoColapsoMaya, 5-10% lower than the other scenarios by 2050. Examining the changes in food demand per capita can help to understand the effect the market situation as well as the income effect on food consumption. Demand for monogastrics increases from 2010-2050 for all scenarios, due to the expansion of monogastric production and a relative decrease in monogastric meat prices, but compared to the demand for ruminant meat, ElNuevoColapsoMaya sees a much smaller increase in demand, due to the low GDP per capita growth as well as high meat prices (Figure 59). The demand per capita of cereals increases less than 20% over the period for ElNuevoColapsoMaya, whereas in the other scenarios, the per capita cereal consumption increases by almost 25-30%.

Figure 57 Central America Available kilocalories per capita per day

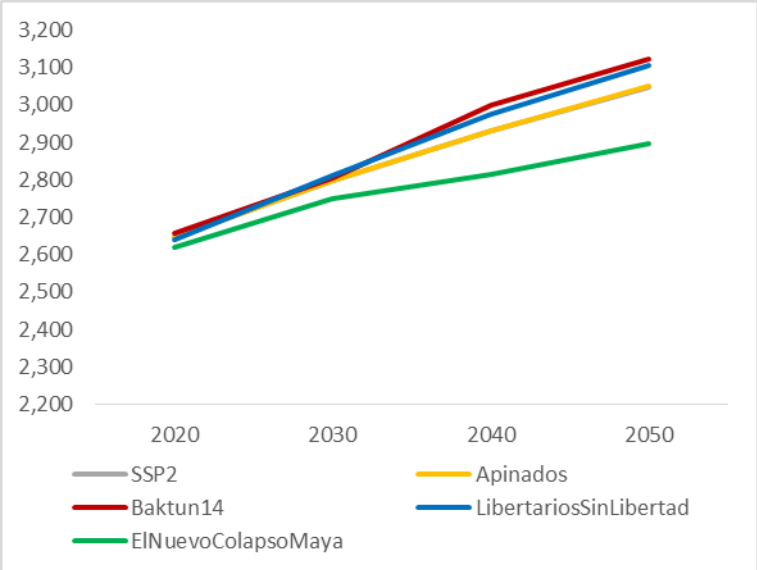


Figure 58 Central America per capita food demand by product indexed to 2010 food demand per capita

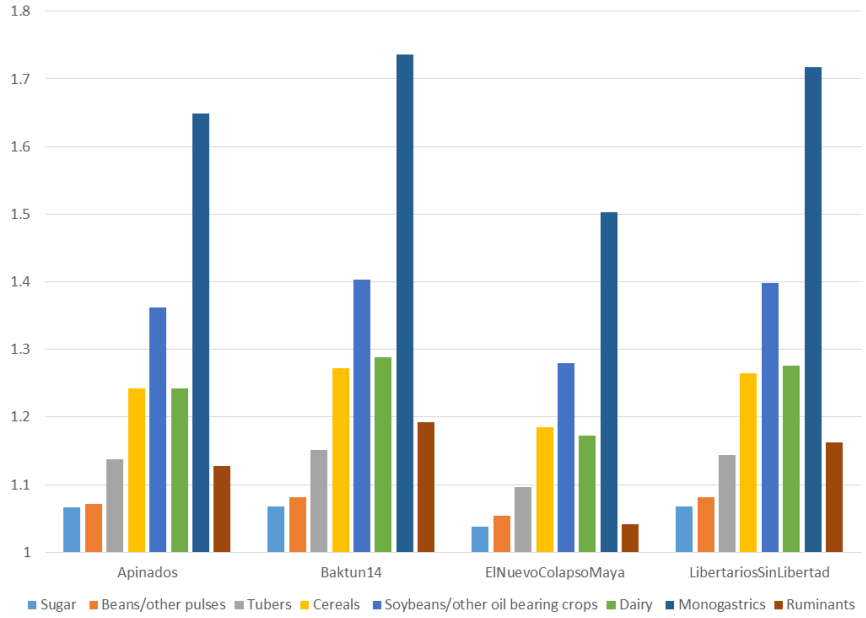
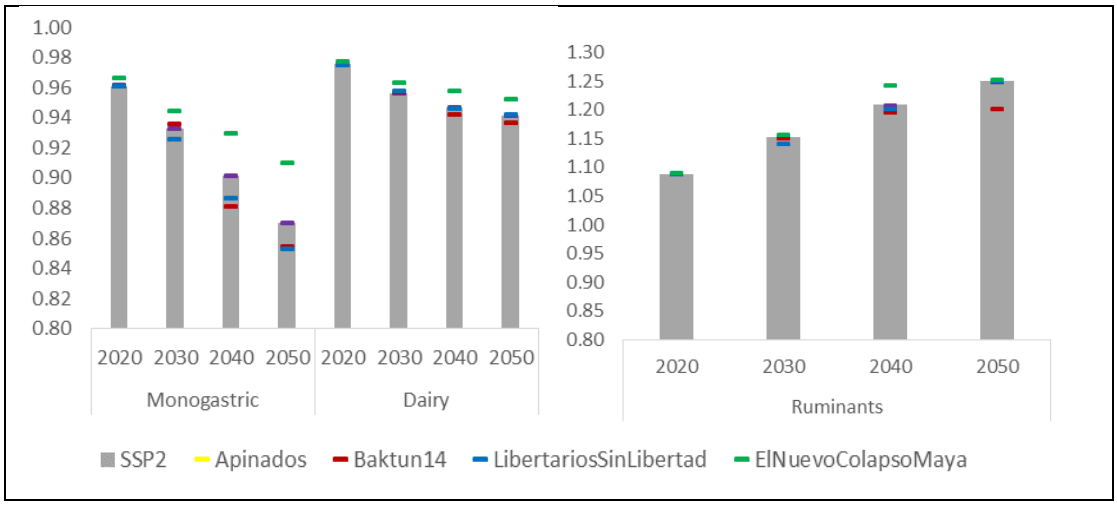
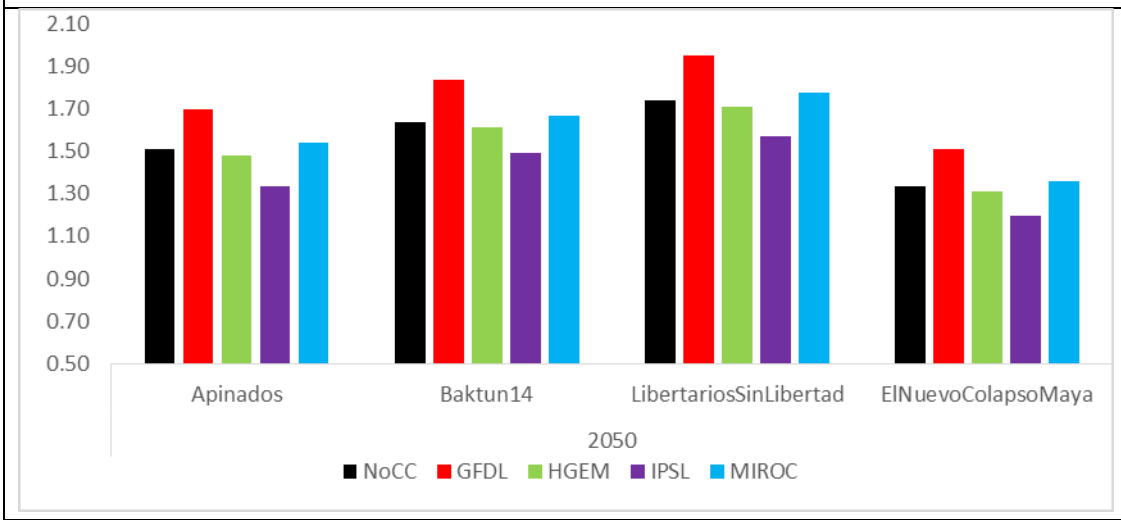


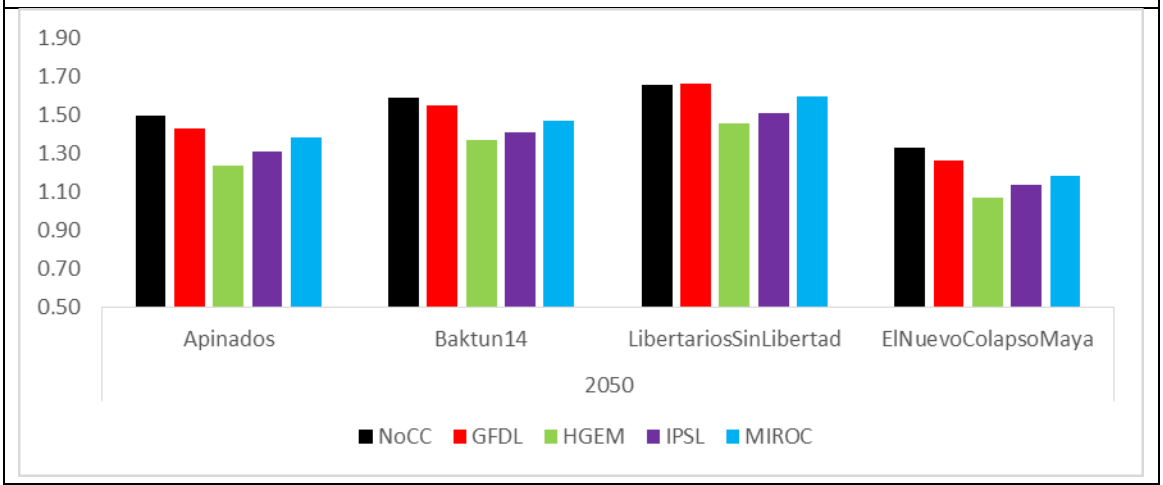
Figure 59 Livestock prices indexed to year 2010 prices



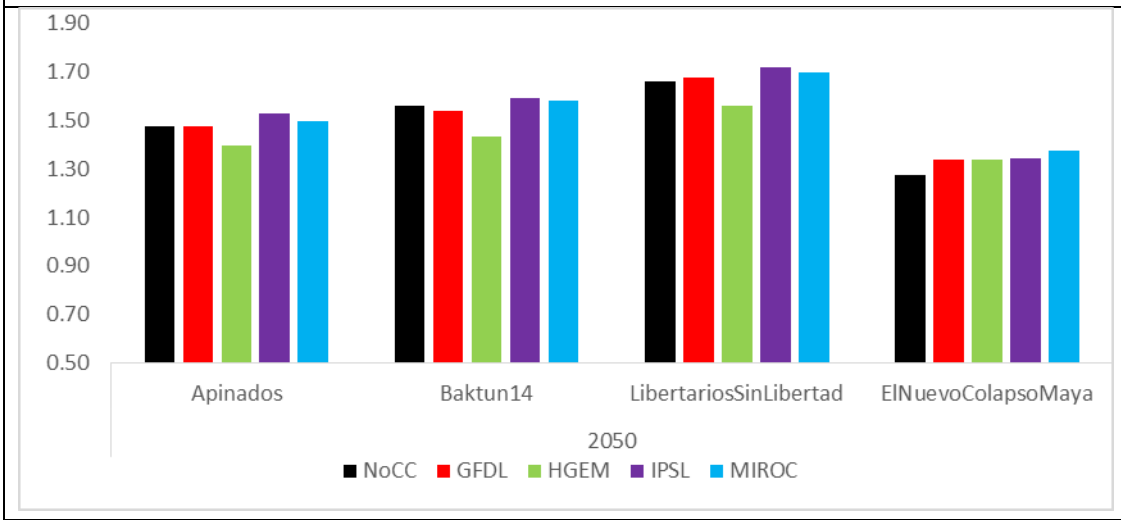
Beans



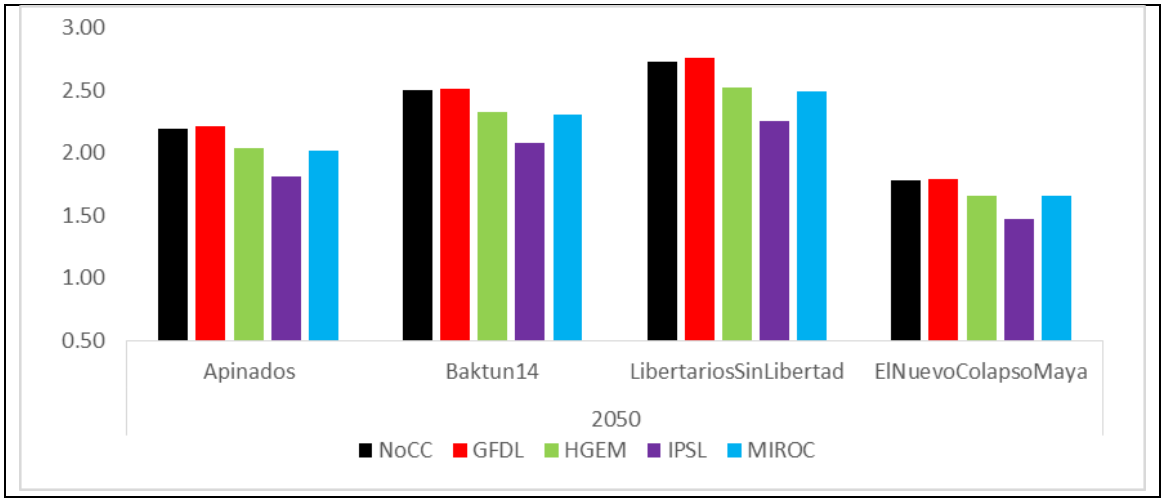
Sugar



Rice



Maize


3.00
2.50
2.00
1.50
1.00
0.50
Apinados
Baktun14
LibertariosSinLibertad
ElNuevoColapsoMaya
2050
NoCC
GFDL
HGEM
IPSL
MIROC

Andes

Stakeholders in the Andean developed scenarios in a process similar to the one used in Central America, South Asia and Southeast Asia. Details from the process can be found in the Workshop Report (CCAFS 2014c). The region of the Andes includes Bolivia, Colombia, Ecuador, and Peru as show in Figure 60. Stakeholders identified the most relevant and most uncertain factors of change they believed could transform or significantly affect agriculture and food security. Concentration of the governmental power, markets, consumer preferences, and level of economic development were chosen by stakeholders as the most relevant and uncertain. For each of these factors, plausible states of being in 2050 presented in both Spanish and English in Table 7. The factors of change and possible end states were combined to create plausible scenarios for the future and storylines were developed by stakeholders using narrative flowcharts, conceptual maps, and semi-quantified indicators such as population growth, economic growth, and yields of agricultural crops. The scenarios are described in Table 8.

The four scenarios for the Andean Region are as follows:

- Ontono Andino (Andean Autumn) Centralized political power, unsustainable and unregulated markets with low economic development and subsistence consumption patterns.
- Chachando Hamburgesas (Flipping Burgers) Decentralized government with unsustainable unregulated markets with high economic growth and sumptuous consumption patterns.
- Veciendo Obstaculos (Overcoming Obstacles) Decentralized government structure with sustainable and regulated markets coupled with high economic development and sustainable need-based consumption patterns.
- Hananta Yuyaspa (New Dawn) Centralized political power with sustainable regulated markets with a need-based consumption pattern coupled with low economic growth.

The semi-quantitative indicators for each region were interpreted in the context around the SSPs. The scenario narratives and semi quantitative indicators are not presented in this Working Paper but have been presented in the workshop report and will presented in the Andean Region Scenarios Working Paper (CCAFS 2014c). The SSPs were developed to offer plausible futures that are globally and regionally consistent. The drivers for scenarios were quantified, using the population and GDP futures developed in the SSP process as a starting point, the semi-quantitative changes from the workshops to add additional context, as well as feedback from stakeholders on plausibility. By using the regional assumptions of the SSPs as

an envelope of possibilities this process was able to add consistency to the scenarios and usefulness of the SSPs themselves.

Figure 60 Andean Region Definition

Table 7 Andean Region Factors of Change and Plausible 2050 End States

Factors of change	Factor states
Nivel de poder político del Estado [level of state power]	Centralizado [centralized]
	decentralizado [decentralized]
Mercado [Markets]	Sostenible [sustainable] y Regulado [regulated]
	No sostenible [unsustainable] y no regulado [unregulated]
Patrones de consumo [consumer preferences]	▪ Subsitencia [subsistence]
	▪ Sostenible [sustainable]
	Consumista [consumerist]
Desarrollo Económico [economic development]	Alto desarrollo económico y especialización [high economic growth and specialization]
	▪ Alto desarrollo económico y diversificación ▪ [high economic growth and diversification]
	▪ Bajo desarrollo económico y especialización ▪ [low economic growth and specialization]
	▪ Bajo desarrollo económico y diversificación ▪ [Low economic growth and diversification]

Table 8 Andean Region scenario definitions: 2050 end states for each factor of change

Escenarios {Scenarios]	Nivel de poder político del Estado	Mercado	Patrones de consumo	Desarrollo económico
Otoño Andino [Andean Autumn]	Centralizado	No sostenible y no regulado	Subsistencia	Bajo desarrollo económico y especialización
Venciendo Obstaculos [Overcoming Obstacles]	Decentralizado	Sostenible y regulado	Sostenible	Alto desarrollo económico y diversificación
Chachando/Mambeando Hamburguesas [Flipping Burgers]	Decentralizado	No sostenible y no regulado	Consumista	Alto desarrollo económico y especialización
Hananta Yayaspa (nuevo amanecer) [New Dawn]	Centralizado	Sostenible y regulado	Sostenible	Bajo desarrollo económico y diversificación

Drivers: GDP per capita

In the Andean region, population grows from 100 million to 120 million in HantanaYayaspa to 140 million in OtonoAndino (Figure 62). Coupled with low economic growth, the GDP per capita grows the least over the period. VenciendoObstuculos also faces low economic growth at the beginning of the period, but by 2050 has managed the GDP per capita is the second highest of all the scenarios (Figure 61). This feature of the scenario highlights the importance of developing a pathway to the end state in 2050 during the scenarios process. Another scenario of high economic growth, ChachandoHamburgesas sees very rapid GDP growth which will have implications for future food demand in the region.

Figure 61 GDP per capita for the Andes Region indexed to the year 2000 values

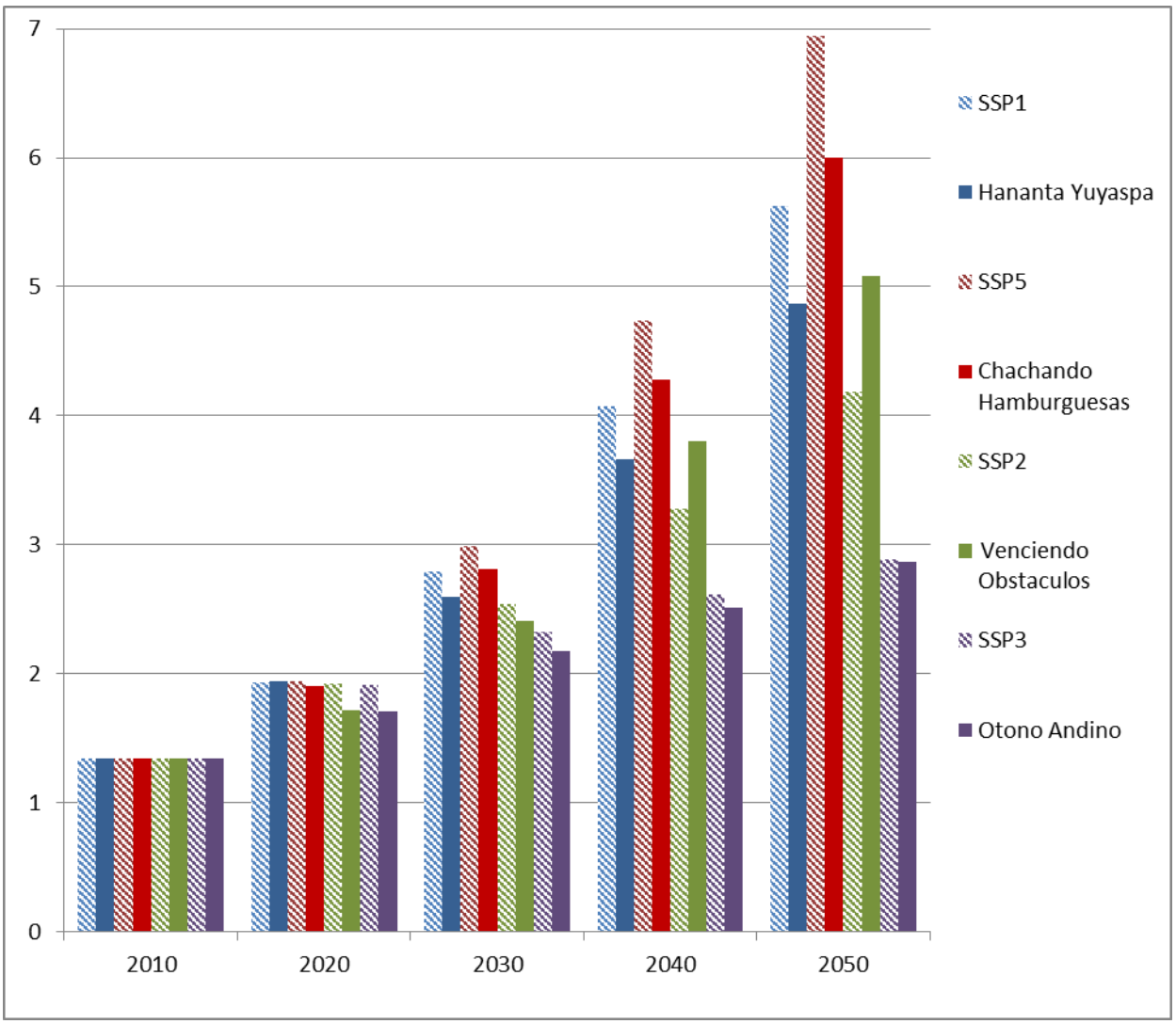
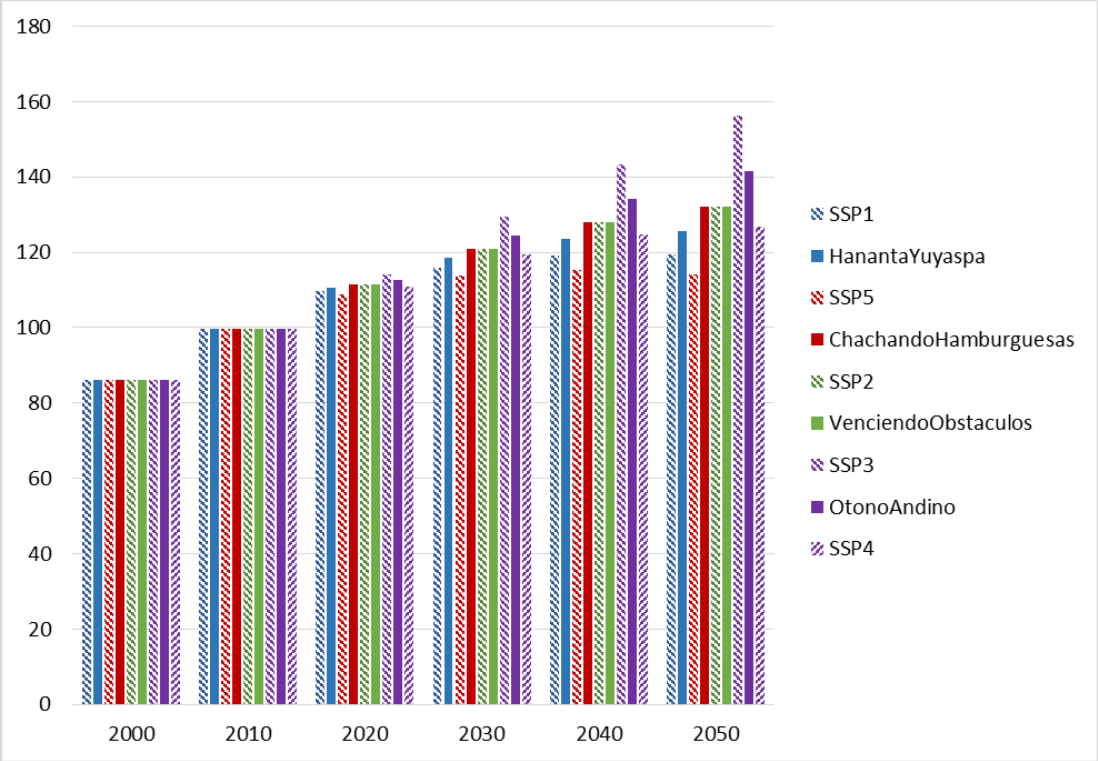


Figure 62 Population of Andean Region (millions of people)



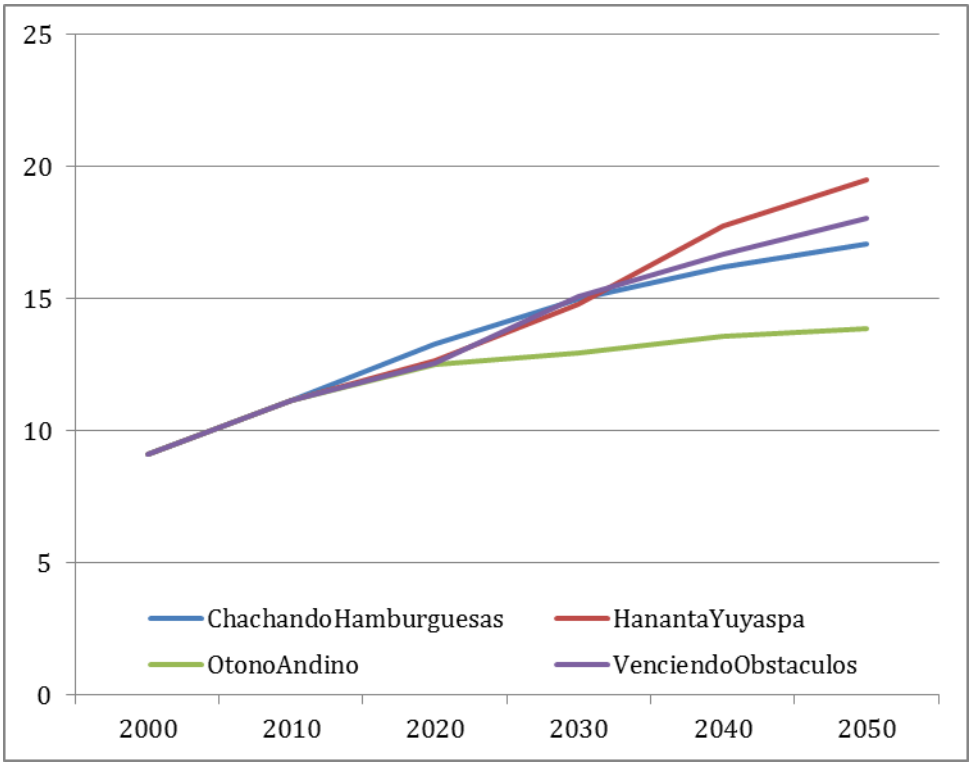
Drivers: Crop and Livestock Yields

As described in the initial section, the exogenous growth in crop yields have been translated from the scenario storylines.

Figure 8Figure 63 gives a summary of the changes assumed in the productivity of agricultural areas, as well as the potential effects it would have on the domestic supply (excluding imports) of calories for each of the scenarios, an important exogenous assumption on changes in food availability within the scenario narratives.

The region, when compared to the global yield average, maintains relatively high yields in 2000, and over the time period. Little investment in agriculture in the OtonoAndio scenario keep yields relatively unchanged over most of the period, while crop yields are highest for HantanaYuyaspa. Even though the economic situation of ChachandoHamburgesas is the best of all scenarios, investment in agriculture is limited and by 2050 yields are the 3rd lowest of the four scenarios.

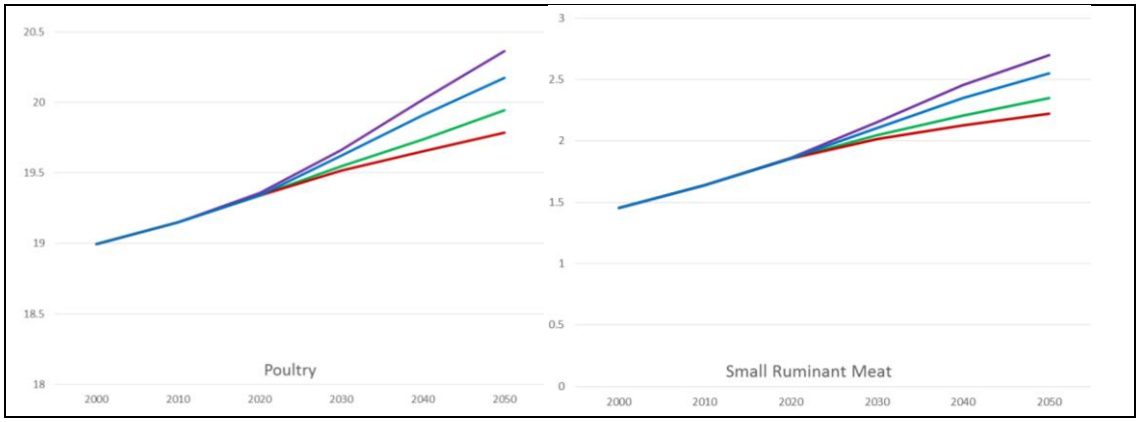
Figure 63 Aggregate exogenous crop yield projections for the Andean Region by scenario (gigacalories per ha)

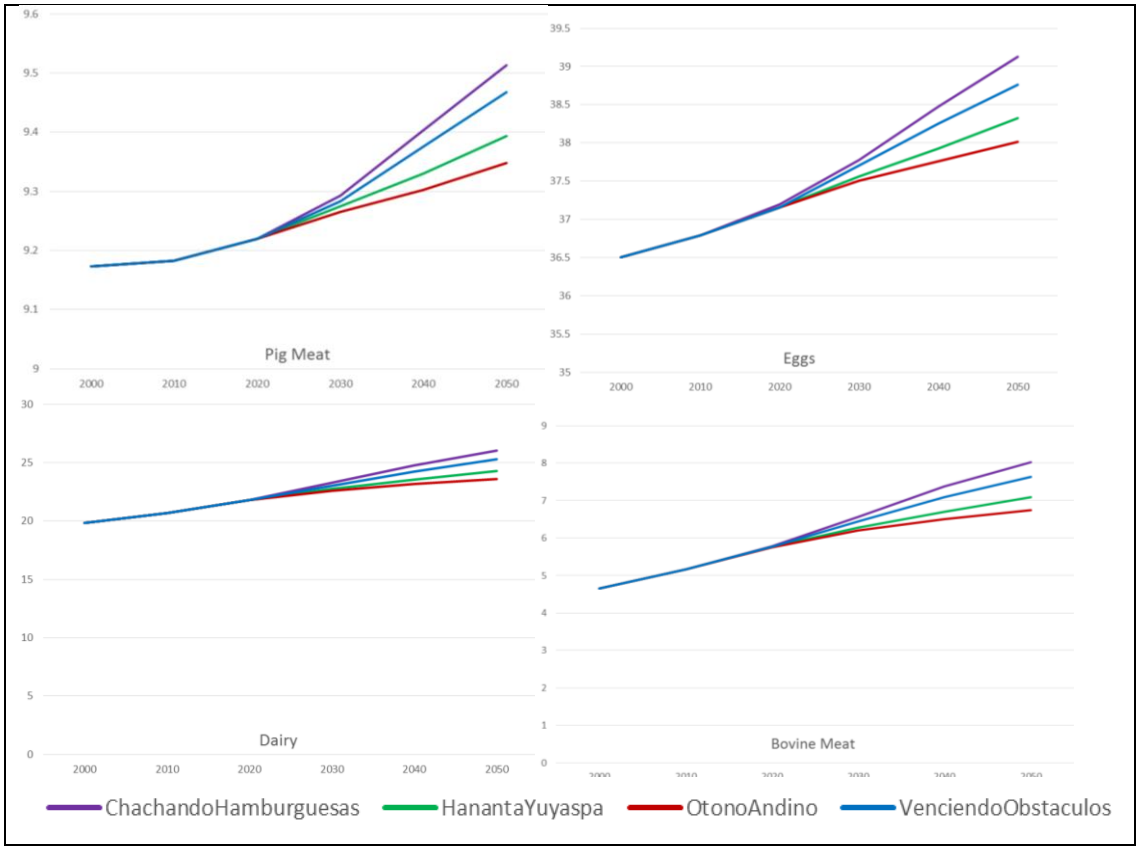


To present the current and future productivity of livestock, the conversion efficiency of livestock product per unit of feed is used. The projections of conversion efficiencies for livestock as presented in *African Livestock Futures* (Herrero et al 2014) for the SSPs were used as a starting point for the regional scenarios.

Whereas the investment in improving crop yields was low for ChachandoHamburguesas, this scenario sees the largest investment in improving livestock yields when compared to the other scenarios. Again OtonoAndino has the lowest yield improvements, as the region.

Figure 64 Exogenous Livestock Feeding Efficiencies (kg protein/t dm feed)





Drivers: Production Costs

As part of the scenarios narratives, the costs of production for the OtonoAndino scenario were increased by 10% to reflect the difficulty for producers in an unregulated marketplace.

Results

The following section presents the quantified results from GLOBIOM for agricultural production, food security, and land use and environmental impacts for the Andean regional scenarios. In these scenarios the growing regional demand for crop and livestock products, the supply of those products was modeled in GLOBIOM for period of the 2000-2050, while also considering the biophysical effects of climate change on crop production.

Total crop production increases by more than 50% in three scenarios. Figure 65 shows the relative growth in production compared to the 2010 levels. The differences in production for HantanaYuyaspa, VeciendoObstaculos, and ChachandoHamburguesas are very small by

2050. A wealthier population requiring more agricultural products pushes the price of goods up and encourages producers to increase production, which can be seen in the high level of production seen in ChachandoHamburgesas, despite the lack of investment in improving crop yields. This extensification effect of lower yielding crops and high demand for products implies that more land is required. Yields under climate change as well as under a no climate change future are presented relative to the 2010 yield levels for the most produced crops in the region in Figure 71, and the lowest yields are found in ChachandoHamburguesas and OtonoAndino. Finding the source for new crop area is important to understand the environmental impact of the extensification effect of low yields and high production, and in the case of ChachandoHamburguesas, the additional cropland and grassland comes from converted other natural land and to a lesser extent pristine forests (Figure 68).

Figure 71 presents the biophysical effects from climate change in 2050 compared to crop yields in 2010. The overall yield effects of climate change are not dramatically different from the no climate change scenario for the region. However, only regional yields have been presented; the local effects from climate change could be significant. In the region, under climate change, production shifts from low input, low yielding crops to higher input, high yielding crops as well as to irrigated agriculture. Because the model maximizes producer surplus, it assumes that there is flexibility of farmers to change production to different crops. GLOBIOM has been used to examine fixed investment adaptation strategies in the face of climate change (Leclère et al. 2014) but these adaptation and maladaptation scenarios are outside the scope of this socioeconomic scenarios analysis.

Figure 65 Andes Crop and Livestock Production Relative to 2010

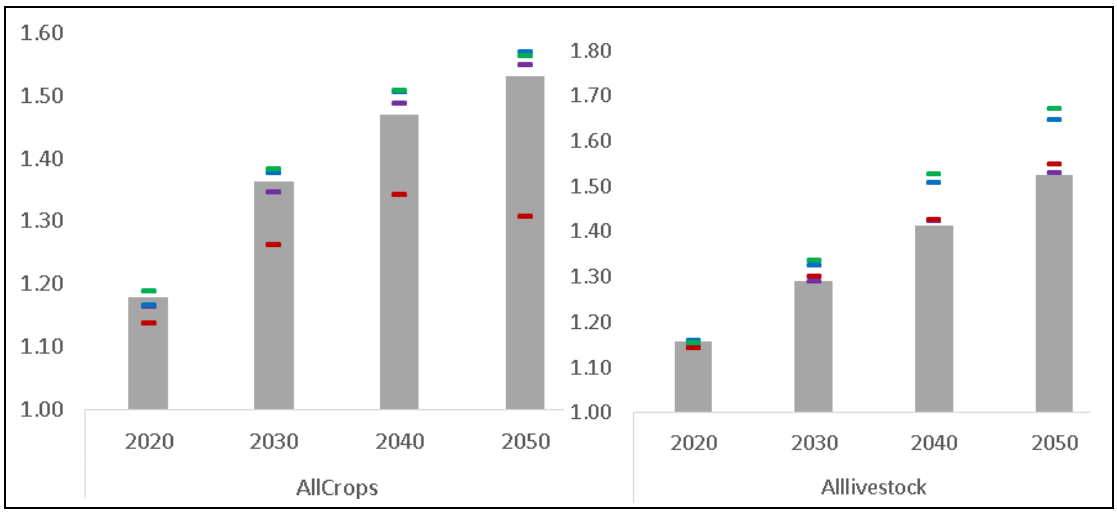
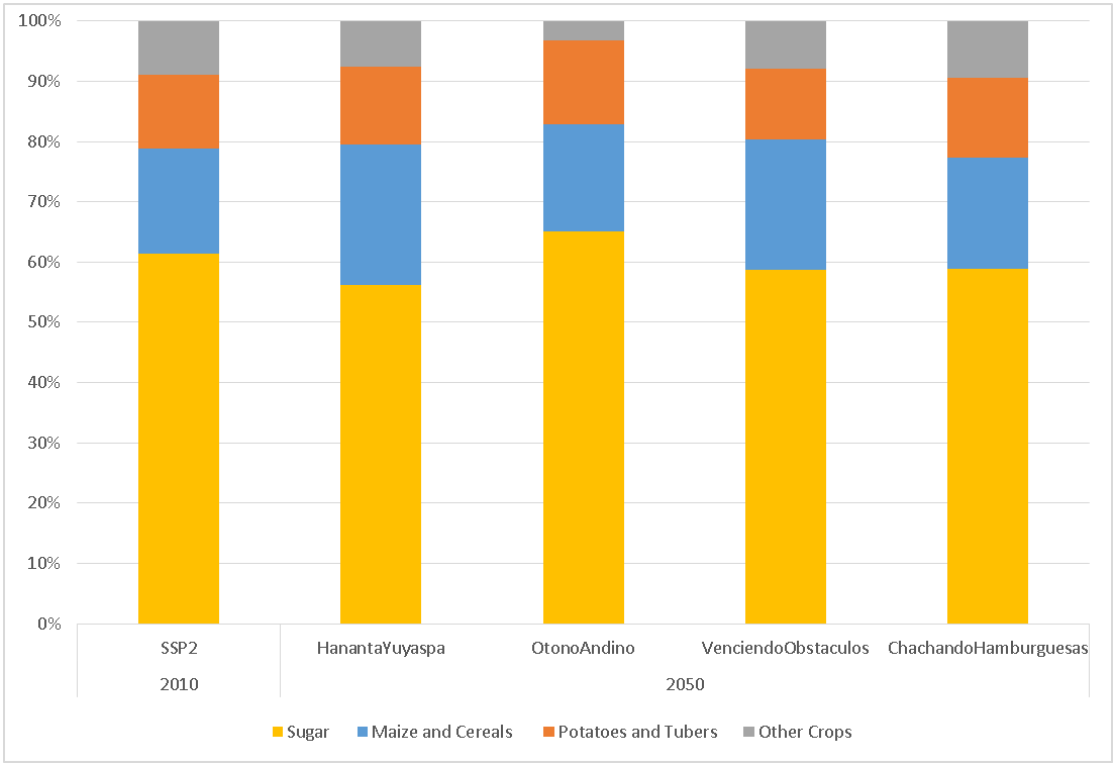


Figure 66 Andes Share of Total Production by Crop Type



In 2010, sixty percent of the total crop production comes from sugar, less than 10% from other crops, such as soybeans and oil palm, more than 15% from maize and other cereals, and 12% from potatoes and other tubers such as sweet potatoes and cassava. In 2050, HanantaYuyaspa and VeciendoObstaculos see a small increase in cereal production, at the expense of increased sugar production. Overall the crop area expands in ChachandoHamburguesas by more than 20% from 2010 to 2050, where nearly the same quantity of prouduction is possible with only 11-15% crop area growth (Figure 67).

Figure 67 Andes Cropland Area Relative to 2010

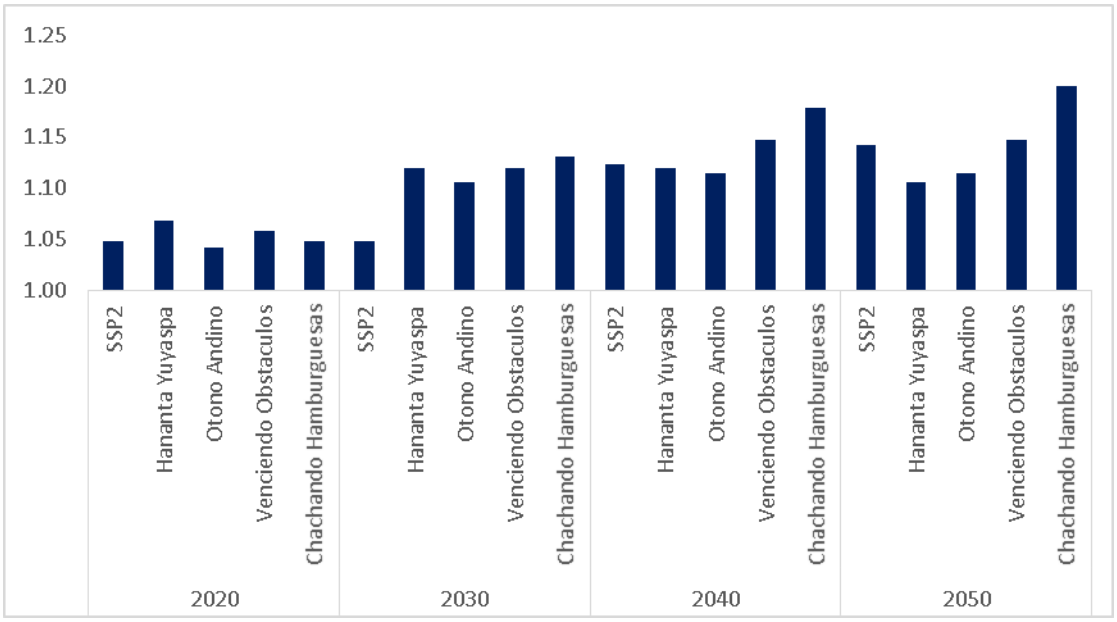
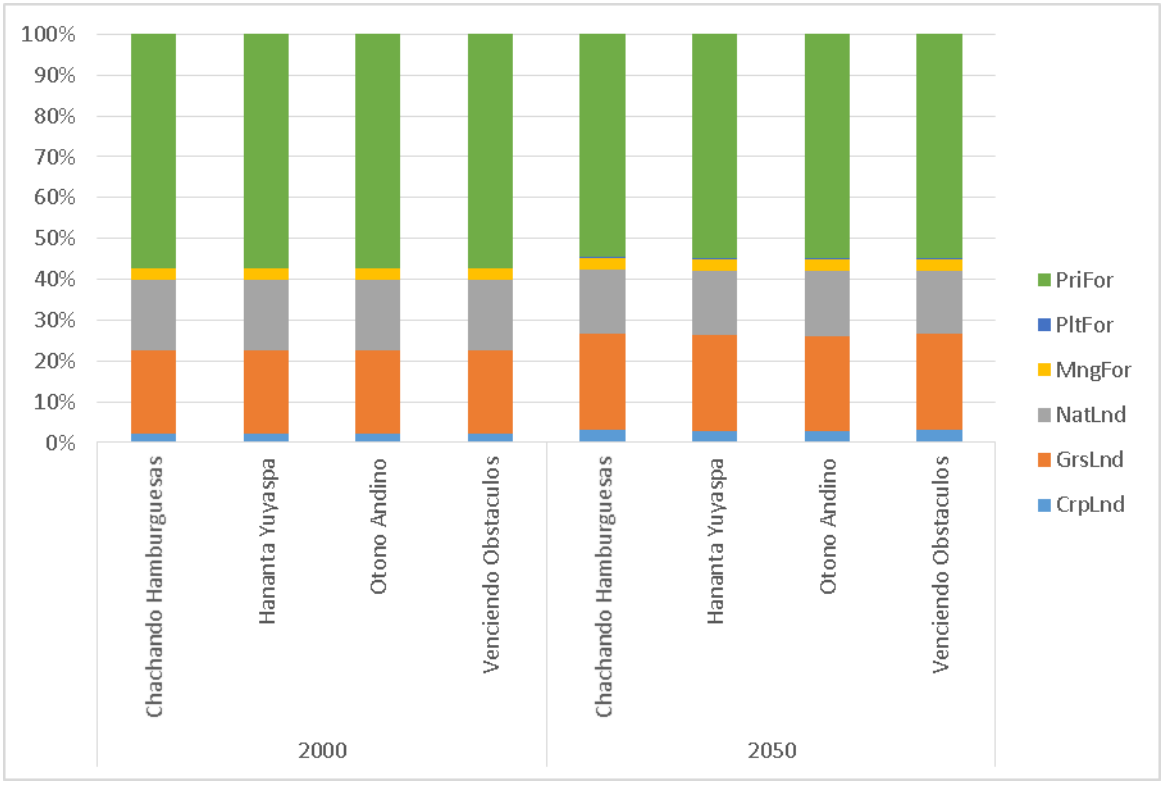


Figure 68 Andes Share of Total Area by Land Type (2010 and 2050)



Food security in the region improves throughout the period for all scenarios. Figure 69 presents one measure of food security, available kilocalories per capita per day. Calorie consumption is highest for ChachandoHamburguesas and VenciendoObstaculos due to the increase in GDP per capita. The food demand per capita relative to 2010 also provide a measure of change in food consumption as incomes change (Figure 70). For these two

scenarios, demand for livestock products grows by nearly 30%. Demand for livestock products in OtonoAndino increases by less than 15%, because GDP per capita growth was low. The investment in livestock production in ChachandoHamburguesas scenario increases the production of and lowers the price of livestock products, specifically ruminant meat. The number of calories coming from livestock products increases more than 30% over the time period, whereas the number of calories coming from crop products increases less than 9 percent over the time period.

Figure 69 Andes Kilocalorie Availability per capita per day

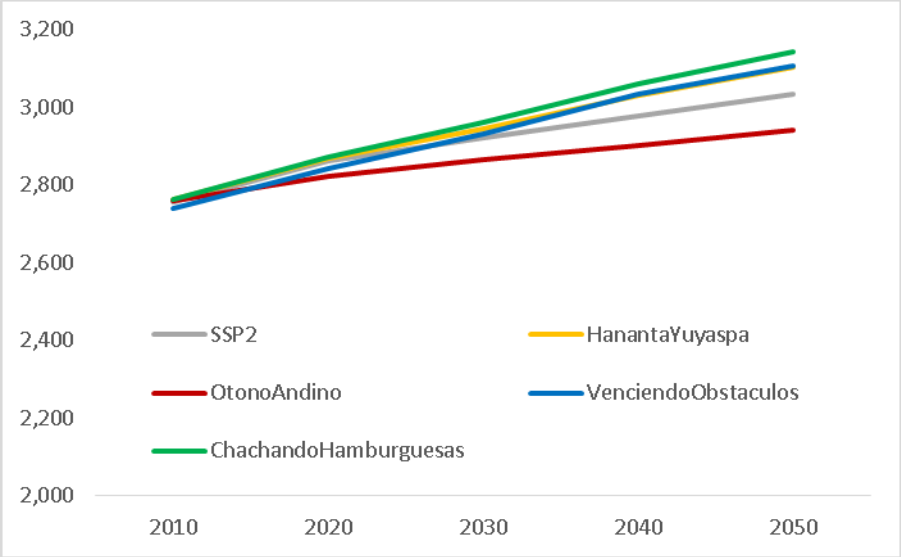


Figure 70 Andes Food Demand per capita for all products (indexed to year 2010 levels of food demand per capita)

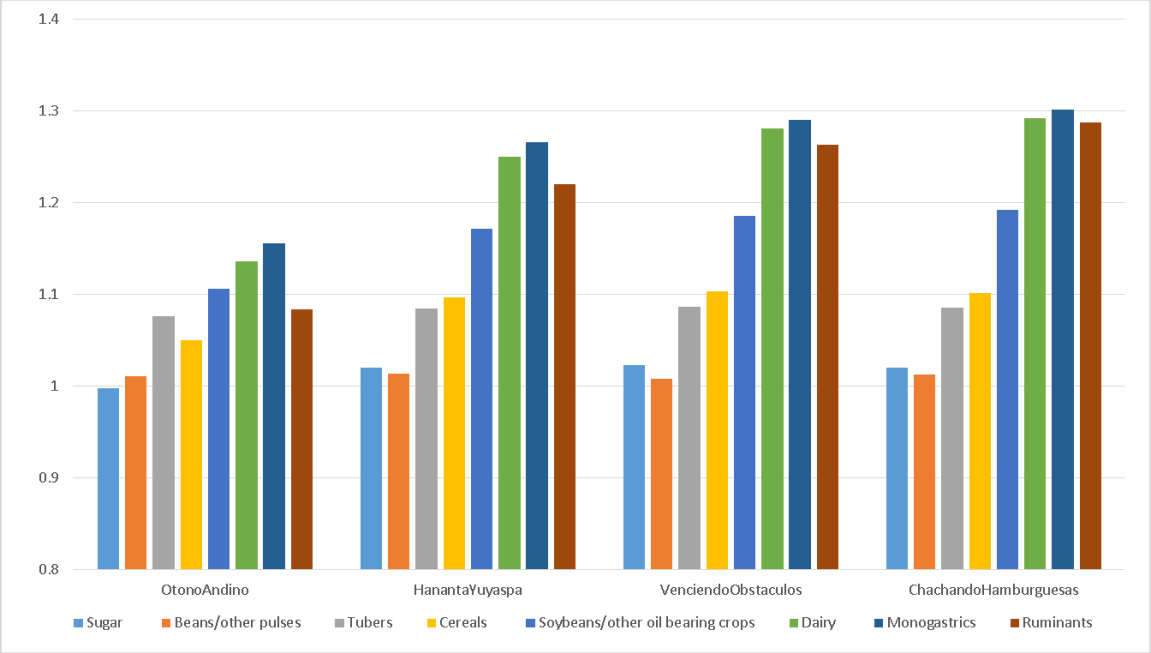
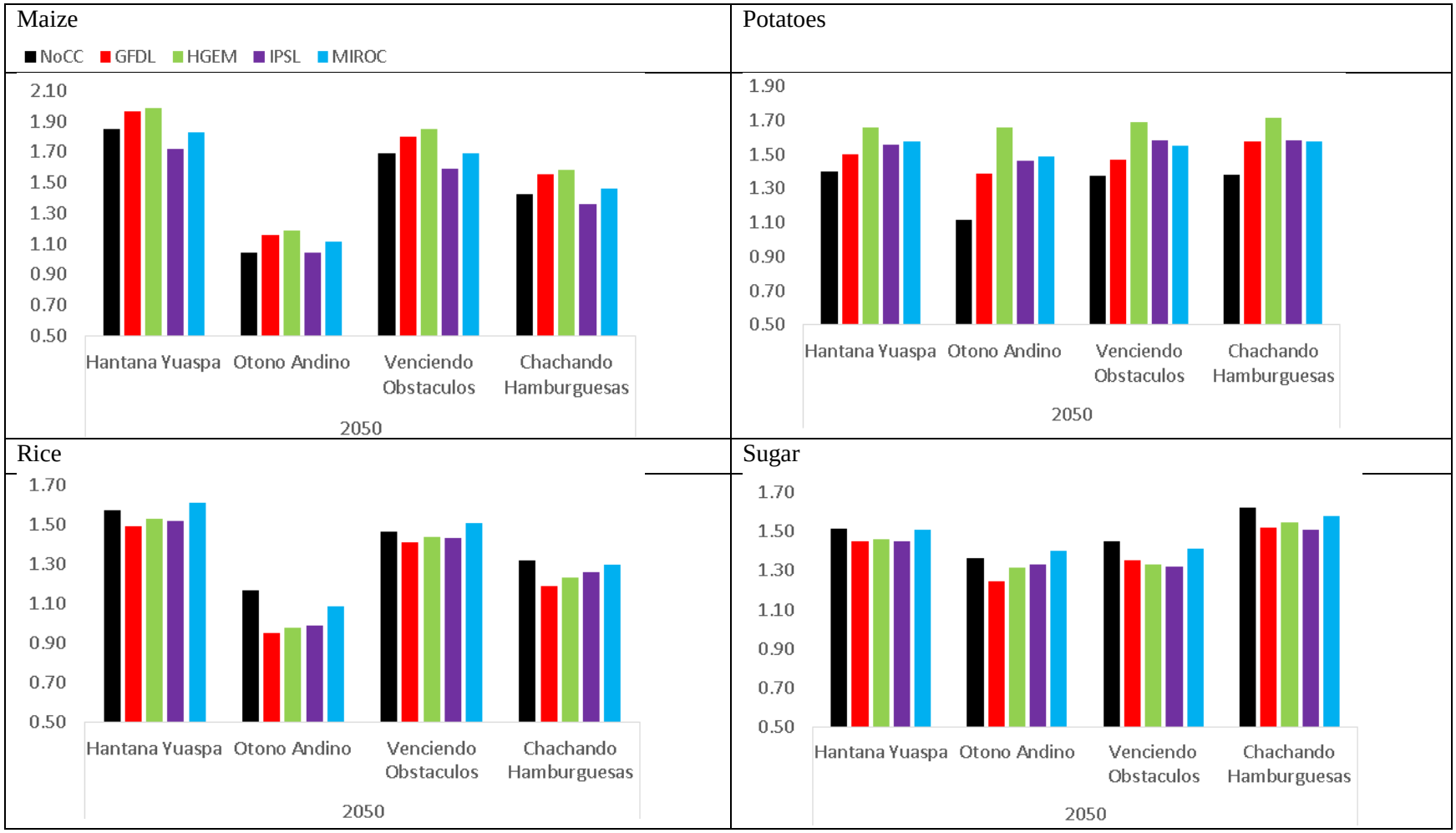

1.4
1.3
1.2
1.1
1
0.9
0.8
OtonoAndino
HanantaYuyaspa
VenciendoObstaculos
ChachandoHamburguesas
Sugar
Beans/other pulses
Tubers
Cereals
Soybeans/other oil bearing crops
Dairy
Monogastrics
Ruminants

Figure 71 Crop Yield Growth with and without climate change effects relative to 2010 levels



Conclusion and recommendations

The development and use of scenarios in all global CCAFS regions has proven to be an effective tool for policy design at national and regional levels. Essential in this success has been the combined use of stakeholder-generated scenarios and simulation models that provide fresh and critical perspectives on regional futures, through which various policies can be tested and improved together with policy developers. The quantitative scenario results have also made the scenarios more useful for partner organizations, who have used the scenarios in subsequent analysis and modelling. The results of quantitative scenario simulation are particular to each region, but a number of key conclusions emerge from across the regions:

- Investment in Agriculture essential to close yield gap to meet growing demand
  - Increases in production costs increases these yield gaps.
- Even under high ag investment, regional production is unlikely to meet regional demand.
- In many cases, climate effects to yields to 2050 have less effect than the scenarios assumptions of ag investment.
- Increased yields can lead to crop area expansion or grassland expansion.
- Protection and enforcement of forests and biodiversity essential, especially with increased investment in agriculture.

Finally, developing a critical connection between the regional, stakeholder-driven scenarios and the global SSPs/RCPs has proven very useful for the applicability of the scenarios and their comparability across regions, as well as for their potential to inform global scenario insights.

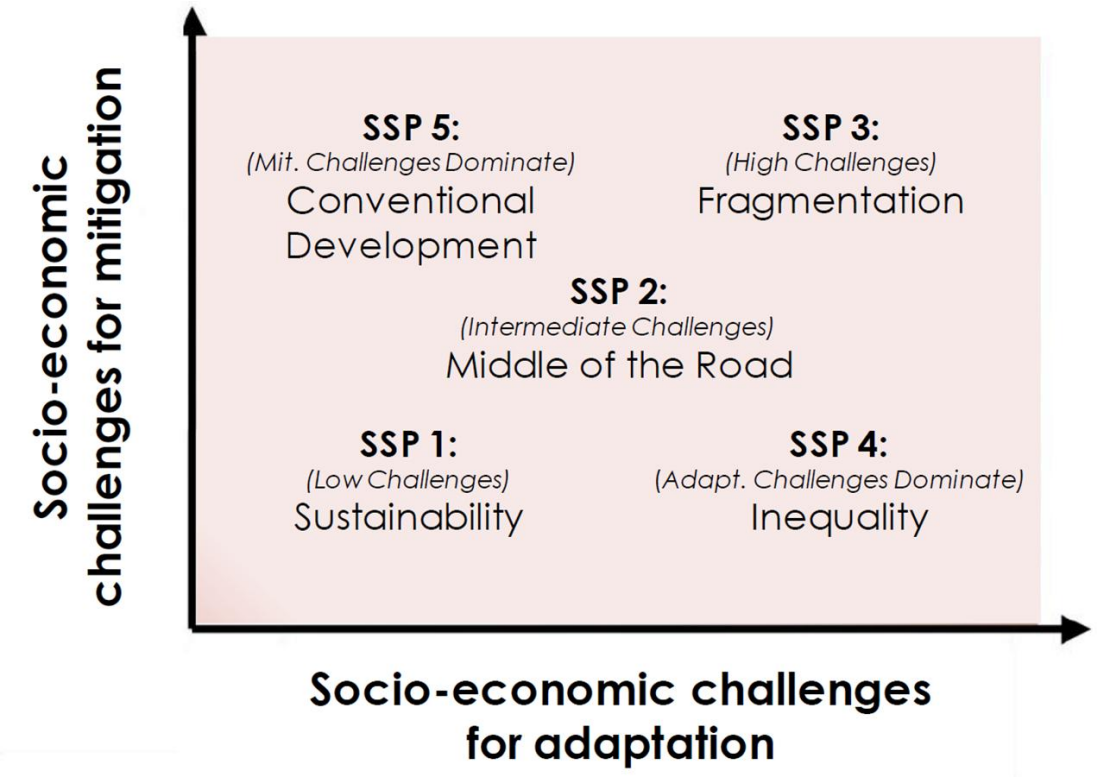
Appendix

SSP Challenge Spaces and Definitions

- SSP1 (Sustainability). A world making relatively good progress toward sustainability, with ongoing efforts to achieve development goals while reducing resource intensity and fossil fuel dependency. It is an environmentally aware world with rapid technology development, and strong economic growth, even in low-income countries.
- SSP2 (Middle of the road). This "business-as-usual" world sees the trends typical of recent decades continuing, with some progress toward achieving development goals. Dependency on fossil fuels is slowing decreasing. Development of low-income countries proceeds unevenly.
- SSP3 (Fragmentation). A world that is separated into regions characterized by extreme poverty, pockets of moderate wealth, and a large number of countries struggling to maintain living standards for a rapidly growing population.
- SSP4 (Inequality). A highly unequal world in which a relatively small, rich global elite is responsible for most of the greenhouse gas emissions, while a larger, poor group that is vulnerable to the impact of climate changes, contributes little to the harmful emissions. Mitigation efforts are low and adaptation is difficult due to ineffective institutions and the low income of the large poor population.
- SSP5 (Conventional Development). A world in which conventional development oriented toward economic growth as the solution to social and economic problems. Rapid conventional development leads to an energy system dominated by fossil fuels, resulting in high greenhouse gas emissions and challenges to mitigation.

  -From IIASA's Options Magazine Summer 2012 (O'Neill et al 2013)

Figure 72 SSP "challenge space" as divided into domains (O'Neill et al 2013)


Socio-economic challenges for mitigation
SSP 5:
(Mit. Challenges Dominate)
Conventional Development
SSP 3:
(High Challenges)
Fragmentation
SSP 2:
(Intermediate Challenges)
Middle of the Road
SSP 1:
(Low Challenges)
Sustainability
SSP 4:
(Adapt. Challenges Dominate)
Inequality
Socio-economic challenges for adaptation

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CCAFS

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Australian Centre for International Agricultural Research

Irish Aid
Ireland's commitment to a world without poverty and hunger

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MANATŪ AORERE