The future of food security, environments and livelihoods in Western Africa

Four socio-economic scenarios

Working Paper No. 130

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

Amanda Palazzo, Lucas Rutting, Robert Zougmoré, Joost M. Vervoort, Petr Havlik, Abdulai Jalloh, Ernst Aubee, Ariella E.S. Helfgott, Daniel Mason-D'Croz, Shahnila Islam, Hugo Valin, Polly J. Ericksen, Zénabou Segda, Abdoulaye S. Moussa, Jules Bayala, Hame A. Kadi Kadi, Pierre C. Sibiry Traoré, and Philip K. Thornton

CGIAR
RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security
CCAFS

Working Paper

The future of food security, environments and livelihoods in Western Africa

Four socio-economic scenarios

Working Paper No. 130

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

Amanda Palazzo, Lucas Rutting, Robert Zougmoré, Joost M. Vervoort, Petr Havlik, Abdulai Jalloh, Ernst Aubee, Ariella E.S. Helfgott, Daniel Mason-D'Croz, Shahnila Islam, Hugo Valin, Polly J. Ericksen, Zénabou Segda, Abdoulaye S. Moussa, Jules Bayala, Hame A. Kadi Kadi, Pierre C. Sibiry Traoré, and Philip K. Thornton

Correct citation:
Palazzo A, Rutting L, Zougmoré R, Vervoort JM, Havlik P, Jalloh A, Aubee E, Helfgott AES, Mason-D'Croz D, Islam S, Valin H, Ericksen PJ, Segda Z, Moussa AS, Bayala J, Kadi Kadi HA, Sibiry Traoré PC, Thornton PK. 2016. The future of food security, environments and livelihoods in Western Africa: Four socio-economic scenarios. CCAFS Working Paper no. 130. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at: www.ccafs.cgiar.org

Titles in this Working Paper series aim to disseminate interim climate change, agriculture and food security research and practices and stimulate feedback from the scientific community.

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is a strategic partnership of CGIAR and Future Earth, led by the International Center for Tropical Agriculture (CIAT). The Program is carried out with funding by CGIAR Fund Donors, the Danish International Development Agency (DANIDA), Australian Government (ACIAR), Irish Aid, Environment Canada, Ministry of Foreign Affairs for the Netherlands, Swiss Agency for Development and Cooperation (SDC), Instituto de Investigação Científica Tropical (IICT), UK Aid, Government of Russia, the European Union (EU), New Zealand Ministry of Foreign Affairs and Trade, with technical support from the International Fund for Agricultural Development (IFAD).

Contact:
CCAFS Coordinating Unit - Faculty of Science, Department of Plant and Environmental Sciences, University of Copenhagen, Rolighedsvej 21, DK-1958 Frederiksberg C, Denmark. Tel: +45 35331046; Email: ccafs@cgiar.org

Abstract

This working paper examines the development of regional socioeconomic scenarios for West Africa's development, agriculture, food security and climate impacts. We present four globally consistent regional scenarios framed and outlined by regional experts who crafted narratives and determined key drivers of change. Stakeholders identified the type of actors driving change and the timeline of strategic planning as the most uncertain and most relevant factors of change affecting food security, livelihoods and environments in the region.

The scenarios were linked to the IPCC community's global Shared Socio-economic Pathways (SSPs) and quantified using two agricultural economic models, GLOBIOM and IMPACT, in interaction with drivers outlined by the SSPs and guided by semi-quantitative information from the stakeholders. The quantification of the scenarios has provided additional insights into the possible development of Western Africa in the context of a global economy as well as how the agricultural sector may be affected by climate change. The scenarios process highlights 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.

The objective of this working paper is to provide scenarios for future regional development for West Africa on the future of food security, environment, and rural livelihoods as well as offer details of the multi-stakeholder scenarios development process. Using both qualitative and quantitative scenarios we provide insights into the possible development of West Africa as well as a scalable framework for regional decision makers and the scientific community to use scenarios to build and test policies to make them more robust in the face of future uncertainty.

In these scenarios, strong economic development increases food security and agricultural development. Increased crop and livestock productivity may lead to an expansion of agricultural areas within the region but productivity improvements may reduce the pressure on land elsewhere. In the context of a global economy, West Africa remains a large consumer and producer of a selection of commodities. However, the growth in population in combination with rising incomes may lead to increases in the region's imports. For West Africa, climate change is likely to have negative effects on both crop yields and grassland productivity, and lack of investment in agriculture may exacerbate them.

The aim of the regional scenarios is provide challenging contexts for policy makers to test and develop a range of national and regional policies. To date, the scenarios have been used in a number of policy design processes which include collaborations with ECOWAS priority setting, the National Plan for the Rural Sector for Burkina Faso (PNSR), and district and national level policy processes in Ghana.

Keywords

Western Africa; food security; livelihoods; environment; climate change; agriculture; futures; scenarios

About the authors

Amanda Palazzo,[a] Lucas Rutting,[b,c] Robert Zougmoré,[c,d] Joost M. Vervoort,[b,c,e] Petr Havlik,[a] Abdulai Jalloh,[f] Ernest Aubee,[g] Ariella E.S. Helfgott,[b] Daniel Mason-D'Croz,[h] Shahnila Islam,[h] Hugo Valin,[a] Polly J. Ericksen,[i] Zénabou Segda, Abdoulaye S. Moussa,[c] Jules Bayala,[j] Hame A. Kadi Kadi,[k] Pierre C. Sibiry Traoré,[d] Philip K. Thornton[c]

a. International Institute for Applied Systems Analysis (IIASA), A-2361, Laxenburg, Austria.

b. Environmental Change Institute, University of Oxford, South Parks Road, Oxford, OX1 3QY, United Kingdom

c. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), University of Copenhagen, Faculty of Science, Department of Plant and Environmental Sciences, Rolighedsvej 21, DK-1958, Frederiksberg C, Denmark

d. International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) Mali, BP 320 Bamako, Mali

e. Copernicus Institute of Sustainable Development, Utrecht University, Heidelberglaan 2, P.O. Box 80.115, 3508TC Utrecht, The Netherlands

f. West and Central African Council for Agricultural Research and Development (CORAF/WECARD), 7 Boulevard du President Habib Bourguiba, Dakar BP 48, Senegal

g. Economic Community of West African States (ECOWAS), Directorate of Agriculture and Rural Development, Abuja, Nigeria

h. International Food Policy Research Institute, 2033 K St, NW, Washington, DC 20006-1002 USA

i. International Livestock Research Institute (ILRI), PO Box 30709, Nairobi, Kenya

j. World Agroforestry Centre (ICRAF), West and Central Africa Regional Office - Sahel Node, BP E5118, Bamako, Mali

k. Institut National de la Recherche Agronomique du Niger (INRAN), B.P. 429, Niamey, Niger

Acknowledgements

The authors would like to acknowledge that the funding for this research was provided by the CGIAR research program on Climate Change, Agriculture and Food Security (CCAFS).

In addition to core program funding, this research benefitted from funding by the EU FP7 Healthy Futures program.

We would like to thank the participants in all of our scenario development and use processes for their active contributions to each process, as well as the institutions who supported and continue to support this work, such as the International Institute of Applied Systems Analysis (IIASA) and the International Food Policy Research Institute (IFPRI).

Contents

Introduction

Researchers, policy makers, entrepreneurs and development practitioners working to improve food security, environmental health and rural livelihoods in the developing world face many uncertainties when exploring the future of food systems (Ericksen et al. 2009). It is difficult to predict what economic, political and social conditions will be like in the next few years and virtually impossible to predict the medium to longer term (van Vuuren et al. 2012). Climate change and variability are among the greatest unknowns, and are likely to have far-reaching effects on food security, environments and livelihoods (Vermeulen et al. 2012).

This working paper presents four alternative plausible futures, or scenarios, for food security, environments and livelihoods in West Africa. The scenarios are based on different assumptions and pathways of socio-economic and political development. They were developed under the auspices of CGIAR's Research Programme 7: Climate Change, Agriculture and Food Security (CCAFS). A number of workshops, attended by stakeholders, drawn from governments, civil society, the research community and the media, fed into the development process. The scenarios describe trends and events since 2010 up to 2050. These scenarios were translated to semi-quantitative assessments of a range of drivers and indicators and quantified with two agricultural economic models, IMPACT (Robinson et al., 2015), developed by the International Food Policy Research Institute (IFPRI) and GLOBIOM (Havlik et al., 2014) developed by the International Institute for Applied Systems Analysis (IIASA). The separate presentation of the semi-quantitative and quantitative results in this report allows the stories to flow and also makes it easier for the reader to compare data between the different scenarios.

The aim of the scenarios process has been to provide alternate, plausible, relevant and challenging futures in narratives and numbers that can be used by policymakers, the private sector, civil society leaders and development researchers to test ideas about the future and the strategies, technologies and research recommendations needed to deal with the future successfully. Specifically, the scenarios can guide policy prioritization, frame research questions and help agenda setting in the drive towards improved food security, environmental management and rural livelihoods in the face of climate change in Western Africa. The West Africa scenarios have been used in several policy development projects, including the revision of the National Program for the Rural Sector in Burkina Faso and the development

of multi-level integrated adaptation plans in Ghana. Both are described in Chapter 3 in greater detail.

The first part of this working paper introduces the CCAFS programme, then outlines why scenarios are valuable as a planning tool, and then presents the narratives and semi-quantitative indicators developed by workshop participants. Part 2 of the working paper will present quantitative results that also integrate the socio-economic scenarios with climate scenarios.

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

Climate change is recognised as one of the most pressing threats to food security and wellbeing. It has consequently emerged as a major political issue worldwide. Many advocate the urgent need to design and implement policies that would allow populations to adapt and develop resilience to the impacts of climate change. Also, the challenge of mitigating greenhouse gas emissions remains a key priority. Importantly, for actors across sectors and at different system levels, climate change is one of a number of biophysical, socio-economic and political stressors, as it affects hundreds of millions of people who depend on small-scale agriculture for their livelihoods. Climate change affects agriculture and food security, and likewise, agriculture and natural resource management affect the climate system. These complex and dynamic relationships are also shaped by economic policies, political conflict and other factors such as the spread of infectious diseases. In order to develop practical solutions for agriculture in the face of climate change, we need to integrate knowledge about climate change, agriculture, and food security in a meaningful and innovative way.

The Climate Change, Agriculture and Food Security Program (CCAFS) is a major research partnership between CGIAR and the global environmental change community. As global climate change is comprised of myriad critically important and complex issues that require thorough inter- and transdisciplinary research and knowledge, these issues are addressed through a strategic collaboration between CCAFS and Future Earth, a major international research platform providing the knowledge and support to accelerate our transformations to a sustainable world. Its overall goal is to promote a food secure world through the provision of science-based efforts that support sustainable agriculture and enhance livelihood while adapting to climate change and conserving natural resources and environmental services. To achieve this goal, two main objectives has been defined: a) to identify and develop pro-poor

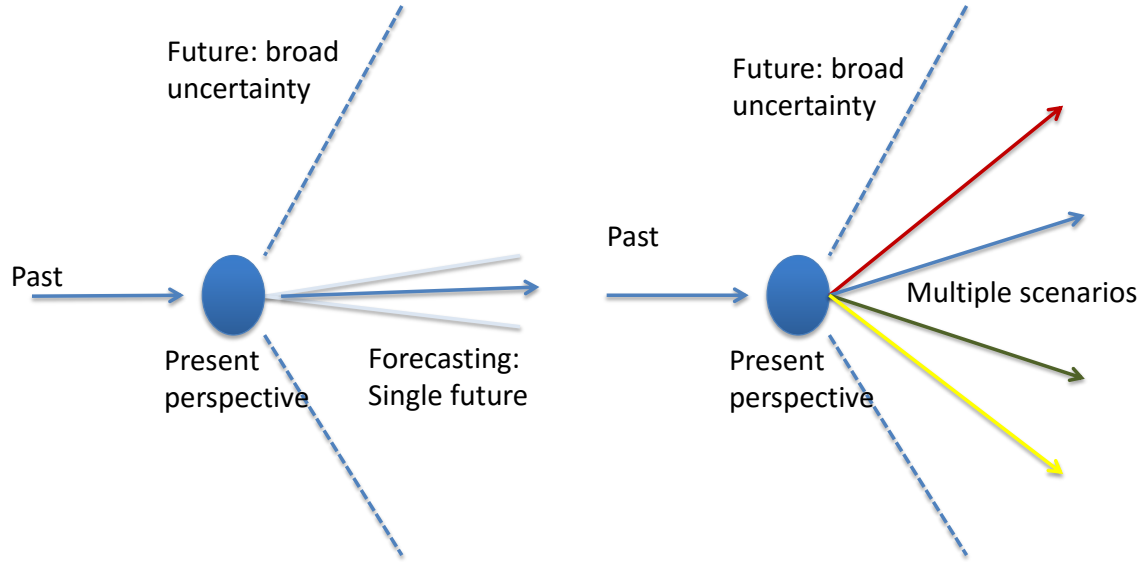
adaptation and mitigation practices, technologies and policies for food systems, adaptive capacity and rural livelihoods, and b) to provide diagnosis and analysis that will ensure the inclusion of agriculture in climate change policies and the inclusion of climate issues in agricultural policies from the sub-national to the global level in a way that bring benefits to the rural poor.

The program covers five regions worldwide namely South Asia, East Africa, West Africa, Latin America and South East Asia. Major activities in West Africa are pertaining to research, engagement, capacity strengthening and communication and have been initiated with various partners at community, national and regional levels. This covered components such as (1) testing of adaptation and mitigation practices and technologies through participatory action research at sites in five pilot countries; (2) Capacity strengthening of partners on research approaches, scientific tools, M&E, knowledge and information management and sharing; (3) Decision making support for policy makers; and (4) Communication and outreach. Gender and social differentiation are mainstreamed across these activities.

What are scenarios and why are they useful?

The development and use of scenarios originates in the military and in the private sector. Scenarios are 'what if' stories about the future, told in words, numbers (models), images, and other means. Rather than attempting to forecast a single future in the face of broad future uncertainty, scenarios represent multiple plausible directions that future drivers of change may take (Figure 1). The CCAFS scenarios process focuses on contextual drivers of change for agriculture, livelihoods, environments and food security – climate change and socio-economic changes (e.g. in markets, governance, broad economic developments, infrastructure).

Figure 1 Rather than providing a single "most likely" forecast, multiple scenarios explore multiple concrete, plausible futures and what these would mean for food security, environments and livelihoods. This way, the set of scenarios engages with broad future uncertainty for the testing of policies, investments and research innovations.

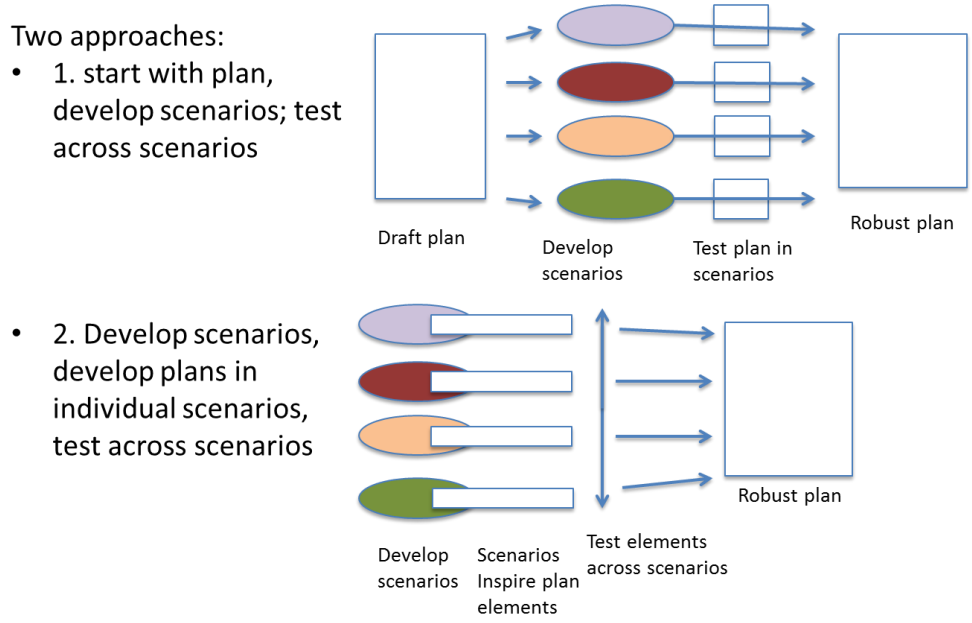


Source: Authors

Within the CCAFS program, scenarios are used to test and develop policies, plans and investments. Each scenario offers different future challenges and opportunities. Therefore, for each scenario, planners can ask the question: how well will our plan work under the specific conditions of this scenario? What needs to be changed? When recommendations for improvement from a range of different scenarios are integrated, the plan has a better chance of being effective in the face of an uncertain future – for instance by having strategies that are expected to work under all scenarios, or by including a range of different options that can be used depending on the specific scenario. Scenarios can also be used before a plan exists, by starting with the challenges and opportunities that different scenarios offer, coming up with ways to approach those issues, and then combining them in a new, robust, plan.

Both approaches are summarized in Figure 2.

Figure 2 Using scenarios to develop and test plans and policies in different stages



Source: Authors

Scenarios in the CGIAR Climate Change, Agriculture and Food Security programme

CCAFS is coordinating regional scenario development and application in East Africa, West Africa, South Asia, Southeast Asia, Central America and the Andean region (Palazzo et al. 2014). In each region it is working with stakeholders from the policy, private, media and research sectors as well as non-government and civil society organizations. The scenarios build on previous work done by the CCAFS team and its Scenarios Advisory Group, in particular the multi-level scenarios work conducted as part of the Millennium Ecosystems Assessment (2005).

The CCAFS regional scenarios process plays a unique role in the context of food security, environments and livelihoods. It helps to articulate the challenges presented by climate change by introducing a complementary focus on socio-economic and governance change. At the same time, by adopting a regional rather than a purely national stance, the scenarios process links different scales and integrates the needs of a wide range of stakeholders, thereby identifying potential synergies and trade-offs (Ericksen et al. 2009). A cross-level, cross-sector approach of this kind that focuses on exploring different futures with

partnerships across food systems has seldom been attempted previously (Zurek & Henrichs 2007). The CCAFS scenarios are specifically developed to guide policy development.

The CCAFS West Africa scenarios and their development

The CGIAR programme on Climate Change, Agriculture and Food Security (CCAFS) has collaborated with a wide range of actors (see Appendix A) in West Africa to develop socio-economic scenarios for the ECOWAS region, with a particular focus on Burkina Faso, Senegal, Niger, Ghana and Mali. Four workshops were organized to this end in the period from 2010 to 2012.

Regional stakeholders outlined four scenarios, structured along two axes of uncertainty, using narrative flowcharts, conceptual maps, storylines, and a range of semi-quantitative indicators including information on governance, agriculture, food security and livelihoods. For stakeholders, the actors driving change in the region (state and non-state actors) and the time priority of policies (short-term and long-term) were the most uncertain but relevant factors for agriculture and food security in the future, represented in Figure 4. Figure 5 depicts a cartoon representation (by André Daniel Tapsoba) of the scenarios resulting these two key drivers of change. Climate change is considered to be a major factor of policy challenges; but this factor is brought into the scenarios through climate models (see next section).

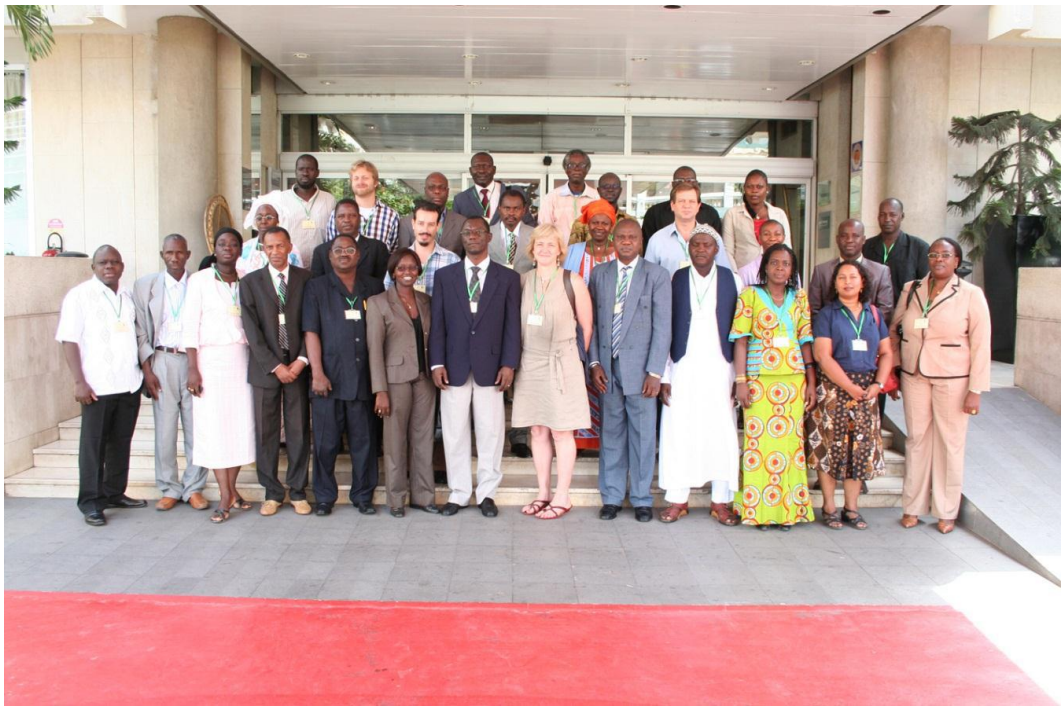
Some key points to consider while using this set of scenarios:

- The distinction ‘short-term versus long-term’ relates to the prevailing paradigm in each scenario, along the entire scenario time line (up to 2050). This means that at any one point in the scenario, whether it is in the next five years or in 2030, short-term concerns are prioritized by actors in the scenario. For instance, dealing with conflicts, immediate poverty crises, short-term profits etc. will be considered a priority and long-term concerns like investments in infrastructure, long-term climate impacts, education etc. are not as high on the strategic agenda. The two scenarios that have this feature therefore go through cycles of dealing with short-term crises and short-term investments. The opposite is true for the scenarios where long-term priorities get a higher standing. The division between short term/long term is not meant as a good/bad division; obviously many pressing problems and opportunities are of a short-term nature and need attention.

- The scenarios are to be used as a set to test and develop policies – each scenario highlights and amplifies certain challenges and opportunities associated with a situation on one end of the extreme of the two scenario axes. The policy reality might be some mix of these scenarios; but by pulling them apart, plans and policies can be tested under a set of extreme conditions, and the plans' strengths and weaknesses can be assessed and improved with regard to these extreme stories.

- In each scenario, two trends are dominant, but this does not mean other trends are not there, merely that these trends are weaker.

Figure 3 Participants in Dakar, Senegal developing scenario narratives



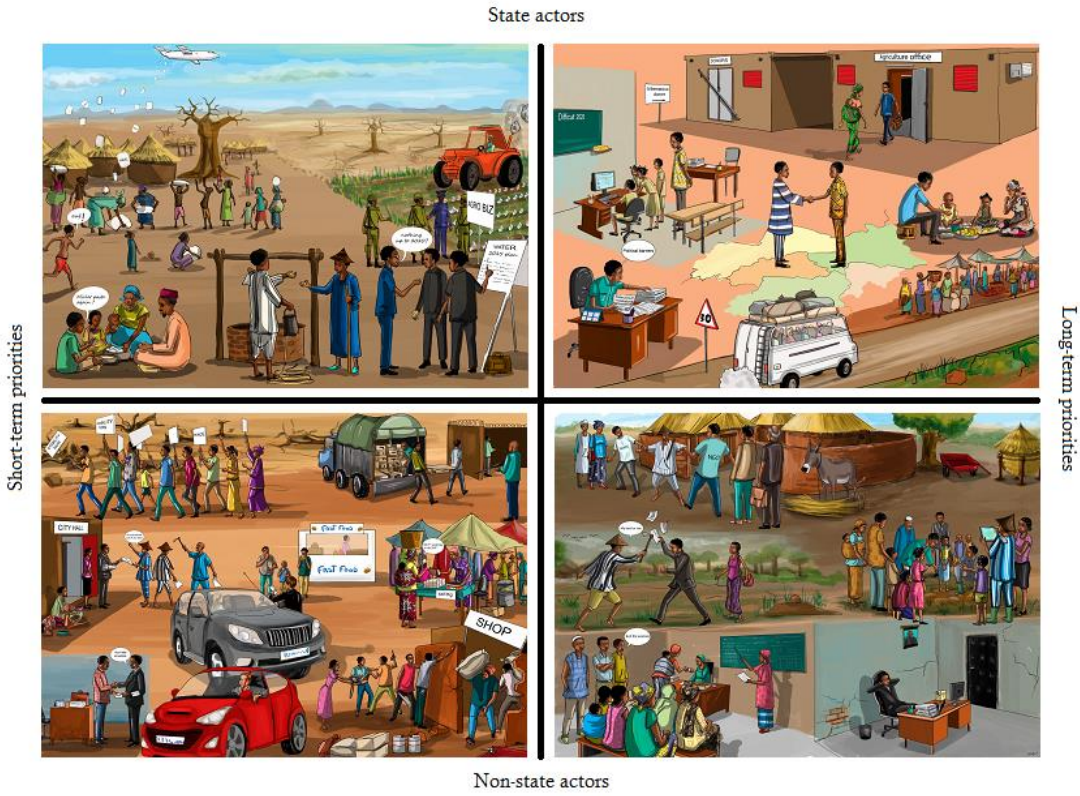
Source: Authors

Figure 4 Four socio-economic scenarios have been developed by stakeholders in West Africa, structured around two axes of uncertainty: a) will short-term priorities or long-term priorities be the focus of governance and b) will state actors or non-state actors be the driving force in the region?

		Policy driver	
		Short-term priorities	Long-term priorities
Dominant Force	State Actors	Governments facilitate short-term gain: cash, carbon and calories	A slow and painful transition to sustainable states
	Non-state Actors	Ungoverned, quick and chaotic development; dealing with crises at the expense of investment	A struggle between civil society and the private sector that is ultimately productive

Source: Authors

Figure 5 Cartoon representation of the scenarios, by artist André Daniel Tapsoba



Source: Authors

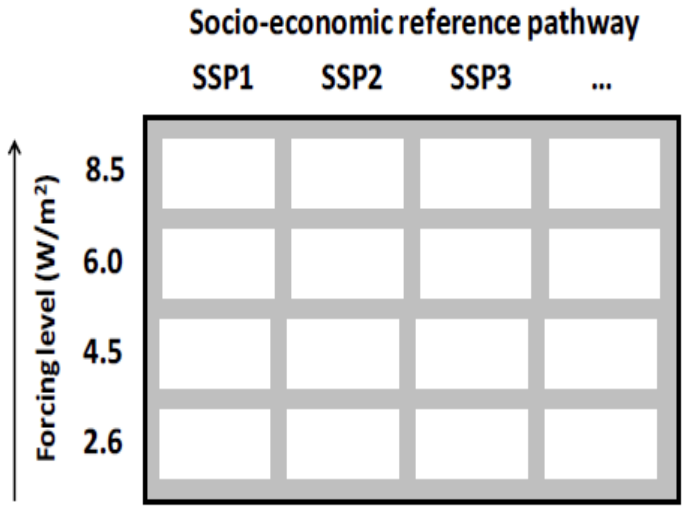
Quantifying the scenarios

Modelling tools have been used to add rigour to the qualitative storylines, since they provide the quantitative data needed to ensure the suggested outcomes and indicators are credible, and to combine the socio-economic scenarios with various climate scenarios. The teams used IFPRI's IMPACT model (Rosegrant et al. 1995) and IIASA's GLOBIOM model (Havlík et al. 2011). These are both 'partial equilibrium' models, meaning, in this case, that they simulate global market dynamics for agricultural products only, not for entire economies. Both models have strengths and weaknesses. IMPACT has a long history of being used to examine alternative futures for global food supply, demand, trade and prices, while GLOBIOM is designed with detailed grid-cell information and follows a bottom-up approach to provide policy advice on global issues concerning competition for land among major production sectors. While IMPACT and GLOBIOM are global models, as part of the CCAFS exercise they are being modified to allow simulation for specific regions. Both models will be described in more detail in section 6 "GLOBIOM and IMPACT".

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. 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 model designers to adapt their models, creating a two-way interaction between the narratives and the modelling results for further improvement of the scenarios.

A socio-economic scenario can be combined with multiple climate scenarios and vice versa. Because of this, a socio-economic scenario that offers few opportunities for adaptation (for instance because of low investment in infrastructure and low government support of rural communities) will play out very differently under a low climate change scenario than under a high climate change scenario. Socio-economic scenarios are combined with climate scenarios, in a process similar to that used by the IPCC-related global environmental change community (see figure 6).

Figure 6 The IPPC-related global environmental change research community generates global socio-economic scenarios or "shared socio-economic pathways" and combines these with different climate scenarios or "representative concentration pathways with different climate forcing levels. The CCAFS scenarios process in West Africa also combines socio-economic and climate scenarios using this approach, but at the regional level.



Using scenarios for policy planning and investment guidance

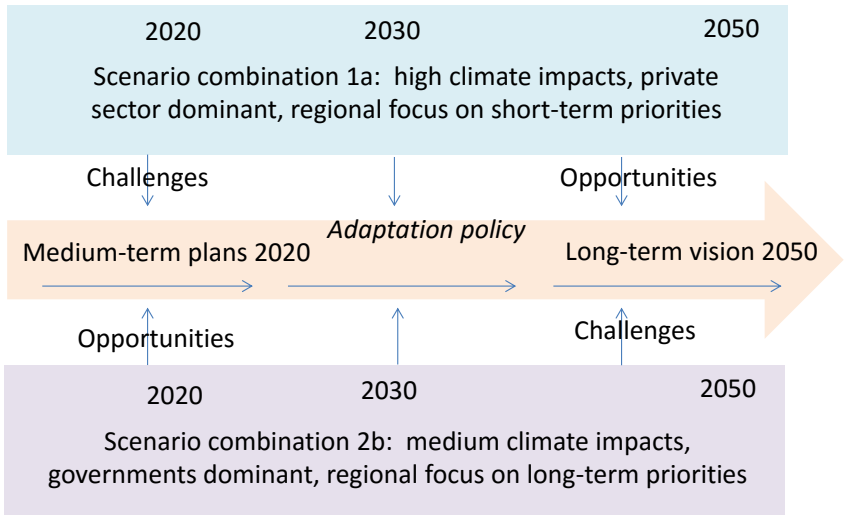
The combined socio-economic and climate scenarios for West Africa are used to guide policy, investment and research in several ways:

1. Organize strategic planning at the sub-continental level in West Africa: the CCAFS West Africa scenarios can be used to bring decision-makers across the region together to exchange knowledge and connect activities for strategic agricultural, adaptation and mitigation policies. ECOWAS plays the key role at the regional level, both through its own regional policies (e.g. ECOWAP, Action Program for Reducing Vulnerability to Climate Change in West Africa) and its convening power in bringing regional decision-makers together for this purpose.
2. Guide and develop agricultural, environmental, adaptation and mitigation policies at the national level in West Africa: scenarios can test whether policies are able to deal with future climatic and socio-economic changes, and help think about more strategic and flexible policies. Examples are the revision of the National Program for the Rural Sector in Burkina Faso and policy review with the Ghana CCAFS national policy

platform. Figure 7 illustrates how multiple scenarios offer different challenges and opportunities for policies and plans.

3. Guide investments into agriculture, food security and environments: scenarios provide a decision context to determine which investments by donors and social entrepreneurs are likely to be successful under a wide range of future contexts. CCAFS is currently working on Climate-Smart Agriculture investments in Southern Africa and South East Asia with FAO using scenarios methodology.
4. Provide a context for research: work on adaptation and mitigation measures such as new crop varieties or management strategies can be tested against multiple climate and socio-economic scenarios for feasibility
5. Provide a regional context for local decision-making: the scenarios offer a regional context (prices, governance, infrastructure, land use change, etc.) for local and sub-national level decision-making processes.

Figure 7 Multiple scenarios each offer different challenges to a given policy (say, national adaptation plans) over different time steps. Two examples of combined climate and socio-economic scenarios are used.



From the perspective of the above goals, two features of the scenarios process are important benefits:

- Key to this process is that policy and investment guidance using the scenarios will be done in a highly participatory fashion in which the decision-makers and investors themselves create ownership with the scenarios and use them to renegotiate plans and priorities, rather than CCAFS coming in as outside experts. Therefore, proposals for

investment and policy change will come from the relevant decision-makers and investments themselves and have a high likelihood of being implemented, especially because CCAFS will help with the facilitation of these changes.

- The proposals that decision makers and investors generate will provide specific engagement points for research by CCAFS and its partners in the sub-region to provide scientific support and recommend innovations and adaptation options. This happens in a demand-driven fashion based on the priorities identified by decision-makers and investors through the scenarios process.

Using the CCAFS West Africa scenarios

In several projects, the CCAFS West Africa scenarios have been put to use. Two examples are described in this section: The scenarios were utilized in a multi-level policy development process focused on climate adaptation in Ghana, as well as the scenario-guided review process of the National Program for the Rural Sector in Burkina Faso.

In Ghana, a project called Multi-level Integrated Adaptation Governance (MIAG) was initiated in 2014 as part of the CCAFS Systemic Integrated Adaptation (SIA) Program. Taking a multi-level approach, this project's objective was to improve efficiency and effectiveness of climate adaptation efforts in Ghana. Actors from the national, regional, district and village level were invited to a workshop in Accra, Ghana that took place in April 2014. During this workshop they developed adaptation plans for all of these levels. The next step was to downscale of the CCAFS West Africa to fit the contexts the respective levels. Subsequently, these downscaled scenarios were used to review the plans, by facilitating an understanding of the factors that may pose challenges to local development such as population growth, urbanization, and government policies, and thereby providing recommendations to make them more robust (Helfgott et al., 2014).

In Burkina Faso, several centers of the CGIAR group (CIFOR[1], ICRAF[2], ICRISAT[3], IWMI[4] and ILRI[5]) implement research under the following CRPs: Forests, Trees and Agroforestry

[1] Center for International Forestry Research

[2] World Agroforestry Center

[3] International Crop Research Institute for Semi-Arid Tropics

[4] International Water Management Institute

[5] International Livestock Research Institute

(FTA), Water, Land and Ecosystems (WLE) Climate Change, Agriculture and Food Security (CCAFS) and Dryland Systems.

Since 2013, these CRPs undertook a joint initiative to tackle the twin challenges to more effectively coordinate their interventions in Burkina Faso and to demonstrate the contribution of their research to the development goals set by the Government of Burkina Faso for the rural sector.

As a part of this project, a workshop was organized focusing on the revision of the National Program for the Rural Sector, or *Programme National du Secteur Rural* (PNSR) in French. This workshop took place in July 2015, in Ouagadougou, Burkina Faso. The workshop participants were representatives of the government, CGIAR research centers, civil society organisations and the (rural) private sector. The workshop process was aimed at examining the policy in the context of multiple socio-economic and climate scenarios (downscaled versions of the CCAFS West Africa scenarios), to improve the policy's robustness, flexibility and feasibility in the face of these diverse futures. In addition, the joint initiative of the CRPs FTA, CCAFS, WLE and Dryland Systems was linked to this process: workshop participants identified how CGIAR research can contribute to strengthening the PNSR. This scenario-guided policy development process is unique as it brings together CGIAR experts and national policy making experts, and links policy formulation directly to research (Rutting et al., 2015).

Scenarios

In the following section we present a summary of the four plausible scenarios for the future socioeconomic development of Western Africa. The four scenarios are derived from two key uncertainties in the region, the actors driving change within the region (state and non-state actors) and the time priority of policies (short-term and long-term). In Appendix B, the longer narratives are presented.

Cash, Control & Calories

A scenario about short-term priorities with state actors as the dominant force in West Africa to 2050

Figure 8 Cash, Control & Calories

Summary:

This scenario sees governments playing a strong role in governing West Africa's food security and livelihoods, following from an ultimately successful intervention of regional militaries to stabilize Mali in the 2010s. However, short-termism drives government policies. Governments are more focused on urban social stability and security than rural lives. Quick fixes and fast gains and cash get priority. Quantity is emphasized before quality. The disregard of rural food security eventually leads to increases in the need for food aid and external safety nets such as urban to rural cash flows. Governments become very adept at mobilizing foreign aid money. Commercial, monoculture agriculture is implemented widely leading to environmental degradation and conflicts between agriculturalists and pastoralists. Resource mining for quick food production has destructive long-term effects. Regional integration plans do not last, and the lack of regional policies means that water conflicts occur regularly. On the other hand, vigorous efforts are made to follow the Millennium Development Goals through mass education and decentralization of power.

Mali, an unfolding example of state-led C^3 prioritization?

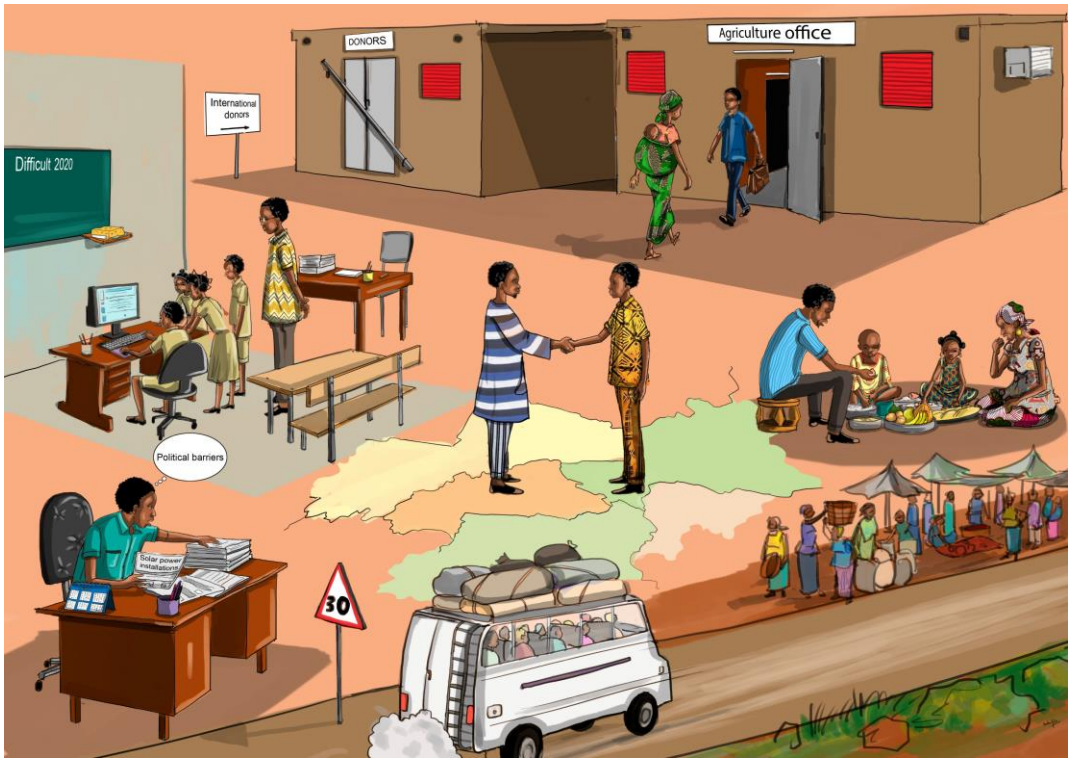
Mali, marked by conflict in the 2010s, provides a characteristic example of the "Cash, Control, Calories" direction that West Africa has taken:

- A trigger event (Libya) led to a democracy growth crisis
- Initially, there is vigorous effort at reaching Millennium Development Goals: mass education, decentralization – but these efforts clash with security concerns.
- Mali eventually develops enhanced capacity to attract funding to improve food security and energy supply, arguing for a "Marshall Plan for West Africa".
- But there is a lack of consistent long-term visioning & strategy in some key secular areas (such as education and security).
- The quality of education & management capacity remains reduced.
- There are growing (social, geographical) inequities in access to resources.
- Social tension and conflicts contribute to macro-level vulnerability.
- Food aid is needed to support vulnerable communities who are suffering from a domino effect of delayed development and sub-par crop yields.

Self-determination

A scenario where state actors are dominant and long-term priorities prevail in West Africa up to 2050

Figure 9 Self-Determination



Summary:

This scenario explores a future that is characterized by a slow, difficult, uncertain and often painful transition to sustainable governance of food security, environments and livelihoods. Governments, emerging out of a period of uncertainty to relative stability and a successfully moderated regional military intervention in Mali, drive the change through regional collaboration, better tools for effective government and a focus on and longer-term investment into infrastructure and access to markets for rural populations, education and direct investments into agriculture. All of this has to be done on a small budget because donor funds have declined after the region's drive to *Self-Determination* has resulted in international disputes about outside influence. By 2030, a measure of regional food self-sufficiency has been achieved by West African countries. However, agricultural intensification has a negative impact on rural employment. Also, increased agricultural productivity and extended land use have impacts on water availability and quality which produces challenges for the region's developments

Civil Society to the Rescue?

A scenario where non-state actors are dominant and long-term issues have priority.

Figure 10 Civil Society at the Rescue?

Summary:

This is a scenario where active private sector interests aiming for the large-scale commercial development of West Africa vie for influence with vibrant and powerful civil society organizations and NGOs who focus on a more community-oriented, sustainable future. Civil society in West Africa had first realised its strength by successfully leveraging its global partners to help ensure that extra-regional military interventions in Mali would be humanitarian rather than destructive. This powerful civil society and the private sector collaborate as well as compete for influence, often for the better, for instance contributing to improved livelihoods and knowledge for rural communities. However, tensions arise around issues of land ownership, and here rural people are caught in the middle, though more empowered to play an active role in governance than was possible in previous decades. Gender relations have changed and amid the other tensions this transition has been a challenging one. Food security on the whole has improved through a combination of commercial investment in regional food systems which has raised urban food security and an increasing professionalization of relatively small-scale farmers. However, uncertainty around the control of land and resources has threatened the stability of incomes for rural communities.

Save Yourself

A scenario where non-state actors are the driving force and short-term priorities dominate in West Africa by 2050

Figure 11 Save Yourself

Summary:

In this scenario, where non-state actors are the driving force of change, governments are passive, corrupt and unstable, playing a facilitating role for the short-term oriented, extractive actions of the private sector, while civil society organizations focus almost exclusively on emergency issues and longer-term development objectives are not part of societal debates. Extra-regional interventions to try and stabilize Mali have failed and instead led to great regional unrest. Hyper-liberal market policies have led to an increasing diversity of available food for the urban middle class, while at the same time the rural poor are highly food insecure due to the fiercely expansive presence of commercial agriculture. Rural livelihoods are decreasing and there are massive movements to urban areas in search of work, ungoverned by national governments. Environmental health has suffered greatly from a lack of policy in this domain and the scramble for new rural sources of livelihood.

Semi-Quantitative Indicators

In the development of the scenarios, narratives are not the only way to elaborate on scenarios. In addition to the development of scenario narratives, a semi-quantitative assessment of key indicators was conducted. This set of indicators representing the scope of interest for food security, environments and livelihoods was generated by participants. They subsequently indicated what they thought were the directions and magnitudes of change for each indicator over multiple time steps, and provided the logic for these changes from respective scenario. In this way, each of the four scenarios was quantified.

The following indicators were outlined on a scale of -3 to +3 using descriptions of the logic for change:

- GDP
- corruption
- political stability
- infrastructure development
- urbanization
- yields for rain-fed crops
- yields for irrigated crops
- area for rain-fed arable land
- area for irrigated arable land
- livestock numbers
- livestock yields
- agricultural input costs
- nutrition
- dietary diversity
- poverty
- equity
- access to health care
- forest cover change
- biodiversity

The semi-quantitative assessments of change conducted by stakeholders provide information on the scenarios that can be translated into assumptions to be used as drivers for the quantitative model scenario, which will be presented in the following section. Some of the indicators, such as changes in GDP growth, improvements in crop and livestock yields, and input costs were directly translated into values to be used as drivers within the quantitative models. Others such as changes in cropland area and level of deforestation, are final outputs

of the model simulations and have been examined in the context of the semi-quantitative indicators to improve the consistency of the scenarios. The details of the semi-quantitative indicators for each scenario can be found in Appendix C.

Western Africa Quantitative Regional Scenarios

When quantified with global partial-equilibrium models, the scenarios provide additional insight to region, as well as offer context for the impact of global developments on the region. Illustrating the narratives with numbers gives prospective users more detailed information, by which the scenarios can be compared to one another more adequately, and that can be applied in the testing of policies and research recommendations. Additionally, 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. 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.

The quantification of the scenarios has two parts. The first part of the quantification involves interpretation of the semi-quantitative indicators and logic for change in each scenario into number values to be used as drivers in the model. The second part of the quantification involves including the factors of change for each scenario into both models and solving the model over the time period. This process has been well documented in the working paper by Palazzo et al. (2014). The drivers for this quantification, population, GDP, technological improvements in crop and livestock yields, farm input costs and others were discussed with the scenario developers and then linked to the SSP scenario elements (Dellink, Chateau, Lanzi, & Magné, 2015; Kc & Lutz, 2014; O'Neill et al., 2014; O'Neill, Kriegler, Ebi, Kemp-Benedict, et al., 2015) for the region. We have translated the semi-quantitative indicators into model drivers by using the socioeconomic drivers of the SSPs as a starting point for CCAFS scenarios and made a critical comparison between the stakeholder-generated scenarios and the SSPs. The model quantification results are then examined for consistency with the scenarios storylines as developed by the stakeholders. In the following section we present the quantitative regional scenarios for Western Africa, first as the numerical socioeconomic

drivers of change used by both models and second as the modelling results for agricultural production, food security, land use, and environmental impacts over the time period 2000-2050.

GLOBIOM and IMPACT

The scenarios were quantified using two agricultural partial-equilibrium economic models, each with different assumptions – GLOBIOM (Havlík et al., 2014), developed by the International Institute for Applied Systems Analysis (IIASA) and IMPACT (Robinson et al., 2015) developed by the International Food Policy Research Institute (IFPRI). The features of both models are presented in Table 1.

Table 1 GLOBIOM and IMPACT comparison

	GLOBIOM	IMPACT
Economic Sector	Agriculture sector including crops, livestock, bioenergy, and forestry	Agriculture sector including crops, ag. processing, and livestock
Time Horizon	2000–2050/2100	2005-2050
Role of Markets	Regional markets linked through global markets determine supply and demand	Global markets determine supply and demand
Geography	Global representing 30 country/regions	Global representing 159 country/regions
Resolution of Production side	Bottom-up approach at detailed gird-cell level (>10,000 worldwide) (4 crop production systems and 8 livestock production systems)	320 food production units (intersection of national and hydrological boundaries) (2 crop production systems and 8 livestock production systems)
Commodities	30 agricultural commodities (18 crops, 5 forest products, 7 livestock products, 9 bioenergy products)	60 agricultural commodities (39 crops, 6 livestock, 15 processed goods)
Environment	GHG accounting, irrigation water use, and endogenous land-use change	Hydrology, water basin management of irrigation water, exogenous and endogenous cropland area expansion
Climate Change	Represented by EPIC crop model	Represented by DSSAT crop models and linked hydrology models

Source: Authors

GLOBIOM and IMPACT have a significant focus on the agriculture sector to varying degrees of spatial disaggregation and consider the demand and use of products for food, livestock feed, bioenergy, and process production. GLOBIOM and IMPACT use the underlying assumptions of relationships between supply and demand of products at the initial year of the time period (2000 for GLOBIOM, 2005 for IMPACT) and examine how changes in certain model drivers change the relationship in the future. The representation of trade between the two models offer a significant difference as GLOBIOM employs a spatial equilibrium approach and considers regional trade based on bilateral trade policies and barriers and transportation costs and the relative cost competitiveness of homogenous goods (Takayama and Judge 1971; Schneider et al 2007), whereas IMPACT assumes that country markets are linked to global markets through perfect price transmission. Using a multi-model approach, while allowing one model to serve as the representative, or "marker" model for the

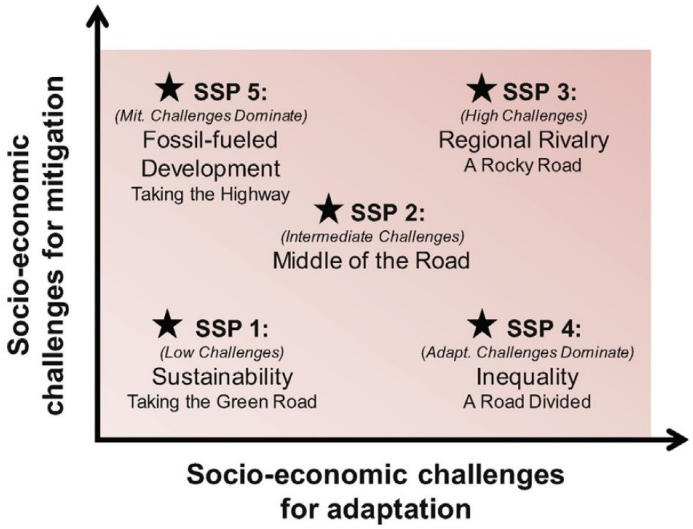
region similar to the Marker Scenario SSP model interpretation, allows us to utilize the strengths of both models while addressing the uncertainty of the scenarios. For the quantification of the scenarios in Eastern and Western Africa and South Asia, GLOBIOM will act as the "marker" model, while IMPACT will represent the scenarios for Southeast Asia, Central America, and the Andes. To include the scenario semi-quantitative indicators as inputs for the IMPACT and GLOBIOM models, indicators were given numerical values, using the socioeconomic drivers of the shared socioeconomic pathways (SSPs) as a starting point which is further discussed in the section called "Linking SSPs and CCAFS scenarios".

Shared Socioeconomic Pathways (SSPs)

The global scenarios developed by the IPCC community that combine emissions scenarios (Representative Concentration Pathways; RCPs) and socio-economic and policy scenarios (Shared Socio-economic Pathways; SSPs, and Shared Policy Assumptions; SPAs) (O'Neill et al., 2014) contrast the previous set of global change scenarios, the SRES (Nakicenovic et al., 2000), that combined assumptions on socio-economic development with assumptions on emissions in a time-consuming, consecutive process (Zurek & Henrichs, 2007). The new process has allowed the global climate models (GCMs) and integrated assessment models (IAM) to work in parallel with the RCPs, speeding up the interactions between the modelling communities as well as improving the final product, a quantified assessment of plausible future development that considers the impact, the role and challenges of adaptation to and mitigation of the effects of climate change (O'Neill et al., 2014). The framework to develop the scenarios has been thoroughly documented (Müller & Robertson, 2014; O'Neill et al., 2014; Schweizer & O'Neill, 2013; van Vuuren et al., 2013), linked to previous scenario assessments (van Vuuren & Carter, 2013), and are beginning to be scrutinized through a national (Absar & Preston, 2015) and human impact (Hasegawa, Fujimori, Takahashi, & Masui, 2015) lens. The purpose of this paper is not to explore the process by which the integrated scenarios were created but instead to explore their usefulness in addressing the uncertainty of future development as tool to build a consistent regional context. This regional context serves to assist policy makers in developing robust climate adaptation plans and strategies but also provides the scientific community working at the regional, national, and sub-national scale with multiple pathways for development, of the agriculture sector in particular, that can be disaggregated or linked to adaptation assessments (Antle et al., 2015; Kihara et al., 2015; Valdivia et al., 2015). As the concept of the SSP is vital to this purpose, it

serves to present a summary of the narratives here. Rather than using two drivers of uncertainty, as many future scenarios processes have considered (Nakicenovic et al., 2000; Vervoort et al., 2014), these scenarios were built on two-axis, mitigation and adaptation, where the outcome, or level of, challenge are the end points of each axis (high and low challenges) and the combination of these define "challenge space" of the scenario (O'Neill et al., 2014) and are presented in Figure 12. The combination of challenges from which scenarios emerged were then constructed by identifying the drivers of the challenge outcomes such as population and urbanization (Jiang & O'Neill, 2015; Kc & Lutz, 2014) and economic growth (Crespo Cuaresma, 2015; Dellink et al., 2015; Leimbach, Kriegler, Roming, & Schwanitz, 2015) and building a rich narrative of each pathway using the quantitative and semi-quantitative drivers (O'Neill, Kriegler, Ebi, Kemp-Benedict, et al., 2015). The SSPs, as they focus globally and offer a long-term focus that exceeds the regional scenario time horizon of 2050, are generally more optimistic than the regional scenarios and fail to capture some of the uncertainty around governance and political stability that are captured by the regional scenarios as they pose a challenge for development in Western Africa.

Figure 12 Five Shared Socio-economic Pathways (SSPs) and each SSPs' representation of challenges to adaptation to mitigation.



Source: O'Neill, Kriegler, Ebi, Kemp-Benedict, et al., 2015

Representative Agricultural Pathways

The challenges to study global scenarios of climate impacts and socioeconomic development or compare the sector specific pathways of modelling assessments are numerous. The

challenge is to, on one hand, integrate and model the key factors of change such as emissions, climate forcing, agricultural development and land use change, and human development, and on the other hand, to address the issue of uncertainty using a multi-model, multi-scale approach. Agriculture continues to remain an important source for income in many regions in the world and how it will develop in the future will have significant impacts on the food security as well as the environment. Increasingly connected markets, socioeconomic development, and future climate uncertainty and vulnerability serve as a motivation for developing appropriate trends for agricultural development, known as "representative agricultural pathways" (RAPs) for each SSPs (O'Neill, Kriegler, Ebi, Kemp-Benedict, et al., 2015).

Wilbanks and Ebi (2013) highlight the challenges of long-term projections in impact, adaptation and vulnerability (IAV) research to consider quantitative modelling for small geographic regions. Linking the global pathways, for any sector but for the agricultural sector, to the sub-global, sub-continental, or national pathways is a meaningful way to disaggregate and maintain consistency and plausibility (Valdivia et al., 2015; Zurek & Henrichs, 2007). National and subnational impact assessments that represent farm systems and households of small geographic units often require a globally-consistent market equilibria for commodities, which are produced by global or regional economic models. (Valdivia et al., 2015). Additionally, drivers of the development of region at local levels can influence the adoption of soil and water conservation practices. (Sietz & Van Dijk, 2015).

The AgMIP community has worked to understand the differences in global and local modelling strategies of the agricultural sector (Antle, Stoorvogel, Valdivia, & B, 2014; Kihara et al., 2015; Nelson, Valin, et al., 2014). In terms of providing plausible future agricultural pathways, an effort was undertaken to examine global economic modelling approaches using common drivers for biophysical effects from climate change and socioeconomic effects as part of the AgMIP Project (Lotze-Campen et al., 2014; Nelson & Shively, 2014; Nelson, van der Mensbrugghe, et al., 2014; Robinson et al., 2014; Schmitz et al., 2014; Valin et al., 2014; von Lampe et al., 2014). Two of the global economic models participating in the AgMIP exercise, GLOBIOM and IMPACT have also been used quantify the regional scenarios.

Using the unique link between the CCAFS regional scenarios developed with stakeholders and quantified by economic models in the plausibility space of the SSPs, we can offer

regionally appropriate and climate independent regional RAPs. To some extent, field level and subnational economic impact analysis has begun to integrate the agricultural technology trends from global economic models (Antle et al., 2015). Outputs from GLOBIOM may prove useful in providing inputs for field level modelling of regional representational agricultural pathway because it considers multiple management systems, or *technologies*, the biophysical environment of production, or *climates*, and the *socioeconomic* context of the region (Antle et al., 2015). IMPACT has a long history of providing global trends for commodities, and recent modelling improvements have expanded its relevance to include nearly all statistically surveyed commodities. As global models, GLOBIOM and IMPACT cover the future development of, not only the region, but of the rest of the world creating globally-consistent regional scenarios.

Parallel process

Although the CCAFS regional scenarios development process has focused its objectives around policy engagement and planning, facilitators of the process have been participants of the SSP development community (REF). In particular, IIASA has been an active member of the SSP development process, first through the development of the scenarios and their narratives (O'Neill et al., 2014; O'Neill, Kriegler, Ebi, Kemp-Benedict, et al., 2015), and then by modelling the future economic and demographic quantitative change for each pathway (Kc & Lutz, 2014) needed for integrated-assessment models (IAM). As such, it is follows that since the SSPs and the CCAFS scenarios have moved in a parallel direction in terms of scenarios development *process*: participatory, end-state oriented (O'Neill et al., 2014; Vervoort et al., 2014); *focus*: socio-economic development with an uncertainty of future climate leading to challenges for adaption; and consistent sources for quantitative drivers of future change (Herrero, Havlik, McIntire, Palazzo, & Valin, 2014; O'Neill, Kriegler, Ebi, Kemp-Benedict, et al., 2015; Vervoort et al., 2014; Zurek & Henrichs, 2007), that the the scenarios can be linked in a practical way. We have followed Van Ruijven et al (2014) suggested methods for downscaling and using the global SSPs for regional impact, adaptation, and vulnerability (IAV) studies which include using the SSPs as a boundary condition and developing nested regional storylines that would be internally consistent within the global framework. In the sections that follow we present the outcomes of the downscaling of SSPs within the regionally appropriate storylines of the CCAFS scenarios.

Linking SSPs and CCAFS scenarios

The quantitative drivers for the SSPs can be used as a plausibility envelope for generating the initial set of drivers to be tailored to use for modelling context for the CCAFS regional scenarios. As a first step it is necessary to find commonality in the narratives and semi-quantitative indicators in both scenarios exercises. A comparison of the semi-quantitative indicators for the CCAFS regional scenarios and those of the SSPs, can find an overlap that allows the authors of this paper to make a mapping of the regional scenarios in the context of the SSPs space. KC and Lutz (2014) differentiate population growth of countries within SSP storylines using fertility rates: low fertility, rich OECD, and high fertility; which 14 of the 15 Western African belong. The SSP narratives also consider the assumptions for the development pathways between the low, middle and high income countries according to the World Bank Classification.

Historically, nearly all of the countries in the ECOWAS region of Western African have been categorized as low income countries, and for the GDP projections of the SSPs all of the countries in Western Africa were placed in the low income country group (Crespo Cuaresma, 2015; Dellink et al., 2015; Leimbach et al., 2015).

We examined the scenario indicators to determine to what extent the scenarios were coherent across scales (Zurek & Henrichs, 2007). As a first step, it is important to match what is contained within the scenario narratives and the semi-quantitative indicators. The CCAFS indicators in some cases, mapped quite easily to the SSP indicators (Table 3 and figure 13), such as “gross domestic product” and “growth per capita”, “population growth and urbanization” and “urbanization”, and “dietary diversity” and “consumption and diets”, from the CCAFS scenarios and SSP scenarios, respectively (O’Neill, Kriegler, Ebi, Kemp-Benedict, et al., 2015).

Table 2 Semi-quantitative Indicators of Interest for West Africa Scenarios Stakeholders

Demographics/Human Development	Economy & Lifestyle/ Policies & Institutions	Environment and Natural Resources/ Technology
Population Growth/Urbanization[+, *]	Gross Domestic Product[+, *]	Terrestrial species biodiversity indicator[+, *]
Women with higher education*	Percent population in poverty*	Marine species biodiversity indicator *
Access to health care*	Dietary Diversity[++, *]	Forest cover[++, *]
Access to potable water*	Farmer input prices[+]	Yields for rainfed crops[+, *]
Equity*	Transportation infrastructure	Yields for irrigated crops[+, *]
Prevalence of malaria*	Existence of social protection schemes; percent population covered *	Area for rainfed arable land[++, *]
	Number of community based organizations *	Area for irrigated arable land[++, *]
	Corruption index *	Livestock yield change[+, *]
	Crime rates	Livestock numbers[++]
	Reports of contaminated food/ food borne diseases; aflatoxins *	Water Availability for Agriculture[++, *]

+ indicates this indicator was translated from semi-quantitative information into values used as a model input

++ indicates that this indicator is was evaluated in the context as a model output

* indicates that this indicator aligns to a qualitative element of the SSPs (O'Neill, Kriegler, Ebi, Kemp-Benedict, et al., 2015)

Note: The table shows which indicators are an input or model output and have been grouped into categories consistent with those presented by O'Neill et al (2015), also noted are indicators, such as GDP and population growth, further mapped The quantification process of the regional scenarios has two parts: interpretation of the stakeholder semi-quantitative indicators, into numerical values to be used as drivers in both models; and then running the models over the time period with the drivers for each scenario and examining the model results for consistency using the scenarios storylines and the semi-quantitative indicators.

Table 3 elaborates on how we have mapped the CCAFS scenarios indicators with SSP indicators. The first column presents the CCAFS semi-quantitative indicators. The second, third, and fourth columns present the SSP indicators that can be linked to the CCAFS semi-quantitative indicators. Each column represents a separate grouping of indicators from O'Neill et al. (2015). Colors have been added for the SSP indictors that map to multiple CCAFS indicators. In many cases the CCAFS scenarios provide a more detailed regional representation of the region than the SSPs by providing multiple indicators for a single SSP indicator.

Table 3 Mapping of CCAFS semi-quantitative indicators and SSP indicators

Semi-Quantitative Indicators	Demographics Human Development	Economy & Lifestyle Policies & Institutions	Environmental & Natural Resources Technology
Population Growth/Urbanization	Population growth Urbanization Level Urbanization Type		
Women with higher education	Education Gender equality		
Access to health care	Access to health facilities, water, sanitation		
Access to potable water	Access to health facilities, water, sanitation		
Equity	Equity		
Prevalence of malaria	Health investments Access to health facilities, water, sanitation		
Gross Domestic Product		Growth (per capita)	
Percent population in poverty		Inequality	
Dietary diversity		Consumption and Diet	
Farmer input prices		International Trade	Agriculture
Transportation infrastructure		International Trade Institutions	
Existence of social protection schemes; percent population covered		Institutions	
Number of community based organizations	Societal Participation	Institutions	
Corruption index		Institutions	
Crime rates		Institutions	
Reports of contaminated food/ food borne diseases; aflatoxins	Access to health facilities, water, sanitation	Institutions	
Terrestrial species biodiversity indicator		Environmental policy	Environment
Marine species biodiversity indicator		Environmental policy	Environment
Forest cover			Land Use
Livestock yields and numbers			Agriculture
Yields for rainfed/irrigated crops			Agriculture
Area for rainfed/irrigated arable land			Agriculture Land Use
Water availability for agriculture			Agriculture Land Use Environment

Source: O'Neill et al. 2015

For example, “access to health care”, “access to potable water”, and “prevalence of malaria” fall under the “access to health facilities, water, and sanitation” indicator from the narrative elaboration of the SSPs (O’Neill, Kriegler, Ebi, Kemp-Benedict, et al., 2015). Even though access to health care is not an indicator that can be quantitatively examined in the modelling of the scenarios it is still useful to use for mapping purposes which are presented in Figure 13. The CCAFS scenario is given in Column A, the CCAFS semi-quantified indicator is found in column B. Column I contains the SSP name that corresponds 1 to 1 with the CCAFS scenario and the SSP indicator to compare is in Column L. The qualitative information for each indicator of each SSP is taken from O’Neill et al. (2015) and appears in Column M. We have added color to the qualitative information of each indicator based on how well the narrative/indicator of each SSP fits with the narrative/indicator of each CCAFS scenario. Green indicates a “good match”, yellow indicates a “neutral match”, and red indicates a “bad match”.

For *Save Yourself, SSP3: Fragmentation* matches well in that both scenarios assume low access to health care, however access to potable water improves, though not dramatically, due to profit-driven investments, which is not in line with SSP qualitative information. *Self-Determination* and *Civil Society to the Rescue?* also match to their SSP well as they both describe improvements to the access to health care and potable water, high (*SSP1: Sustainability*) and medium (*SSP2: Middle of the Road*) access, respectively. However, *Cash, Control, Calories* does not map as well because the CCAFS narrative describes an improving, but unstable future where some strides are made to improve access but the system is still overwhelmed by the growing population, whereas *SSP 5: Conventional Development* sees a future with high access to health care and sanitation. We have flagged this mis-mapping as “neutral”, because it neither supports a good match to the SSP nor supports a bad match to this SSP.

The scenario insights into the prevalence of malaria in the region are complicated to map directly to the SSP indicators for access to health care and sanitation because prevention of malaria relies on not only investments in water and sanitation infrastructure to limit mosquito breeding, but also access to and use of preventative measures such as mosquito nets. In *Civil Society to the Rescue?,* action to reduce the prevalence of malaria begins quickly and continues over the entire period due to the actions of the CSOs in deploying mosquito nets, an effective action that cannot be captured within the SSP indicators, while in *Self-*

Determination actions by the state to improve water infrastructures and sanitation improve the incidence, albeit later in the period. We view the mis-mappings of the SSP indicators for health investments and access to health care and sanitation with CCAFS scenario indicator for malaria as an important message from the regional stakeholders that improving livelihoods requires engagement from multiple institutions as well as scientific and culture understanding of the multiple challenges to and solutions for a problem as complicated as the prevention and treatment of malaria.

Figure 13 Comparison of the CCAFS semi-quantitative indicators of access to health care (top four lines, left columns A-G), access to potable water (middle four lines, left columns A-G) and prevalence of malaria bottom four lines, left columns A-G) with the SSP indicator access to health facilities, water, and sanitation. Colors are added based on how well the narrative/indicator of each SSP fits with the narrative/indicator of each CCAFS scenario: green indicates a "good match", yellow indicates a "neutral match", and red indicates a "bad match". Note also that prevalence of malaria is also mapped to the SSP indicator for health investments.

A	B	C	D	E	F	G	I	L	M	O	P
Scenario	**Indicator**	**2010–2020**	**2020–2030**	**Logic for change**	**2030–2050**	**Logic for change**	**SSP map**	**SSP ind map 1**	**SSP qualitative information**	**SSP ind map 2**	**SSP qualitative information**
Cash, Control, Calories	Access to health care	=	+	Government and private sector investments are limited, knowledge capacity limited, slow, quality questionable	+	Trend continues; population overwhelms available health care; capacity to deal with some emergencies does exist; governments can leverage donor funds well.	SSP5	Access to health facilities, water, sanitation	High		
Self-Determination		+	+	Slow improvement through government policies	++	Institutional, knowledge and technical capacity have	SSP1		High		
Civil Society to the Rescue?		=	+	CSOs not best equipped to deploy health care infrastructure; private sector invests but not available for the poorest	+	Technology increases health care for middle and upper classes, but not for poorest – tech still costs money	SSP2		Medium		
Save Yourself		-	-	Prices too high, street medicine, fake medicaments	-	New technologies available but these do not reach the majority	SSP3		Low		
Cash, Control, Calories	Access to potable water	+	+	Government investment, focusing on a short-term issue; debate for privatization will be high	=	Failure of long-term insight into population growth	SSP5	Access to health facilities, water, sanitation	High		
Self-Determination		+	++	Access for whom? Government willingness, but limiting factors are technology, pollution	++	Investment in infrastructure; pressure from population; pollution by irrigated agriculture; climate change	SSP1		High		
Civil Society to the Rescue?		-	+	Private and civil society intervention and collaboration	+	Technology increases, but population pressures and CC impacts also increase	SSP2		Medium		
Save Yourself		=	+	Some investment when profits can be made	+	Water is available when profitable	SSP3		Low		
Cash, Control, Calories	Prevalence of malaria	+	+	Shame related to disease – sanitation issues due to increasing population	+	Governments are able to cure but not prevent	SSP5	Access to health facilities, water, sanitation	High	Health investments	High
Self-Determination		+	+	No change at first	--	Vaccine supported by government policy; education; better water infrastructure; sanitation	SSP1		High		High
Civil Society to the Rescue?		-	-	easily deployable technology by CSOs (impregnated mosquito nets etc.)	---	Vaccine available – but not for everybody	SSP2		Medium		Medium
Save Yourself		++	++	Moderated by non-state, environment-borne diseases, lack of infrastructure/facilities to reach sick	++	Civil society slightly better at dealing with outbreaks but largely continues	SSP3		Low		Low

Additionally, the CCAFS scenarios consider the impacts of food safety in the region which reflect the strength of institutions to monitor food production system as well as home access to prepare, consume, and store safe and healthy food, which falls outside the scope of focus for the SSP narratives (O'Neill, Kriegler, Ebi, Kemp-Benedict, et al., 2015). Although the impacts of food safety are not modelled by GLOBIOM or IMPACT, the richness of the narratives has helped in the downscaled scenarios workshops such as the Ghana Institute of Management and Public Administration (GIMPA) in July 2014 which highlighted the current functional and non-functional connections between basic nutrition and education among other things, and how the scenarios would play out on regional, national, district, and village scales.

In the following four paragraphs we offer our translation of the CCAFS scenarios to the SSP scenarios.

Self-Determination, is a scenario where strong state actors focus on long-term issues, semi-quantitative indicators align closely with the *SSP1: Sustainability*, in nearly all qualitative elements describing the SSP narrative, such as investments in productivity and extension services, increased education and health and sanitation services, regulations to reduce deforestation, and effective social protection schemes.

The scenario is not entirely coherent with the SSP narrative on land use because the CCAFS scenario assumes that the progress to avoid deforestation takes time and improved productivity in the agriculture sector could have environmental impacts through increased fertilizer use. The CCAFS scenarios also highlight the struggle for institutional change opening up the opportunity for corruption, which is inconsistent with *SSP1* where strong institutions are effective at the national and international levels.

Save Yourself is a scenario where action is not taken by the weak and unstable governments, but by CSOs in an emergency response manner and the private sector acting with short-term profitability interests, mirroring the low-income country narrative of *SSP4: Inequality* and the overall global narrative of *SSP3: Regional Rivalry*. This scenario sees low technology development for the agriculture sector (with investments limited to export crops or large scale industrial farming), widespread environmental degradation and deforestation due to lack of regulation and enforcement, and health and food security issues due to growing inequality and high population growth.

Civil Society to the Rescue? is a scenario where weak governments are replaced with strong CSOs tackling food security with a long-term focus, is most closely represented by SSP2: Middle of the Road. Some actions for protection lead to a decline in deforestation rates, but modest productivity and commercialization benefits fall to those who already have capacity rather than inducing a transformation of small-holders, and moderate increases in education and health issues are largely taken up by CSOs.

The short-sighted prioritization of governments interested in maintaining power, within the *Cash, Control, Calories* scenario, create an highly urbanized, high economic growth, resource-intense diet scenario driving reactive and politically motivated investments in education and health services, (similar to *the SSP5: Fossil-fuelled Development*). The narrative for *SSP5*, global and long-term, relies on an underlying assumption about the availability and adoption of technology solutions for agriculture that within the narrative of *Cash, Control, Calories* is not available and limits the intra-regional cooperation to protect environment. The weaknesses of institutions, and the sputtering economic development within the region have created environmental challenges by 2050 that may not be captured entirely by the storyline of *SSP5*. However, O'Neill et al (2015) discuss the possibility that of actions taken within a development pathway may change the pathway and alter the challenges for adaptation or mitigation, which can be seen by the end of the time period in *Cash, Control, Calories*.

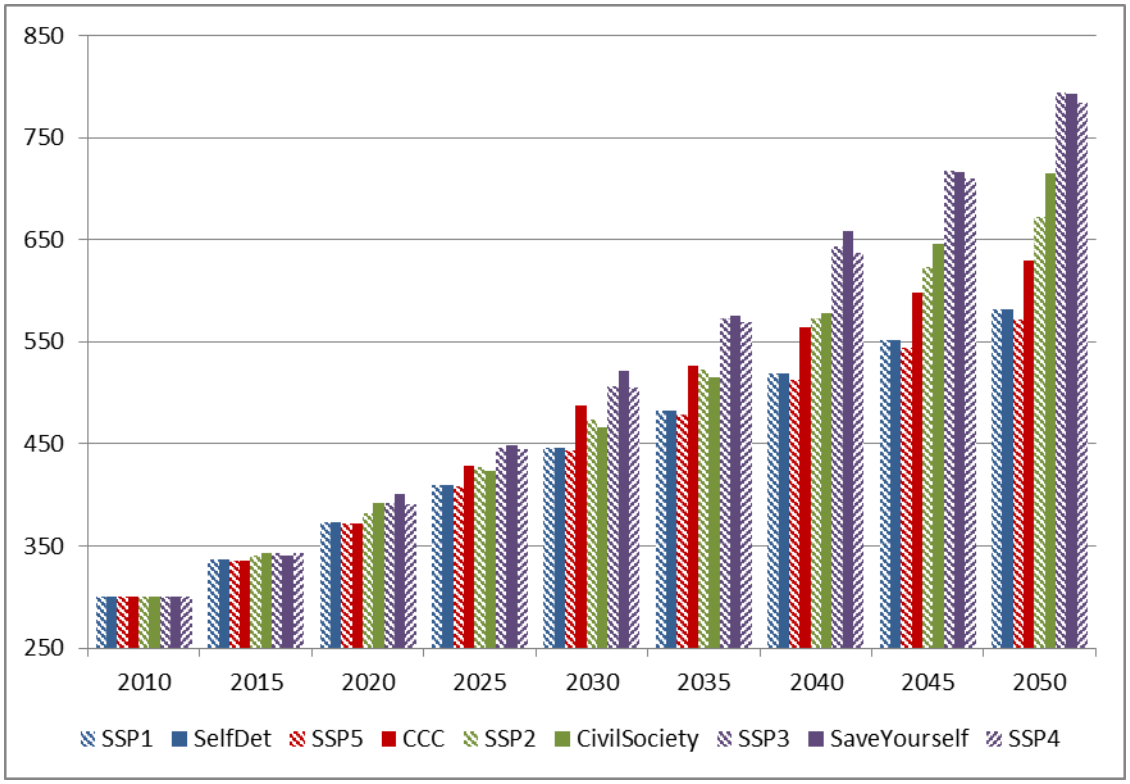
After thorough the linkage of the CCAFS scenarios with the SSP scenarios we present the drivers of the CCAFS scenarios used by in the economic models and then later revisit the semi-quantitative indicators when examining the model outputs to provide feedback for consistency in the narratives. For the SSP indicators that have been numerically quantified already, such as urbanization and population (Jiang & O'Neill, 2015; Kc & Lutz, 2014), economic growth (Crespo Cuaresma, 2015; Dellink et al., 2015; Leimbach et al., 2015), and the resulting transformation of the livestock sector (Herrero et al., 2014), were used as an envelope of plausibility and the regional values were adjusted to match the context of the CCAFS scenario.

Quantitative Regional Drivers

Socioeconomic Development: GDP and Population Growth

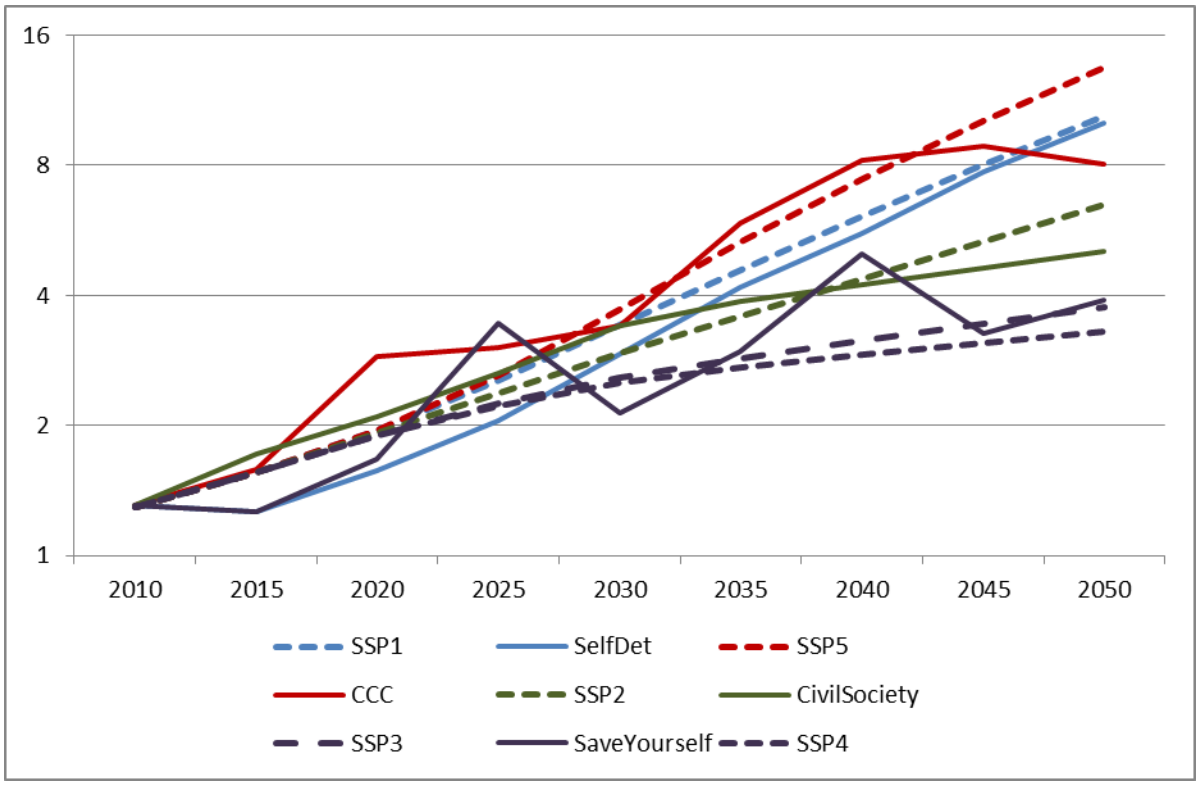
Economic development and population growth are essential elements in determining future demand of agricultural products within the modelling framework. To be used in the quantitative models, we considered the GDP and population projections to be linked due to the importance of the per capita income in food demand. We employed a "one-to-one" mapping system (Zurek & Henrichs, 2007) of the GDP per capita of the SSPs to the CCAFS scenarios. The SSPs, focused globally and under a longer-term perspective that exceeds the regional scenario time horizon of 2050, are generally more optimistic than the regional scenarios and fail to capture some of the uncertainty around governance and political stability that are captured by the regional scenarios as they pose a challenge for development in Western Africa. Therefore we used the scenario narratives, semi-quantitative indicators, including logic and direction of changes to relate and adjust the socioeconomic and demographic developments for the SSPs over the same time period as quantified by the SSP developers (Dellink et al., 2015; Kc & Lutz, 2014; O'Neill et al., 2014). Under these socioeconomic futures, in Western Africa, the population of the region grows from 300 million in 2010 to between almost 600 million (*Self-Determination* and *SSP1*) and 800 million (*Save Yourself*, *SSP3* and *SSP4*) (Figure 14).

Figure 14 Population of Western Africa in millions of people for the CCAFS scenarios and SSPs. Note that the axis begins at 250 million.



GDP per capita increases across all scenarios, but by 2050 all remain lower than the regional SSP projections. *Cash, Control, Calories* initially sees the largest increase, but its GDP development is unstable, and it begins to slow and actually declines slightly after 2040 – reflecting the short-termism of the scenario. Per capita GDP is highest in *Self-Determination* by 2050. *Civil Society to the Rescue?* experiences a steady and consistent increase in per capita GDP, albeit not a particularly large one over time. Per capita GDP in *Save Yourself* increases the least of the scenarios over the time period and follows cycles of growth and recession, which represents unstable economic development (Figure 15).

Figure 15 Relative change in GDP per capita 2000-2050 for the CCAFS scenarios and SSPs (2000=1) (note that the axis appears in a $\log_2$ scale for ease of viewing the values)
Note: for the scenario time horizon, GLOBIOM is run decennially while IMPACT is run annually.



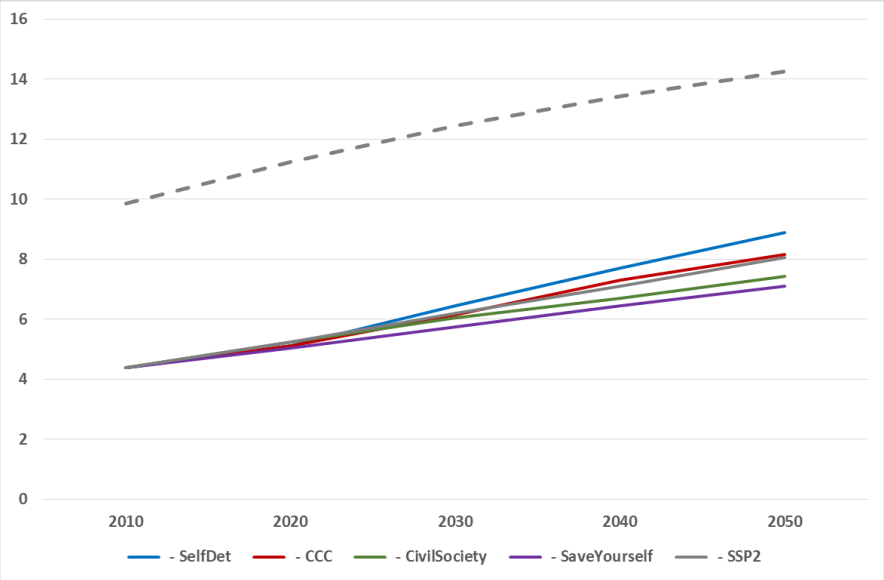
Agricultural Productivity: Crop and Livestock Yields

Crops

Technical progress in crop production is represented in both models through an increase in crop yields. As a starting point for the future projections of crop yields, we have used an econometric estimate of the relationship between crop yields and GDP per capita assumptions of the SSPs (Herrero et al., 2014). The crop yield projections, with the SSPs values being a starting point, consider the scenario narratives on agricultural productivity both for scenario-specific storylines as well as crop-specific productivity. The exogenous change this would have on domestically produced calories are presented in Figure 16 for the CCAFS scenarios and SSP2, for Western Africa as well as globally. Although these yields, being exogenous drivers and not model outputs, 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 between Western Africa and

the global average will remain a challenge for the agricultural system even in the scenario with the highest investment in agriculture, *Self-Determination.*

Figure 16 Aggregate Exogenous Crop Yields (gigacalories per ha) for Western Africa and global average: Global average is represented by the grey dashed line and Western Africa are the solid lines



Livestock

Sub-Saharan Africa has been the focus of a recent foresight study to examine the potential of the region to meet a growing demand for livestock products, through transitions from extensive land based systems to mixed crop-livestock systems and also yield improvements by feed utilization(Herrero et al., 2014). The suggested actions (intensifying pastoral systems while also protecting pastoralist and protecting animal health) echo those made in the West African assessment of livestock by the Sahel West African Club Secretariat and OCED (Kamuanga, Somada, Sanon, & Kagoné, 2008).

One measure of the future productivity of livestock is the conversion efficiency of livestock product per unit of feed. 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 and were further developed using the narratives and semi-quantitative drivers. The investment in ruminant production due to the growing demand as outlined in the scenario narratives result in a yield improvement in *Self-Determination*, while the focus of dairy production and monogastric production in the early decades of *Cash*,

Control, Calories is considered. In *Civil Society to the Rescue?* meat demand drives the investments from private sector and social entrepreneurs. Little investment is made for livestock or veterinary services in the *Save Yourself* scenario resulting in relatively insignificant yield improvements.

Biophysical Effects from Climate Change

West Africa is highly dependent on agriculture, predominantly rainfed agriculture, which at the mercy of a changing climate, making the region particularly vulnerable. The strictly biophysical impacts on crop production due to changes in climate have been examined extensively within the model intercomparison communities of AgMIP and ISI-MIP through globally-gridded crop models (Müller & Robertson, 2014). For Western Africa, the modelling of impacts through crop models as well as through empirical study find that the negative impacts of climate change on agriculture are robust, though the magnitude of impact remains uncertain (Müller, Cramer, Hare, & Lotze-Campen, 2011; Müller & Robertson, 2014; Müller, 2011; Roudier, Sultan, Quirion, & Berg, 2011; Sultan et al., 2013). These studies stress role of temperature change and of carbon fertilization in the region, and highlight the challenge to produce meaningful scientific projections from studies with significant methodological differences (Müller et al., 2011).

Integrating the impacts of biophysical effects from climate change on crop production and the economic implications within the global agricultural system, have been carried out using globally-gridded crop models and economic models, including GLOBIOM and IMPACT (Nelson, Valin, et al., 2014). The modelling community has not evaluated the climate effects on grassland productivity to the same extent as crop productivity (Wheeler & Reynolds, 2012), although these effect have been recently incorporated into GLOBIOM to understand the economic and land use implications (Havlík et al., 2015). Additionally, assessments of agriculture under future climate change have considered impacts of alternative adaptation strategies (Leclère et al., 2014) and the role of trade (Mosnier et al., 2014) using the GLOBIOM model. Expanding on the global climate and adaptation analysis of agriculture from Nelson et al (Nelson et al., 2010), which uses the IMPACT model to examine the effects of climate change under three global socio-economic futures, national level impacts the focus for three regions within Africa (Hachigonta, Sepo, Nelson, Gerald C., Thomas, Timothy S., & Sibanda, Lindiwe M., 2013; Jalloh, Nelson, Thomas, Zougmoré, & Roy-

Macauley, 2013; Waithaka, Michael, Nelson, Gerald C., Thomas, Timothy S., & Kyotalimye, Miriam, 2013).

IMPACT and GLOBIOM consider multiple general circulation models (GCMs) and different biophysical crop models to capture the uncertainty of the biophysical impacts of climate change on crop yields (see Table 4). Impacts are not limited to only the Western African region but applied globally using the relative changes in the globally-gridded crop models yields from 2000 (Nelson, Valin, et al., 2014; Nelson, van der Mensbrugghe, et al., 2014).

Table 4 Climate Scenarios

Representative Concentration Pathway	General Circulation Models	Crop Model Suite[1]	Crops[2]	Grassland	CO2 Fertilization
8.5	• GFDL-ESM2M • HadGEM2-ES • IPSL-CM5 • MIROC-ESM	EPIC	Barley, Dry Beans, Cassava, Chickpea, Maize, Cotton, Groundnut, Millet, Potato, Rapeseed, Rice, Soybeans, Sorghum, Sugarcane, Sunflower, Sweet Potato, and Wheat	Yes	Additional CO2 fertilization for both crops and grassland
		DSSAT	Groundnut, Maize, Potato, Rice, Sorghum, Soybean, and Wheat	No	CO2 fertilization at current levels
Constant climate	2000		Represented by each models' baseline assumptions without climate change		

Note: All GCM climate data comes from CMIP and ISI MIP (Taylor et al. 2012) and are downscaled for use in the crop models.

[1] The EPIC crop models are used by GLOBIOM, and the DSSAT crop models are used by IMPACT

[2] Crops represented in the economic models not covered by their respective crop model suite are mapped from the above crops based on biophysical similarities

Regional Integration: Production Costs

While the state and potential for economic integration within Africa and the ECOWAS community has been scrutinized and estimated (UNCTAD, 2012; United Nations, 2009); the effects of regional integration as it pertains to food security have also been examined by quantitative modelling (Dijk, 2011) The degree to which regional integration efforts are succeeding within agriculture highlight the challenges facing the region, where competing national interests and standards often clash with competing international donor initiatives (Rohrbach, Minde, & Howard, 2003).

Simson and Tang (2013) suggest that shocks in the agricultural supply chain, stemming from conflicts or climate change, are one of the most important causes of food insecurity in the ECOWAS region. Conflicts are highlighted in each of the scenarios, however, the lack of strong state governments combined with short-term priority setting, in *Save Yourself* give this scenario the most potential for food insecurity. Limitations in the trade of both the inputs to and products of agriculture can have profound effects on food security (Baldos & Hertel, 2015; Mosnier et al., 2014). The CCAFS scenario narratives consider the challenges to regional integration, which have been brought into the quantitative modelling of GLOBIOM through impacts in the farm input costs.

For instance, the state-led regional integration policies of *Cash, Control, Calories*, are poorly coordinated and lack a long term focus, which over time cause similar failures in regional integration noted by Tarvares and Tang (2013), such as countries overly committed to integration programs in multiple, overlapping regional organizations leading to lower program implementation overall and programs that are overly bureaucratic and lack involvement from the private sector, increasing the costs of production for the region increase by 15%. The weak governments unable to control the regional stability in *Save Yourself*, create an environment where conflicts severely limit access to markets and raise costs of production 25% for farmers. In *Civil Society to the Rescue?*, lack of coordination between the private sector and civil society organizations in negotiating integration programs and investing in infrastructure planning increase the costs of production for farmers (smallholder and large scale), limited to 15%. *Self-Determination* sees improved regional integration through merging of regional organizations led by member countries with a focus on the long-term development of the region and therefore the production costs for the region remain unchanged.

Cropland Area

GLOBIOM models the competition for land endogenously, meaning that sectors compete for land based on the value of the land for production of wood products, crops, and livestock grazing, as well as the cost and suitability associated with converting the land to other uses (Havlík et al., 2014). To harmonize the quantitative modelling results, cropland area expansion as modelled by GLOBIOM was used as an input into IMPACT. Within IMPACT, the distribution of crop area by crop type and management system, in this case irrigated or rainfed cropland area, remained endogenous. Cropland expands in the region nearly 55% in SSP 2 by 2050, with expansion in *Cash, Control, Calories* and *Self-Determination* increasing less (4% and 9% less, respectively) and *Save Yourself* and *Civil Society to the Rescue?* increasing slightly more (4% and 2% more).

Globally-Consistent Regional Scenarios: Development outside of West Africa

IMPACT and GLOBIOM are global in scope and consider the future development for Western Africa as well as for the rest of the world, providing insights into how the region will be affected by forces outside its control, such as global markets and climate change. As these impacts can have profound effect and to better examine the impact of the CCAFS scenarios assumptions within the region, the global context was assumed to follow the population and economic development of the *SSP2: Middle of the Road* over the time period, where, by 2050, the global population reaches 9.2 billion people (Kc & Lutz 2014) and the global average GDP per capita is expected to double and to reach around 16,000 USD. This assumption was unchanged among the scenarios to examine the impact of the scenarios assumptions within the region.

As discussed earlier, the climate impacts on crop yields are also applied globally. The impacts of climate change on agriculture will be worse for some regions (Nelson et al. 2010; Leclère et al. 2014; Mosnier et al. 2014). Without considering the potential climate impacts to the regions outside of West Africa, we would underestimate the total climate change impacts, both the local effects as well as the effects on regions from which West Africa imports.

Quantitative Plausible Regional Development

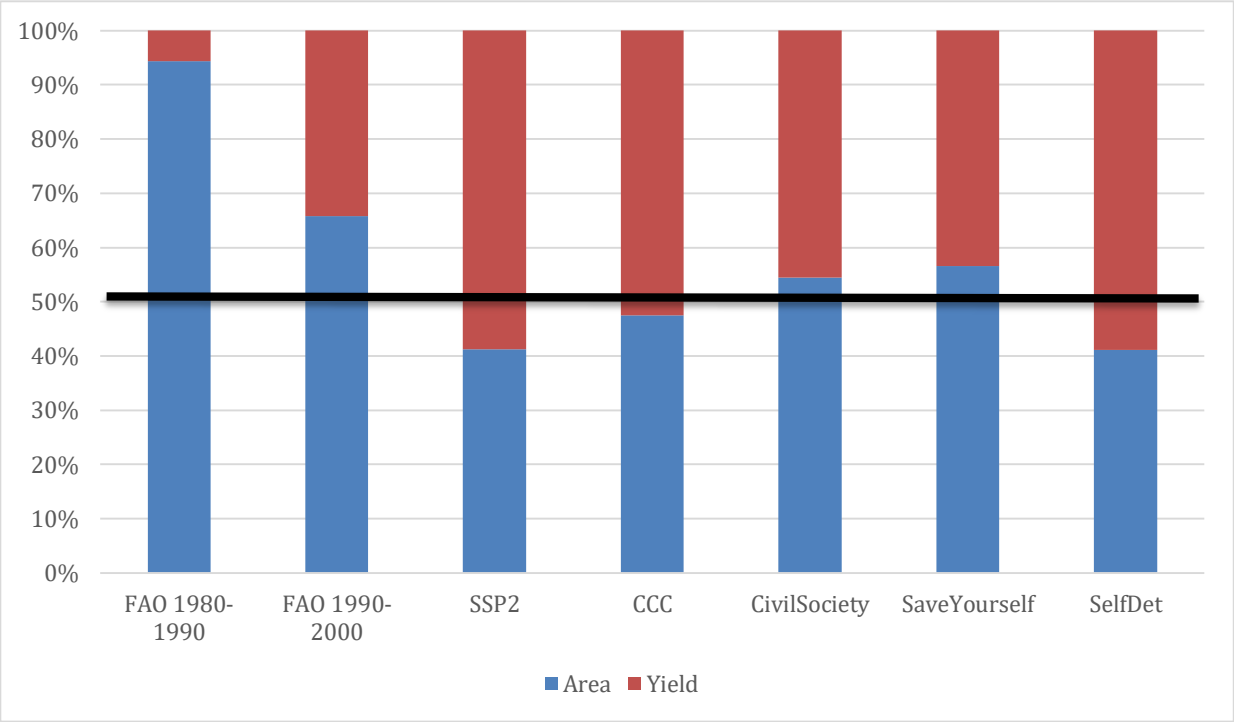
In the following section, the scenarios for Western Africa, quantified using the GLOBIOM and IMPACT models, are summarized to create a complete picture of the changes over time and among the scenarios in terms of socio-economic and agricultural development. The use of the quantified scenarios results as a plausible future for the regional development as they are presented here have been used by policy makers to test policy options under possible futures. In addition to highlighting the regional demand and supply of crop and livestock products, we present the impacts of the scenarios in the improving food security and protecting the environment.

Crop and Livestock Production

Agricultural production currently accounts for about a quarter of the region's GDP, but as much as 35% in the 1980s (World Bank Development Indicators, 2015). Western Africa as a region is the leader, or among the top global producers of cassava, millet, sorghum, and oil palm (FAOSTAT, 2015). In particular, the groundnut, sorghum, cassava, and millet production in the region accounts for nearly 15, 20, 30, and 40 percent of world's production, respectfully. Cassava production in the region is particularly strong, in part due to the local efforts of the CGIAR research centers: International Institute of Tropical Agriculture (IITA) located in Ibadan, Nigeria and Centro Internacional de Agricultural Tropical (CIAT) located in Cali, Colombia. Although cassava is primarily seen as a staple food crop is consumed less

as incomes rise, it is also utilized as livestock feed in some parts of the world making it still a highly important crop due to a growing demand for meat products from rising income. Other important crops such as rice and corn are also highly produced in the region and though the region's share of the total global production is limited to around 1 percent (Figure 18).

Figure 17 Share of source of production growth based on the rate of growth, "area" implies cropland area expansion and "yield" implies increase in the aggregate crop yield in dry matter tons per hectare



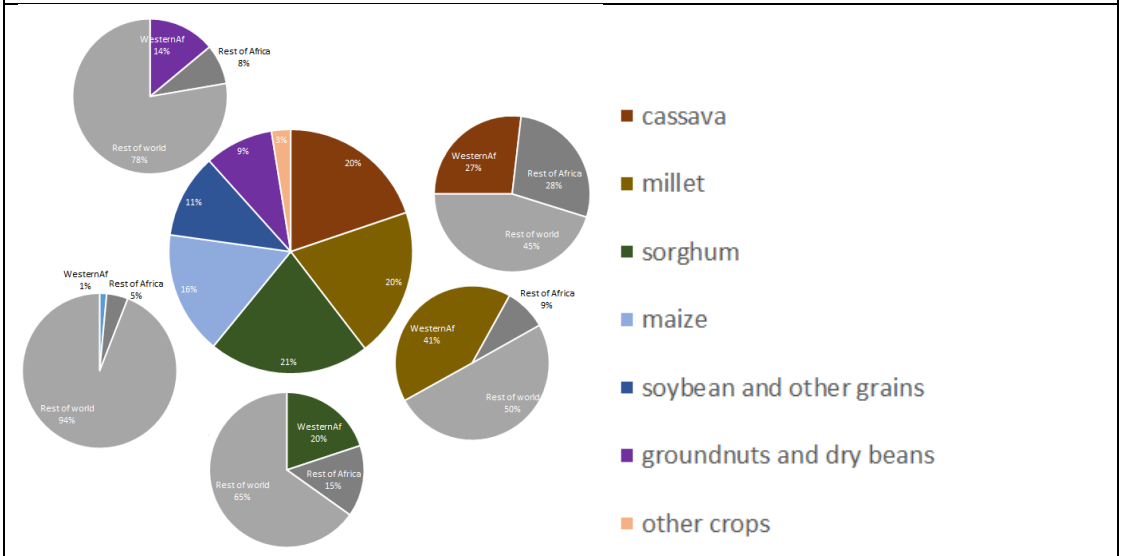
To model changes in crop yields over time, both GLOBIOM and IMPACT use the technological improvements as a starting point for potential yield growth. Additionally, yields will reflect the changes between production systems[6] and, within GLOBIOM, the reallocation of crop production to more or less productive areas. Increases in production over time will come from a combination of the scenario yield improvements, expansion of the crop to current cropland including transitions between production systems, and expansion of the crop to new cropland taking into account the costs associate with land conversion and transitions between systems.). Historically, increases in production within the region have come from expansions in cropland area rather than through significant yield improvements (Byerlee, Stevenson, & Villoria, 2014; Hillocks, 2002). In the CCAFS scenarios, this

[6] in GLOBIOM: extensive rainfed, intensive rainfed, and irrigated; in IMPACT: rainfed and irrigated

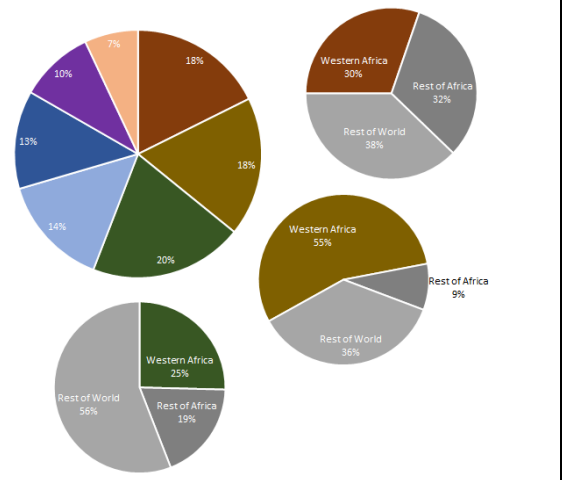
historical trend continues in the *Save Yourse*lf and *Civil Society to the Rescue?* scenarios, where slightly more than half the share of the average annual growth rate in production from 2000-2050 comes from crop area expansion and less than half from yield improvements. In terms of total crop and livestock production, by 2050, *Self-Determination* produces the most in terms of quantity and in terms of calories, with *Cash, Control, Calories* producing the second most (Figure 17). Overall, crop production in the region increases from 2010 to 2050 for all scenarios, with *Self-Determination* having the highest levels of crop production and *Save Yourself* having the least growth in crop production. The development of crops in the region remains of particular importance to the global production by 2050, especially for millet, cassava, and sorghum (Figure 18). Climate impacts are applied to the crop yields in GLOBIOM and IMPACT as relative differences in simulations of crop growth from globally-gridded crop models that use conditions of future climates from GCM models (Leclère et al., 2014; Mosnier et al., 2014; Müller & Robertson, 2014; Nelson, van der Mensbrugghe, et al., 2014).

Figure 18 Western Africa's Share of Crop Production by crop (large circles) and the Region's Production Share of Global Production by crop (smaller circles) in dry matter for 2010 (top most figure) and in 2050 by scenario (figures in lower four rectangles)

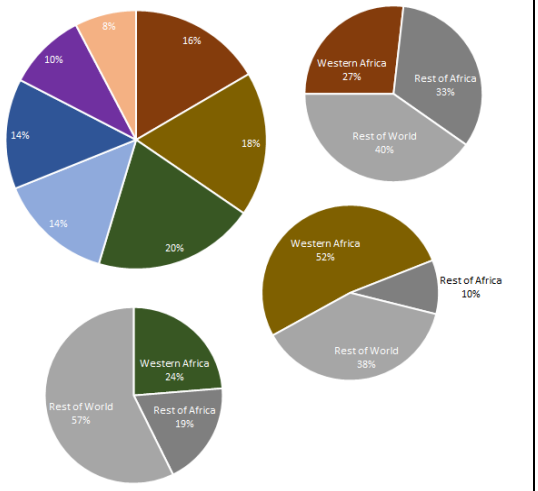
2010



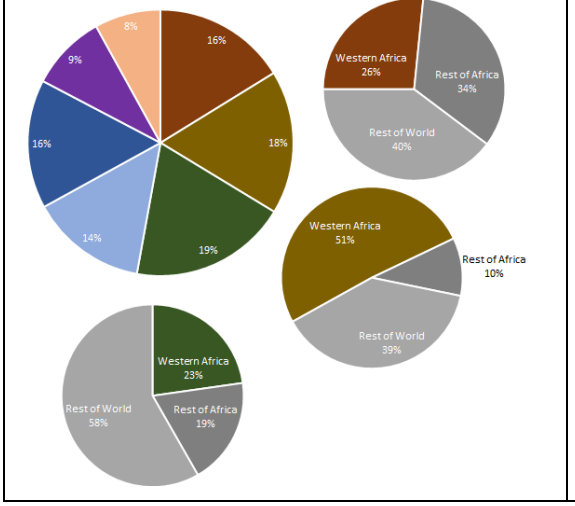
Self-Determination in 2050



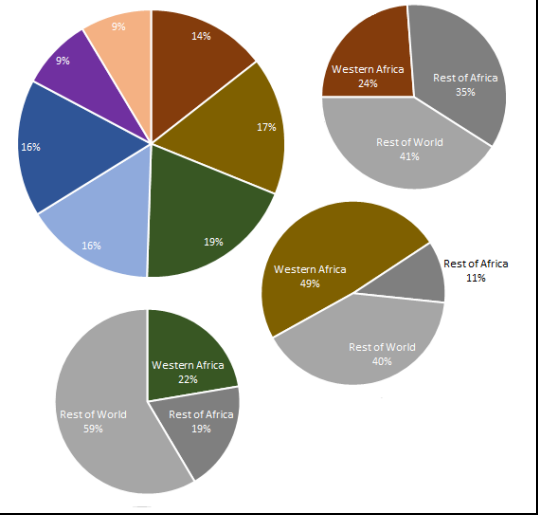
Cash, Control, Calories in 2050



Civil Society to the Rescue? in 2050



Save Yourself in 2050



Note: The large Circle represents each crop's share of the total crop production in Western Africa (excluding tree crops) in dry matter. Slices in the smaller circles of the same color represent Western Africa's share of the global production of the respective crops. Note that for the 2050 scenarios, Western Africa's share of global production of maize has been removed because the share remains very small. Source: FAOSTAT 2015 (2010); GLOBIOM model results (2050).

Cassava

In the decades leading up to 2000, cassava production in Western Africa increased due to an increasing harvested area (+300% expansion from 1965-2000) rather than through yield improvements (+30% total growth from 1965-2000) (Hillocks, 2002; FAOSTAT, 2015). As cassava in the region, historically, has been planted because of its hardiness in periods of drought and pest and disease resistance in an effort to reduce periods of food insecurity (Hillocks, 2002). The CCAFS scenarios consider the importance of this crop to food security in the future by, on one hand a future with continuation of the historically small increase in yields such as with *Save Yourself* or, on the other hand, increases in investments from the national and regional level and dissemination in high yielding varieties leading to an annual growth in *Self-Determination* that is nearly double the historical trend (Appendix E, Figure E4). Despite its hardiness, the impact of climate change on cassava yields is considerable and when compared to a climate neutral future, depressing yields by as little as 3% or as much as 35% (Figure 19). However, in the scenario with the highest yield improvements *Self-Determination*, the cassava yields that consider climate change are in nearly all cases higher than the scenarios with no climate change, suggesting that investments in increasing cassava yields may be a solution for an uncertain climate future (Figure 19).

Maize

Production of maize has grown dramatically in recent years, with area under maize cultivation increasing 4.6% per year from 1980-2010 (Appendix E, Figure E3). Yields for maize in Western Africa increased 250% from 1961-2013 (FAOSTAT, 2015), despite the yield gap relative to the rest of the world (Fischer, Byerlee, & Edmeades, 2014). GLOBIOM projects that the productivity investments and production reallocation will lead to a significant yield increase over the time period for *Self-Determination* (+246%) and *Cash, Control, Calories* (+233%). In 2050, maize yields in the high yield future of *Self-Determination* will be closer to the year 2000 yields for Central European Union countries (3.69 tons/ha) (FAOSTAT, 2015). Climate change is estimated to reduce maize yields in some cases quite significantly compared to a climate neutral world (-3.0% to -25%). IMPACT projects a more modest estimate of around 60% in yields from 2010-2050 in the

higher yield scenarios, and between 30-40% in the lower yielding scenarios an increase. In IMPACT, the effects from climate change reduces yields for maize are reduced significantly (-9% to -57%). The effects in the yields from IMPACT are far greater than those from GLOBIOM, because IMPACT estimates the crop yields using a crop model that does not consider the impacts of CO2 fertilization. The impacts of CO2 fertilization on crop yields are included in the EPIC (Environmental Policy Integrated Climate model) crop modelling simulations used within GLOBIOM, while IMPACT simulates climate impacts without CO2 fertilization with DSSAT (Decision Support System for Agrotechnology Transfer) (Table 1). The scientific community has yet to reach an agreement on the whether the potential benefits from increases in CO2 can be taken up and used by crops, especially if temperature and precipitation reduce crop yields, but taken together the yields from GLOBIOM and IMPACT can show the potential range of the biophysical and economic impacts on crop yields from climate change.

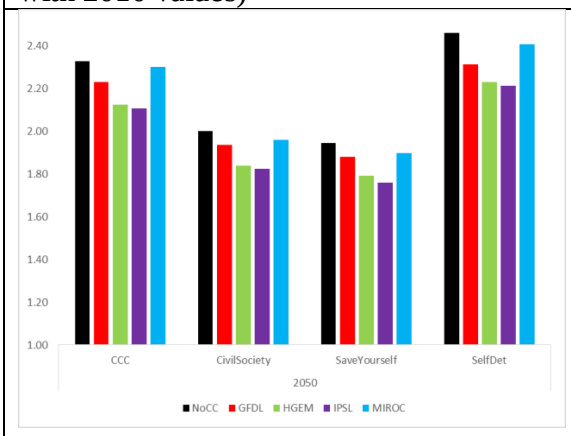
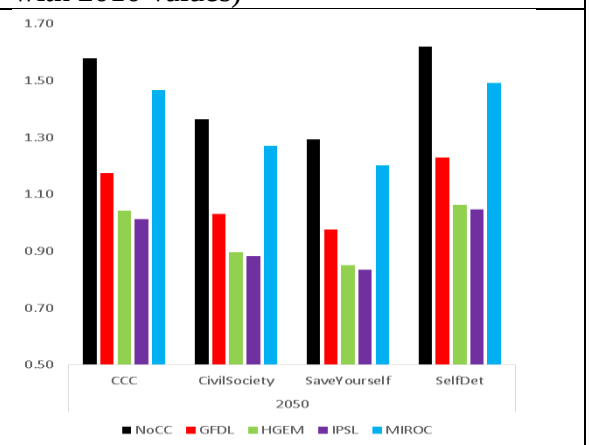
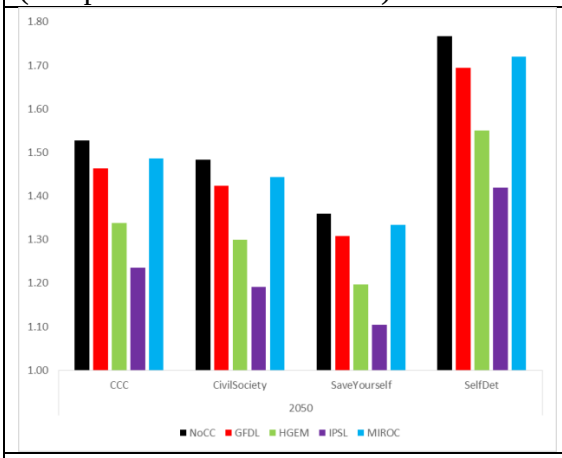
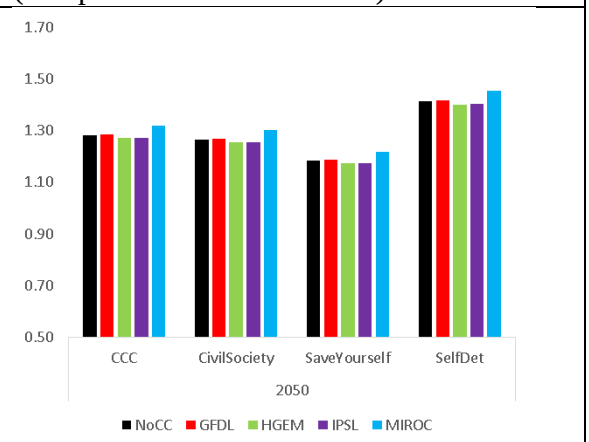
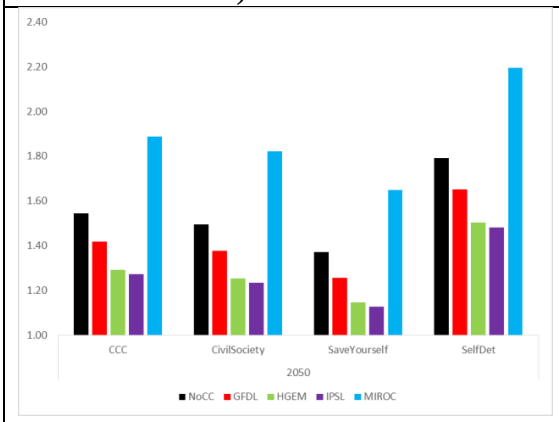
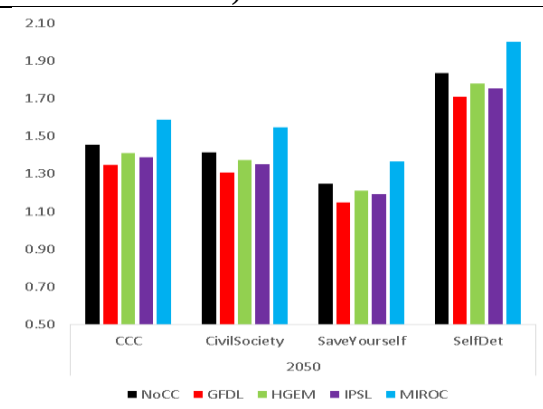
Millet

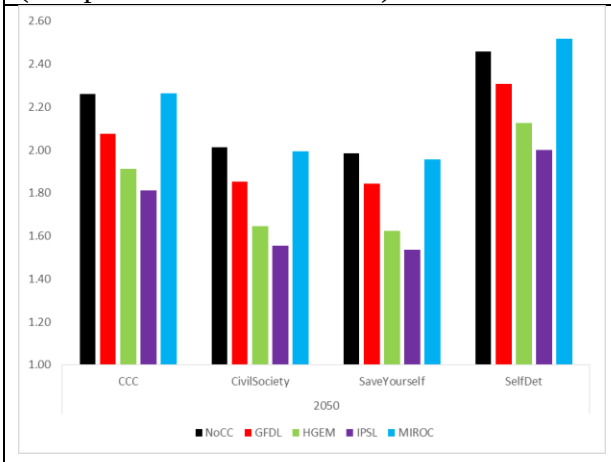
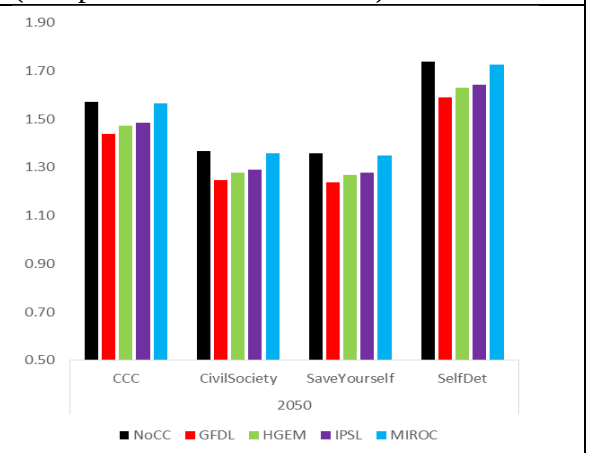
Western Africa contributes more than 40% to the global supply of millet, the highest share for crops produced in the region (FAOSTAT, 2015) (Service, Division, Division, & Pradesh, 1996). International trade in millet is low, with around 4% of the global production traded internationally, although about 9% of the millet produced in Western Africa was exported outside the region at the beginning of the century (FAOSTAT, 2015). From 1980-2000, production increased around 2.7% per year due primarily to cropland expansion (2.3% per year growth) rather than yield improvements (0.5% per year growth) (Appendix E, Figure E1). In the CCAFS scenarios, production follows the historical trends for *Self-Determination*, though more than half the annual growth in production coming from improvement in yields. The additional growth in production in other the scenarios, more than half of which comes from area expansion, allows the region to keep up with demand and retain most of its competitiveness by 2050. However in *Save Yourself*, which has the lowest growth yields over the period, millet becomes an imported crop by 2040. The climate impacts on millet may seem inconsistent at first glance (+41% in MIROC; -0.31% for IPSL), however other assessments that use a regional specific crop model find that the purely biophysical crop yields under varied climatic conditions produce negative effects in nearly 88% of scenarios (Sultan et al., 2013) (Figure 19).

Sorghum

Sorghum is the one of the most produced crop in the region grown for to its drought resilience, where it is used both for human and livestock consumption (Fischer et al., 2014). From 1963-2010, production in the region doubled, while yields increased 30% over that same period, though yields have had the longest steady upward trend in yield growth since 1990. Western Africa contributed around 20% of the global share of the sorghum (FAOSTAT, 2015; Figure 18) at the start of the century, and by 2050 its global contribution grows to between 22% and 25% (*Save Yourself* and *Self-Determination*). Nigeria, the largest sorghum producer in Western Africa, saw a sharp decline since 2009 in sorghum production, due to a shift in crop area to other cereals (Gourichon, 2013). However, the CCAFS scenarios consider sorghum to maintain its prominence in the region to 2050, with production increasing on average 2.4% per year (Appendix E, Figure E2). Increases in yields are seen for both models. Over the period 2010-2050 sorghum yields in GLOBIOM increase from almost 100% (in *Save Yourself)* 150% (in *Self-Determination*) (Figure 19). Sorghum yields in IMPACT have a more modest increase with yields increasing 36% (in *Save Yourself*) to 75% (in *Self-Determination*). Both models project that the effects of climate change lower yields (in four of the five GCMs), but for those remaining GCMs, the models differ on the magnitude of negative effects: yield loss of 15% compared to a 2000 climate for IMPACT and 51% yield loss for GLOBIOM.

Figure 19 Relative change in average crop yields for maize, cassava, and millet compared to 2010 yields as modelled by GLOBIOM and IMPACT for the Scenarios with and without the climate change effects on crop growth included (note: the y-axis is not the same for both models

GLOBIOM Maize Yields in 2050 (compared with 2010 values)	IMPACT Maize Yields in 2050 (compared with 2010 values)
	
GLOBIOM Cassava Yields in 2050 (compared with 2010 values)	IMPACT Cassava Yields in 2050 (compared with 2010 values)
	
GLOBIOM Millet Yields in 2050 (compared with 2010 values)	IMPACT Millet Yields in 2050 (compared with 2010 values)
	

GLOBIOM Sorghum Yields in 2050 (compared with 2010 values)	IMPACT Sorghum Yields in 2050 (compared with 2010 values)
	

Livestock

The development of the livestock sector in Western Africa, of which contributions to the national GDP range from 10%-15% (Kamuanga et al., 2008), depend on not only the overall productivity in the region to meet the growing demand but also supporting the transformation of livestock systems from pastoral to mixed systems, where more productive livestock both graze and consume feed crops. In the CCAFS scenarios, the investments in livestock production nearly doubles the total livestock output of dairy and ruminant and monogastric meat for *Cash, Control, Calories* and *Self-Determination*. Although there is little investment in the livestock sector (aside from the dairy sector) in *Save Yourself* and limited investment in *Civil Society to the Rescue?*, the scenarios still see an annual increase of total livestock production of around 2%.

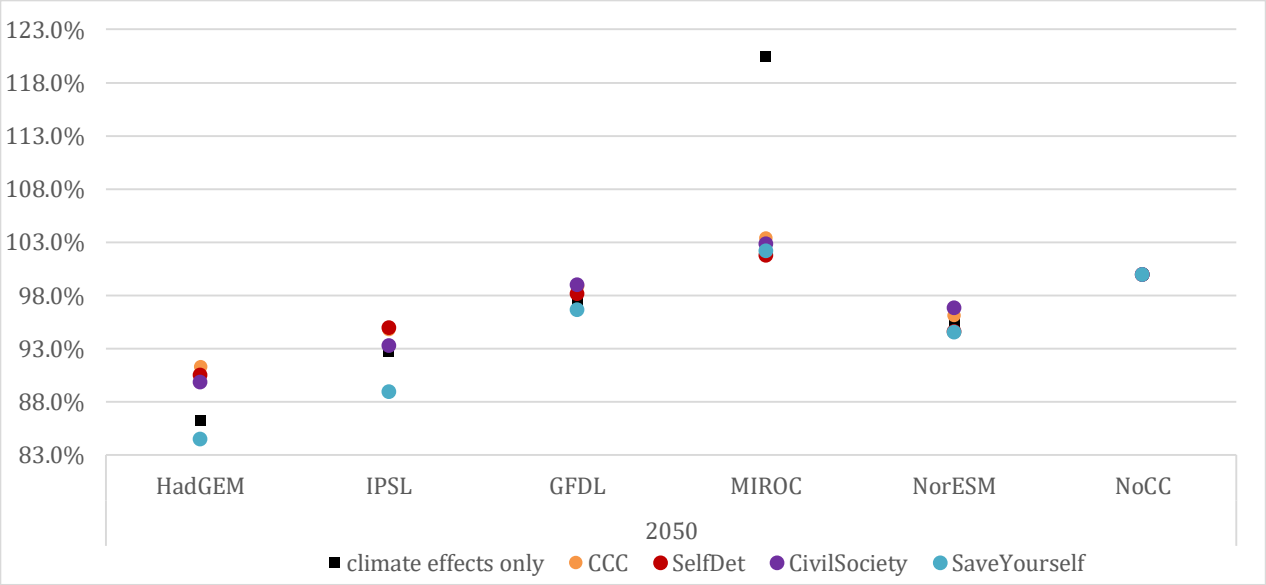
While the increase in both ruminant and monogastric meat is largest for *Self-Determination* (closely followed by *Cash, Control, Calories*), *Save Yourself* has the least productive livestock sector of the scenarios, but still sees a large expansion in the dairy sector. The per capita demand for dairy is the lowest in *Save Yourself*, but due to large growth in population, the total dairy demand is highest. This drives the growth in supply, although most of the demand for dairy is met with imports. Not surprising, in the scenario with the least investment in dairy over the period (*Civil Society to the Rescue?*) has the largest imports as a share of the total milk production. Interestingly, in *Self-Determination*, where a productive crop sector competes for land with the livestock sector for grassland, dairy production grows

the least out of all scenarios by 2050, suggesting that milk imports are cheaper than regionally produced milk.

In Western Africa, over the time period ruminant livestock numbers increase for all scenarios, although the share of bovines to sheep and goats shifts in nearly all scenarios from 60% bovine [40% sheep and goats] to 60% sheep and goat [40% bovine] by 2050 in TLUs. The expansion of bovine numbers comes not only through an expansion of mixed-crop livestock systems in the humid and arid regions but also through a decline in land-based grazing systems. With sheep and goats, land-based grazing systems and mixed-crop livestock systems in humid systems increase fivefold. Ruminant meat production in Western Africa increases 275% by 2050 compared to 2010 in SSP2 with *Self-Determination* producing 9% more and *Save Yourself* producing 20% less than in SSP2. For monogastric meat production (pork and poultry meat), when compared with SSP2 in 2050, the additional investments in monogastrics in the *Cash, Control, Calories* and *Self-Determination* scenario produce 5% and 30% more meat respectively, while the both *Civil Society* and *Save Yourself* produce less meat than in SSP2 (nearly 84% less in *Save Yourself*).

The strictly biophysical climate impacts on grassland productivity as modelled by EPIC and are relatively negative for the region (Figure 20). Climate change for all GCMs except MIROC, reduces grassland production. Although the quantification of the drivers for the CCAFS scenarios did not consider direct impacts on grassland productivity, the feedbacks from other drivers as well as expansion of grassland for livestock production increase Western Africa's grassland production compared to the climate change future in all scenarios except for Save Yourself. The overall production in *Save Yourself* is less than the potential production under climate change with no endogenous feedbacks, suggesting that actions or inactions this scenario, such as expanding pastures and limited productivity for animal feed, could exacerbate the effects of climate change.

Figure 20 Grassland production under climate and socio-economic scenario for Western Africa: Endogenous grassland production for each climate and regional socio-economic scenario (colored circle) and exogenous climate effects on grassland production (represented by the black square)



Land Use Change

To understand how the development of the agriculture sector in each scenario will affect the land use we identify where the cropland and grassland expansion occurs: within Western Africa, outside the Western Africa but within Sub-Saharan Africa, and in the rest of the world.

GLOBIOM endogenously models the global demand for land by considering the main users of land. IMPACT, which can model cropland expansion endogenously, uses the changes in total cropland as modelled by GLOBIOM as in input to harmonize the modelling of land use.

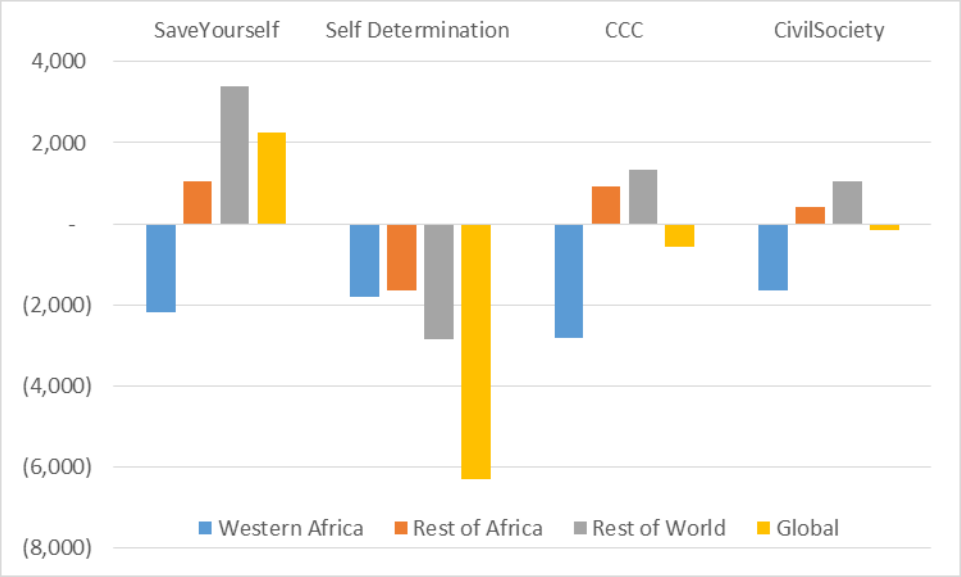
Increases in food demand are met by the region's supply through productivity increases or though expansion of crop and grassland. Demand not met by regional production will be met by increased production from outside the region. Shifting agricultural expansion outside the region can lead to unintended environmental effects such as deforestation.

Globally, agricultural area expands more than 11% in SSP2 by 2050 and while there is relatively little difference when comparing the *Middle-of-the-Road SSP2* scenario among the CCAFS scenarios. The difference in agricultural area between the scenarios to a savings of

6.2 million ha (*Self-Determination*) or an expansion of 2.6 million ha *(Save Yourself*) globally by 2050 compared to SSP2. The Green Revolution, where the adoption of improved seeds increased agriculture output worldwide, is credited with saving at least twice as much land over forty years in developing countries from being converted to agricultural land (Stevenson, Villoria, Byerlee, Kelley, & Maredia, 2013).

Although the deforestation and conversion of natural land within Western Africa is highest in SSP2 than in the CCAFS scenario, the pristine forest area and natural land converted to agricultural land (cropland and pasture land) is slightly higher in *Self-Determination* than in the other CCAFS scenarios suggesting that the assumed market conditions and large agricultural productivity gains increase the profitability and may incentivize expanding crop and grassland, in what is known as Jevon's paradox (Alcott, 2005; Byerlee et al., 2014). However, the regional level hides the true global land sparing in *Self-Determination*. When compared to the average conversion of natural land in the other CCAFS scenarios, *Self-Determination* saves almost 3.64 ha outside the region for every 1 ha converted within the region. On average, of the unconverted agricultural area half is saved from within Africa. Shifting the share of production growth from area expansion to yield improvements is an indication that the region may be increasing the profitability in *Self-Determination* (Appendix E). In *Save Yourself*, where the regional agriculture sector struggles and the lack of regional integration keeps farm input prices high, less land is used for agriculture in the region by 2050, but at the expense of, on average, 4.5 million additional agricultural area converted outside the region (most of which is natural land). Similarly, the relative land sparing that occurs globally in *Cash, Control, Calories* and *Civil Society to the Rescue?*, comes from a large decrease in agricultural area of Western Africa (2.8 million ha and 1.7 million ha respectively), but an increase of nearly that much area in the rest of the world (Figure 21).

Figure 21 Difference in total land conversion from 2010-2050 compared to SSP2 (M ha) Note: negative values imply land savings compared to SSP2



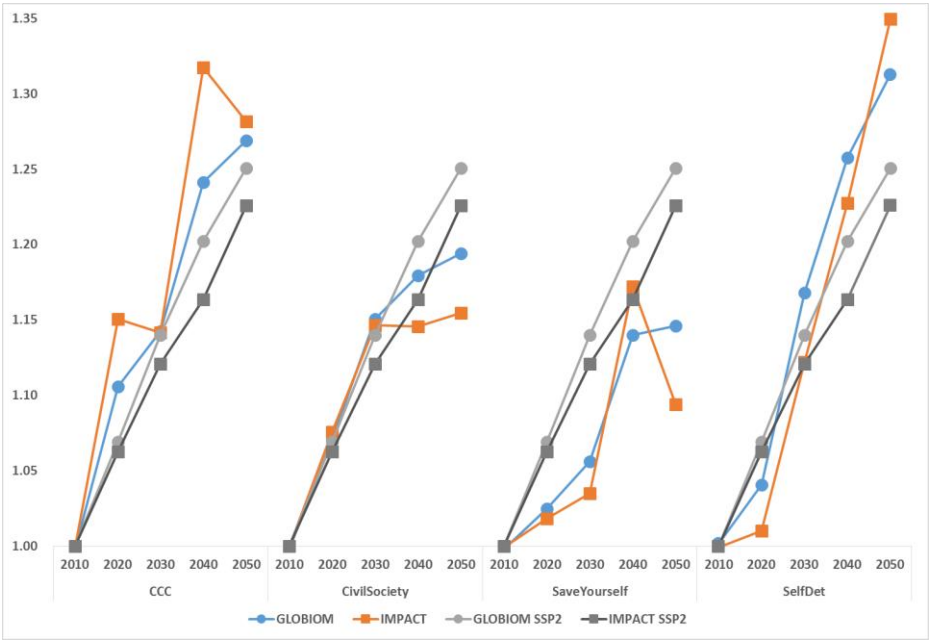
By 2050, nearly 5 % of the global forest area will be converted to agricultural land in SSP2, though policies in Western Africa that reduce the burden on land such as those in *Self-Determination* can preserve the global forest area by nearly 2 million ha (half saved outside the region). In most of the scenarios, a larger share of agricultural land is converted from natural land than from forest in Western Africa, in the *Save Yourself*, the share of new agricultural area coming from forest is highest, leaving only 60% of the WA forests remaining in the future.

Food Demand and Kilocalorie Availability

Kilocalorie availability per capita per day is one of the indicators used to measure food security, which considers the total food products demanded by a region and translates the quantity of product to calories. Both models employ a double-log demand system to model consumer food demand, considering both a dynamic adjustment to demand based on income growth as well as a demand response based on prices (Valin et al., 2014). For this assessment, to limit the effects of food security to the socio-economic development rather than an underlying shift in dietary preferences, the income elasticities of demand were kept constant between the scenarios. As the income per capita increases over the time period in all scenarios, food demand, and kilocalories available, increase in the region (Figure 22). *Self-Determination* sees the greatest improvement in food security due to the long-term

prospective and economic growth incorporates the supply chain from production, through technological improvements to close the yield gap, to market, through production costs. *Cash, Control, Calories*, with a relatively high increases in the GDP per capita and improvements in the agricultural production at the start of the period, sees an increase in the food security but the effects are limited due to the increases in production costs. When coupled with lack of investment in the regional food supply, the increase in production costs and conjointly consumer costs, due to the relative regional insecurity, the food security of the region remains a challenge. The SSP mirror of *Save Yourself*, SSP3, was also found to present challenges for the food security in Africa in other quantitative assessments. (Hasegawa et al., 2015). In terms of the diet composition, the scenarios with the highest economic growth and largest investment in livestock productivity, *Cash, Control, Calories* and *Self-Determination*, have the largest consumption of meat products. *Civil Society to the Rescue?* and *Save Yourself* have a larger increase in the per capita demand for cassava and other tubers than in the other scenarios, which follows with the socio-economic development of the scenarios, as cassava is a staple food crop typically consumed less with rising incomes.

Figure 22 Kilocalorie availability per capita per day as modeled by GLOBIOM (circles) and IMPACT (squares) for West Africa CCAFS scenarios compared to SSP2 and indexed to year 2010 values



Prices and Net Trade

The regional price for crops increase over time for both *Save Yourself* and *Civil Society to the Rescue?* (+6% and +4% higher in 2050 than in 2010). By 2050, prices decrease in *Cash*,

Control, Calories, although the early periods see an increase of nearly 5%, while *Self-Determination* sees an overall decline over the entire time period.

Dairy prices remain relatively stable and by 2050 decrease (-3%) in all the scenarios. Monogastrics meat, excluding eggs, increase the most in *Save Yourself* and *Civil Society to the Rescue?*, but the focus and investment in the monogastric industry in *Cash, Control, Calories* keeps the price from increasing as is seen in the other scenarios. Keeping producer input costs low and improvement in crop yields provide more feed for monogastrics in the *Self-Determination* scenario keeping the price from increasing more than 2% by 2050 despite the growing per capita demand which triples from 2010 to 2050.

Despite the large share of production in region, in all the scenarios by 2050, cassava becomes imported, with imports equalling between 12% and 18% the production in the region. Cassava is primarily seen as a staple food crop and is consumed less as incomes rise, while it is also utilized as livestock feed making it an important crop due to a growing demand for meat products from rising income. It is no surprise then that among the scenarios the share of cassava used for livestock feed accounts for 68% of the demand for *Self-Determination*, due to growing incomes and meat demand, and only 26% for Save Yourself.

Expressed as a share of the regional production, net imports of crop products by 2050 are as large as 16%/29% (*Cash, Control, Calories*) and as little as 12%/22% (in *Self-Determination*) of the total crop production, in GLOBIOM and IMPACT respectively. Although GLOBIOM and IMPACT model results agree that imports of all livestock products increase in the region over time, there is no agreement in the scenario with the greatest imports as a share of regional production.

Development Outside of Western Africa

In all the scenarios by 2050, socioeconomic growth in rest of the world increases demand for and production of agricultural products increases 42% for crop products and 65% for livestock products. In 2010, South Asia, China, and South America were the largest consumers of crop products, but by 2050, South Asia and all of Africa will see the largest growth in demand for both crop and livestock products. South America (including Brazil) will become the largest producer for crop and livestock products, followed by South Asia. In terms of food security outside the region, kilocalorie consumption improves in nearly all regions, with India and the rest of South Asia calorie consumption increasing 15% and 23%,

and Eastern and the rest of Sub-Saharan Africa calorie consumption increasing 31% to 37% by 2050.

Discussion and Conclusions

Linking SSPs and CCAFS scenarios for improved regional context

SSPs have been developed and are being quantified very well at the global scale due to the nature of the global modelling community. While the quantified socioeconomic storylines of the SSP have been provided at the national and sub-national level the scientific literature and insights into the regional developments has been lacking. This scenarios exercise as it is developed from stakeholder driven scenarios for the future of the region and linked with the global narratives of the SSPs offers one of the first globally consistent regional scenarios of the SSPs. As the CCAFS scenarios process continues more regional scenarios will be available for use by the policy making and research community alike.

Diverse Scenarios are useful for developing robust climate policy that is scalable

The two axis approach of the Eastern and Western Africa scenarios have diverse scenarios, while the multi-factor scenarios for SA, SEA, Andes, and CA use a scenario modelling tool to choose the most diverse scenarios (Mason-D'Croz et al. under revision.). Creating relatively few pathways, but representing widely different outcomes for socio-economic development, which is important for examining and using scenarios at different scales (Valdivia et al., 2015).

The regional level is a key level at which to develop scenarios – because they are equivalent across scales while still relevant to regional economic bodies like ECOWAS and are easy to connect to global scenarios assessments (Zurek & Henrichs, 2007). Scenarios that provide a plausible development of the agricultural system provide appropriate and necessary inputs for more disaggregated impact assessment (Antle et al., 2015; Valdivia et al., 2015). Additionally, linking the scenarios between scales allows policy makers to address the issues within his or her decision context and its effect while leaving room at for others more aggregated or disaggregated scales to consider their decision context.

A primary purpose for the scenarios discussed in this paper is to use them for national and regional policy guidance (Vervoort et al., 2014). In such processes, a close collaboration with decision-makers results in the design of a process in which the regional scenarios are downscaled to the national level and to the concerns of a specific plan or policy. In an inclusive process that involves state and non-state actors, including those responsible for the policy and those who are most likely to be affected by it, the future scenarios offer multiple, challenging contexts in which to test draft plans and policies, providing recommendations for improved strategies which are then integrated. Examples of such use of the regional scenario are as follows:

- In Burkina Faso, the West Africa scenarios were used to develop and test the country's new National Plan for the Rural Sector for Burkina Faso (PNSR) and to identify research priorities needed to help the plan succeed (see Chapter 3 and https://ccafs.cgiar.org/blog/using-future-scenarios-design-policy-and-research-together-burkina-faso#.VfF4shGqpBd). The quantified CCAFS scenarios were useful for adding regional context to the country level scenarios developed by drafters of the PNSR.
- The CCAFS scenarios have helped guide and inform national and subnational level policy processes in Ghana (see Chapter 3 and https://ccafs.cgiar.org/blog/scenarios-help-guide-discussions-what-ghana%E2%80%99s-future-could-look#.VfF4ZRGqpBd)
- Informed by these national-level processes, a collaboration with ECOWAS and other research partners has been set up to use the regional scenarios for ECOWAS-level priority setting, notably with the current process of new reshape of the ECOWAS common agricultural policy to meet the new challenges facing West Africa agriculture (ECOWAP+10).

Trade-offs at the regional level

Investments directed at improving agricultural yields of crops and livestock may lead to additional conversion of area used by agriculture within the region, but the without significant productivity gains, agricultural area will expand within the region through extensification, or outside the region through compensating land use change.

Although the increased profitability of yield improving technologies and increased market access that reduces production costs in agriculture may increase the expansion of area under agriculture, the effects of land use change must be examined in the context of global land use change. Technologies that improve the returns to land in Western Africa and increase region's competitiveness within Africa may reduce potential land use change.

Although the agricultural sector faces low crop yields, the region produces and will continue to produce a significant share of the global production for a selection of crops. Large shares of these crops are consumed within the region, but trade in these crops continues to be important in the future. Cassava is presently a staple food crop in the region and will continue to serve as a vital crop for the region, both for food consumption and, under changing diet preferences due to increasing incomes, as livestock feed. Even when strides are made to improve productivity, the region's agricultural sector cannot keep up with the growing regional and global demands, and for many crops, competitiveness declines and the region sees an increased share of imports relative to the region's overall production, cassava included.

Climate change is likely to have a negative effect on both crop yields and grassland productivity, and the lack of investment in crop productivity may exacerbate the challenges of climate change. Since the region that has historically seen production growth through expansion of cropland area rather than through yield improvements, this is troublesome.

Food security poses a challenge in the future where population grows rapidly and economic growth does not keep up. In the scenarios, long term priority setting that focuses on economic growth increases the food availability, however, the quantitative models are not yet equipped to model income inequality equity or urban and rural poverty.

Quantification of scenarios through modelling builds consistency of scenarios

The quantified scenarios offer the opportunity to reflect on the potential agricultural, food security, and climate futures of the ECOWAS region as well as its socio-economic developments. By providing multiple narratives and quantitative assessments of plausible futures based around the SSPs, when taken together provide a meso-scale representative agricultural pathways (RAPs) which can be disaggregated and downscaled for other subregional, national and subnational assessments (Kihara et al., 2015; Valdivia et al., 2015).

GLOBIOM and IMPACT do not attempt to provide forecasts; but instead, they provide a diverse set of futures, with the understanding that multi-dimensional challenges such as climate change are highly unpredictable. Scenarios gain credibility and become more relevant to the local realities by involving stakeholders at multiple levels, and the quantification of scenarios using models gives credibility and consistency to the scenarios by using data and consistent representations of different agricultural systems and considering the future development for the rest of the word. By providing insights to how the region will be affected by forces outside its control, such as global markets and climate change, the scenarios benefit from quantification by identifying the profound effects these influences have on regional outcomes.

Some of the semi-quantitative indicators fell outside the scope of the applicability for the quantitative modelling, such as indicators regarding equity, health, and human services, while others could not be used as a model drivers because they were endogenous model results. It is useful to examine these modelling results through the lens of the semi-quantitative indicators. Forest cover and cropland expansion are two such indicators. The quantification by the models does not include policies and enforcement to protect areas from deforestation, and under these conditions, the scenarios with the least regional deforestation are those with the highest crop yield growth, while the semi-quantitative indicators suggest that the scenarios with the least regional deforestation will be due to the activities from the civil society. Exploring how these policies would look within a modelling exercise may provide a useful tool for policy makers.

Limitations of Modelling

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.

References

Absar, S. M., & Preston, B. L. (2015). Extending the Shared Socioeconomic Pathways for sub-national impacts, adaptation, and vulnerability studies. *Global Environmental Change, 33,* 83–96. http://doi.org/10.1016/j.gloenvcha.2015.04.004

Alcott, B. (2005). Jevons' paradox. *Ecological Economics*, *54*(1), 9–21. http://doi.org/10.1016/j.ecolecon.2005.03.020

Antle, J. M., Stoorvogel, J. J., Valdivia, R. O., & B, P. T. R. S. (2014). New parsimonious simulation methods and tools to assess future food and environmental security of farm populations New parsimonious simulation methods and tools to assess future food and environmental security of farm populations, (February).

Antle, J. M., Valdivia, R. O., Boote, K. J., Janssen, S., Jones, J. W., Porter, C. H., … Thorburn, P. J. (2015). AgMIP's Transdisciplinary Agricultural Systems Approach to Regional Integrated Assessment of Climate Impacts, Vulnerability, and Adaptation. In C. Rosenzweig & D. Hillel (Eds.), *Handbook of Climate Change and Agroecosystems* (pp. 27–44). Joint Publication with American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. http://doi.org/10.1142/9781783265640_0002

Baldos, U. L. C., & Hertel, T. W. (2015). The role of international trade in managing food security risks from climate change. *Food Security*, *7*(2), 275–290. http://doi.org/10.1007/s12571-015-0435-z

Byerlee, D., Stevenson, J., & Villoria, N. (2014). Does intensification slow crop land expansion or encourage deforestation? *Global Food Security*, *3*(2), 92–98. http://doi.org/10.1016/j.gfs.2014.04.001

Crespo Cuaresma, J. (2015). Income projections for climate change research: A framework based on human capital dynamics. *Global Environmental Change*. http://doi.org/10.1016/j.gloenvcha.2015.02.012

Dellink, R., Chateau, J., Lanzi, E., & Magné, B. (2015). Long-term economic growth projections in the Shared Socioeconomic Pathways. *Global Environmental Change*. http://doi.org/10.1016/j.gloenvcha.2015.06.004

Dijk, M. Van. (2011). African Regional Integration : Implications for Food Security, 1–29.

Ericksen, P.J., Ingram, J.S.I., Liverman, D.M. (2009). Food security and global environmental change: emerging challenges. *Environmental Science and Policy* 12(4): 373-377

Fanta, E., Shaw, T. M., & Tang, V. T. (2013). *Comparative Regionalisms for Development in the 21st Century: Insights from the Global South*. Retrieved from https://books.google.at/books/about/Comparative_Regionalisms_for_Development.html?id=ykCYMQEACAAJ&pgis=1

Fischer, T., Byerlee, D., & Edmeades, G. (2014). Crop yields and global food security: Will yield increase continue to feed the world? *ACIAR Monograph*, (158), 634. http://doi.org/978 1 925133 06 6

Gourichon, H. (2013). *Analysis of incentives and disincentives for sorghum in Nigeria*. *Technical Note Series, MAFAP*. Rome.

Hachigonta, Sepo, E., Nelson, Gerald C., E., Thomas, Timothy S., E., & Sibanda, Lindiwe M., E. (2013). *Southern African agriculture and climate change A comprehensive analysis*. Washington D.C. Retrieved from http://www.ifpri.org/publication/southern-african-agriculture-and-climate-change

Hasegawa, T., Fujimori, S., Takahashi, K., & Masui, T. (2015). Scenarios for the risk of hunger in the twenty-first century using Shared Socioeconomic Pathways. *Environmental Research Letters*, *10*(1), 014010. http://doi.org/10.1088/1748-9326/10/1/014010

Havlík, P., Leclère, D., Valin, H., Herrero, M., Schmid, E., Jean-Francois Soussana, C. M., & Obersteiner, M. (2015). Climate change and food systems: global assessments and implications for food security and trade. In A. Elbehri (Ed.), (pp. 176–208). Food Agriculture Organization of the United Nations (FAO).

Havlik, P., Valin, H., Herrero, M., Obersteiner, M., Schmid, E., Rufino, M. C., … Notenbaert, A. (2014). Climate change mitigation through livestock system transitions. *Proceedings of the National Academy of Sciences*, *111*(10), 3709–3714. http://doi.org/10.1073/pnas.1308044111

Havlík, P., Valin, H., Herrero, M., Obersteiner, M., Schmid, E., Rufino, M. C., … Notenbaert, A. (2014). Climate change mitigation through livestock system transitions. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(10), 3709–14. http://doi.org/10.1073/pnas.1308044111

Helfgott, A., Sova, C., Thorn, J., Chaudhury, A., Bailey, M., Vervoort, J.M., Ademiluyi, A., Van de Grift, E. (2014). Multi-level Integrated Adaptation Governance Ghana - Workshop Report. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Herrero, M., Havlik, P., McIntire, J. M., Palazzo, A., & Valin, H. (2014). *African Livestock Futures: Realizing the Potential of Livestock for Food Security, Poverty Reduction and the Environment in Sub-Saharan Africa*. Geneva, Switzerland.

Hillocks, R. J. (2002). Cassava in Africa. In *Cassava: biology, production and utilization* (pp. 41–54). http://doi.org/10.1079/9780851995243.0041

Jalloh, A., Nelson, G. C., Thomas, T. S., Zougmoré, R., & Roy-Macauley, H. (2013). *West African Agriculture and Climate Change: A comprehensive analysis*. Washington, D.C.: International Food Policy Research Institute. http://doi.org/10.2499/9780896292048

Jiang, L., & O'Neill, B. C. (2015). Global urbanization projections for the Shared Socioeconomic Pathways. *Global Environmental Change*. http://doi.org/10.1016/j.gloenvcha.2015.03.008

Kamuanga, M. J. B., Somada, J., Sanon, Y., & Kagoné, H. (2008). *OECD Report: Livestock and regional market in the Sahel and West Africa Potentials and challenges*. *OECD*.

KC, S., & Lutz, W. (2014). The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100. *Global Environmental Change*. http://doi.org/10.1016/j.gloenvcha.2014.06.004

Kihara, J., MacCarthy, D. S., Bationo, A., Koala, S., Hickman, J., Koo, J., … Jones, J. W. (2015). Perspectives on Climate Effects on Agriculture: The International Efforts of AgMIP in Sub-Saharan Africa. In C. Rosenzweig & D. Hillel (Eds.), *Handbook of Climate Change and Agroecosystems* (Vol. 3, pp. 3–23). Joint Publication with American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. http://doi.org/10.1142/9781783265640_0013

Leclère, D., Havlík, P., Fuss, S., Schmid, E., Mosnier, A., Walsh, B., … Obersteiner, M. (2014). Climate change induced transformations of agricultural systems: insights from a global model. *Environmental Research Letters*, *9*(12), 124018. http://doi.org/10.1088/1748-9326/9/12/124018

Leimbach, M., Kriegler, E., Roming, N., & Schwanitz, J. (2015). Future growth patterns of world regions – A GDP scenario approach. *Global Environmental Change*. http://doi.org/10.1016/j.gloenvcha.2015.02.005

Lotze-Campen, H., von Lampe, M., Kyle, P., Fujimori, S., Havlik, P., van Meijl, H., … Wise, M. (2014). Impacts of increased bioenergy demand on global food markets: an AgMIP economic model intercomparison. *Agricultural Economics*, *45*(1), 103–116. http://doi.org/10.1111/agec.12092

Millenium Ecosystems Assessment (2005). *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC.

Mosnier, A., Obersteiner, M., Havlík, P., Schmid, E., Khabarov, N., Westphal, M., … Albrecht, F. (2014). Global food markets, trade and the cost of climate change adaptation. *Food Security*, *6*(1), 29–44. http://doi.org/10.1007/s12571-013-0319-z

Müller, C. (2011). Agriculture: Harvesting from uncertainties. *Nature Climate Change*, *1*(5), 253–254. http://doi.org/10.1038/nclimate1179

Müller, C., Cramer, W., Hare, W. L., & Lotze-Campen, H. (2011). Climate change risks for African agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(11), 4313–4315. http://doi.org/10.1073/pnas.1015078108

Müller, C., & Robertson, R. D. (2014). Projecting future crop productivity for global economic modeling. *Agricultural Economics*, *45*(1), 37–50. http://doi.org/10.1111/agec.12088

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., … Dadi, Z. (2000). *Special Report on Emissions Scenarios : a special report of Working Group III of the Intergovernmental Panel on Climate Change*. *Other Information: PBD: 3 Oct 2000* (Vol. New

York,). Retrieved from http://www.osti.gov/energycitations/servlets/purl/15009867-Kv00FB/native/

Nelson, G. C., Rosegrant, M. W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., … Zhu, T. (2010). *Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options*. *Research reports IFPRI*. International Food Policy Research Institute. http://doi.org/10.2499/9780896291867

Nelson, G. C., & Shively, G. E. (2014). Modeling climate change and agriculture: an introduction to the special issue. *Agricultural Economics*, *45*(1), 1–2. http://doi.org/10.1111/agec.12093

Nelson, G. C., Valin, H., Sands, R. D., Havlík, P., Ahammad, H., Deryng, D., … Willenbockel, D. (2014). Climate change effects on agriculture: economic responses to biophysical shocks. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(9), 3274–9. http://doi.org/10.1073/pnas.1222465110

Nelson, G. C., van der Mensbrugghe, D., Ahammad, H., Blanc, E., Calvin, K., Hasegawa, T., … Willenbockel, D. (2014). Agriculture and climate change in global scenarios: why don't the models agree. *Agricultural Economics*, *45*(1), 85–101. http://doi.org/10.1111/agec.12091

O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-benedict, E., & Riahi, K. (2015). The Roads Ahead : Narratives for Shared Socioeconomic Pathways describing World Futures in the 21 st Century. *Global Environmental Change*, 1–48. http://doi.org/10.1016/j.gloenvcha.2015.01.004

O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., … Solecki, W. (2015). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global Environmental Change*. http://doi.org/10.1016/j.gloenvcha.2015.01.004

O'Neill, B. C., Kriegler, E., Riahi, K., Ebi, K. L., Hallegatte, S., Carter, T. R., … van Vuuren, D. P. (2014). A new scenario framework for climate change research: the concept of shared socioeconomic pathways. *Climatic Change*, *122*(3), 387–400. http://doi.org/10.1007/s10584-013-0905-2

Palazzo, A., Vervoort, J., Havlik, P., Mason-D 'croz, D., & Islam, S. (2014). Simulating stakeholder-driven food and climate scenarios for policy development in Africa, Asia and Latin America: A multi-regional synthesis CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), (109).

Robinson, S., Mason-D'Croz, D., Islam, S., Sulser, T. B., Robertson, R., Zhu, T., … Technology, E. and P. (2015). *The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) Model Description for Version 3* (IFPRI Discussion Paper No. 1483). Washington D.C. Retrieved from http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/129825/filename/130036.pdf

Robinson, S., van Meijl, H., Willenbockel, D., Valin, H., Fujimori, S., Masui, T., … von Lampe, M.

(2014). Comparing supply-side specifications in models of global agriculture and the food system. *Agricultural Economics (United Kingdom)*, *45*(1), 21–35. http://doi.org/10.1111/agec.12087

Rohrbach, D., Minde, I., & Howard, J. (2003). Looking beyond national boundaries: regional harmonization of seed policies, laws and regulations. *Food Policy*, *28*(4), 317–333. http://doi.org/10.1016/j.foodpol.2003.08.005

Roudier, P., Sultan, B., Quirion, P., & Berg, A. (2011). The impact of future climate change on West African crop yields: What does the recent literature say? *Global Environmental Change*, *21*(3), 1073–1083. http://doi.org/10.1016/j.gloenvcha.2011.04.007

Rutting, L., Zougmoré, R., Vervoort, J.M., Balinga, M., Ouédraogo, M., Rabdo, A., Zida, M. (2015). Scenario-guided review of the *Program National du Secteur Rural* (PNSR) of Burkina Faso - Workshop Report. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Schmitz, C., van Meijl, H., Kyle, P., Nelson, G. C., Fujimori, S., Gurgel, A., … Valin, H. (2014). Land-use change trajectories up to 2050: Insights from a global agro-economic model comparison. *Agricultural Economics (United Kingdom)*, *45*(1), 69–84. http://doi.org/10.1111/agec.12090

Schweizer, V. J., & O'Neill, B. C. (2013). Systematic construction of global socioeconomic pathways using internally consistent element combinations. *Climatic Change*, *122*(3), 431–445. http://doi.org/10.1007/s10584-013-0908-z

Service, B. F., Division, T., Division, P., & Pradesh, A. (1996). The World Sorghum and Millet Economies : Facts, Trends and Outlook. *Outlook*, 2–5. Retrieved from https://books.google.com/books?id=OrMCxUHJXqwC&pgis=1

Sietz, D., & Van Dijk, H. (2015). Land-based adaptation to global change: What drives soil and water conservation in western Africa? *Global Environmental Change*, *33*, 131–141. http://doi.org/10.1016/j.gloenvcha.2015.05.001

Stevenson, J. R., Villoria, N., Byerlee, D., Kelley, T., & Maredia, M. (2013). Green Revolution research saved an estimated 18 to 27 million hectares from being brought into agricultural production. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(21), 8363–8. http://doi.org/10.1073/pnas.1208065110

Sultan, B., Roudier, P., Quirion, P., Alhassane, a, Muller, B., Dingkuhn, M., … Baron, C. (2013). Assessing climate change impacts on sorghum and millet yields in the Sudanian and Sahelian savannas of West Africa. *Environmental Research Letters*, *8*(1), 014040. http://doi.org/10.1088/1748-9326/8/1/014040

UNCTAD. (2012). *Structural Transformation and Sustainable Development in Africa*.

United Nations. (2009). *Economic Development in Africa Report 2009*.

Valdivia, R. O., Antle, J. M., Rosenzweig, C., Ruane, A. C., Vervoort, J., Ashfaq, M., … Singh, H. (2015). Representative Agricultural Pathways and Scenarios for Regional Integrated Assessment of Climate Change Impacts, Vulnerability, and Adaptation. In C. Rosenzweig & D. Hillel (Eds.), *Handbook of Climate Change and Agroecosystems* (pp. 101–145). Joint Publication with American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. http://doi.org/10.1142/9781783265640_0005

Valin, H., Sands, R. D., van der Mensbrugghe, D., Nelson, G. C., Ahammad, H., Blanc, E., … Willenbockel, D. (2014). The future of food demand: understanding differences in global economic models. *Agricultural Economics*, *45*(1), 51–67. http://doi.org/10.1111/agec.12089

Van Ruijven, B. J., Levy, M. a., Agrawal, A., Biermann, F., Birkmann, J., Carter, T. R., … Schweizer, V. J. (2014). Enhancing the relevance of Shared Socioeconomic Pathways for climate change impacts, adaptation and vulnerability research. *Climatic Change*, *122*(3), 481–494. http://doi.org/10.1007/s10584-013-0931-0

Van Vuuren, D. P., & Carter, T. R. (2013). Climate and socio-economic scenarios for climate change research and assessment: reconciling the new with the old. *Climatic Change*, *122*(3), 415–429. http://doi.org/10.1007/s10584-013-0974-2

Van Vuuren, D. P., Kok, M.T.J., Girod, B., Lucas, P.L., de Vries, B. (2012). Scenarios in global environmental assessments: key characteristics and lessons for future use. *Global Environmental Change*, 22: 884-895

Van Vuuren, D. P., Kriegler, E., O'Neill, B. C., Ebi, K. L., Riahi, K., Carter, T. R., … Winkler, H. (2013). A new scenario framework for Climate Change Research: scenario matrix architecture. *Climatic Change*, *122*(3), 373–386. http://doi.org/10.1007/s10584-013-0906-1

Vermeulen, S., Zougmore, R., Wollenberg, E., Thornton, P., Nelson, G.C., Kristjanson, P., Kinyangi, J., Jarvis, A., Hansen, J., Challinor, A., Campbell, B., Aggarwal, P. (2012). Climate change, agriculture and food security: A global partnership to link research and action for low-income agricultural producers and consumers. *Current Opinion in Environmental Sustainability* 4(1): 128-133

Vervoort, J. M., Palazzo, A., Mason-D'Croz, D., Ericksen, P. J., Thornton, P. K., Kristjanson, P., … Rowlands, H. (2013). The future of food security, environments and livelihoods in Eastern Africa: four socio-economic scenarios. *CGIAR Research Program on Climate Change, Agriculture and Food Security Working Report*, (63).

Vervoort, J. M., Thornton, P. K., Kristjanson, P., Förch, W., Ericksen, P. J., Kok, K., … Jost, C. (2014). Challenges to scenario-guided adaptive action on food security under climate change. *Global Environmental Change*, *28*, 383–394. http://doi.org/10.1016/j.gloenvcha.2014.03.001

von Lampe, M., Willenbockel, D., Ahammad, H., Blanc, E., Cai, Y., Calvin, K., … van Meijl, H. (2014). Why do global long-term scenarios for agriculture differ? An overview of the AgMIP Global Economic Model Intercomparison. *Agricultural Economics*, *45*(1), 3–20.

http://doi.org/10.1111/agec.12086

Waithaka, Michael, E., Nelson, Gerald C., E., Thomas, Timothy S., E., & Kyotalimye, Miriam, E. (2013). *East African agriculture and climate change A comprehensive analysis*.

Wheeler, T., & Reynolds, C. (2012). Predicting the risks from climate change to forage and crop production for animal feed. *Animal Frontiers*, *3*(1), 36–41. http://doi.org/10.2527/af.2013-0006

Wilbanks, T. J., & Ebi, K. L. (2013). SSPs from an impact and adaptation perspective. *Climatic Change*, *122*(3), 473–479. http://doi.org/10.1007/s10584-013-0903-4

Zurek, M. B., & Henrichs, T. (2007). Linking scenarios across geographical scales in international environmental assessments. *Technological Forecasting and Social Change*, *74*(8), 1282–1295. http://doi.org/10.1016/j.techfore.2006.11.005

Appendix A: Workshop participants

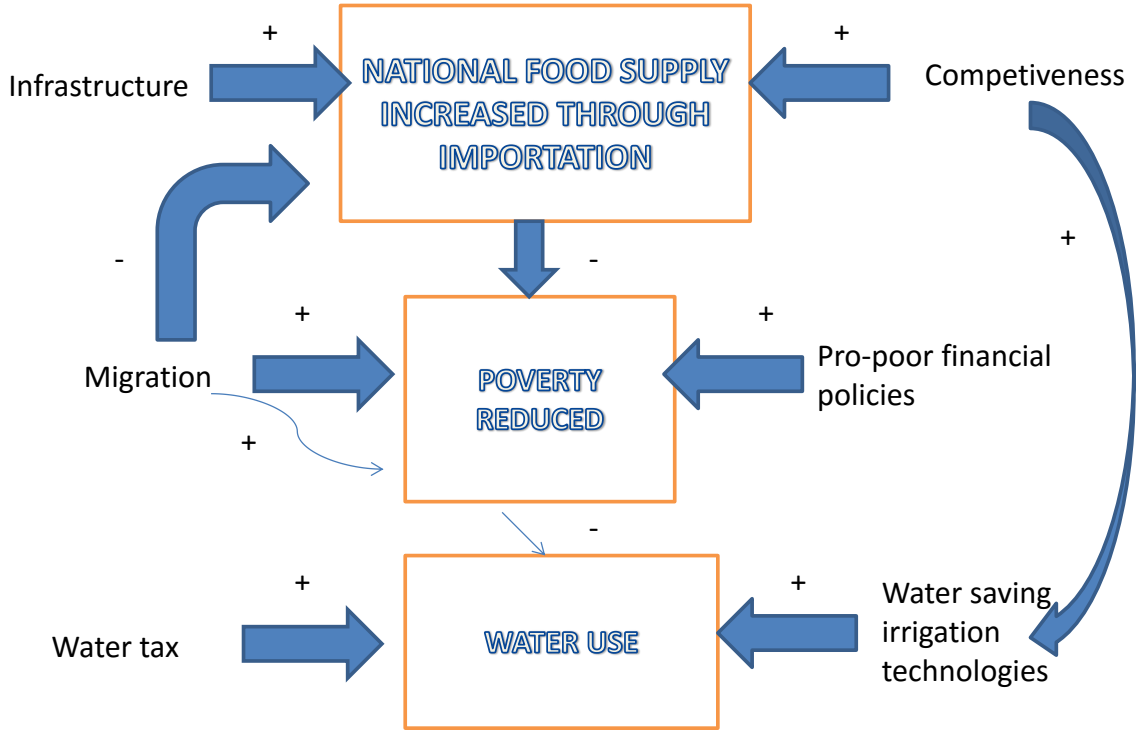
Name	Organization/function	Country
ANGE Alain Louis	FARA	Ghana
AUBEE Ernest	Principal Programme Officer, Agriculture	Nigeria
BAYALA Jules	ECOWAS Commission	Mali
BEND Pauline	ICRAF WAC - Sahel Node	Senegal
CHAUDHURY Moushumi	PANOS INSTITUTE	Kenya
COLY Adrien	CGIAR	Senegal
DAN Vincent	CLUVA	Senegal
DIAGNE Serigne	Conference interpreter	Senegal
DIARRA Niambelé Animata	Conference interpreter	Mali
DIOP Helène Diouf	Direction Nationale de l'Agriculture du Mali (Afrique de l'Ouest)	Senegal
DIOP Mamadou	ASFED	Senegal
AFESEY Kodjo Ekpé Delight	PROGEBE	Senegal
ERICKSEN Polly	Conference interpreter	Kenya
FAYE Abdourahmane	ILRI	Senegal
FAYE Mbène Dièye	Chef du BFPA du Ministère de l'Agriculture	Senegal
FAYE Ndèye Fatou	CORAF/WECARD	Senegal
FAYINKEH Mahamadou	Enda Energy	The Gambia
HANE Libasse	NACOFAG	Senegal
INGRAM John	University of Oxford - facilitation	UK
KADI KADI Hame Abdou	NERC	Niger
KARBO Naaminong	INRAN/ CSIR-ARI	Ghana
KOURESSY Mamoutou	CSIR-ARI	Mali
LO Ndeye Khady	l'IER/Sotuba	Senegal
MOUDY MAMANE Sani	CORAF/WECARD	Niger
MULLER Bertrand	Conseiller Technique du Ministre de l'Agriculture du Niger, CIRAD	Senegal
MWIKYA John	CIRAD - AfricaRice-ISRA-CERAAS	Niger
NDIAYE Cécile Edith	ACMAD	Senegal
NDIAYE Ousmane	CORAF/WECARD	Senegal
NUTSUKPO Delali Kofi	Ministry of Food and Agriculture	Ghana
OFEI-NKANSAH Kingsley	Ministry of Food and Agriculture	Ghana
OUALBIOGO Vie Hermann	General Agricultural Workers' Union	Senegal
PARKOUDA Sibri Dominique Vincent	Conference interpreter	Burkina Faso
SAWADOGO Alfred	SP/CPSA	Burkina Faso
SECK Emmanuel	SOS	Senegal
SEGDA Zenabou	ENDA	Burkina Faso
SENGHOR Abdoulaye	Independent Consultant	Burkina Faso
SOGOBA Bougouna	CEPAPE	Mali
SOME Léopold	ONG AMEDD	Burkina Faso

TRAORE Pierre C. Sibiry	INERA	Mali
VERVOORT Joost	University of Oxford, CCAFS	UK
SECK Marianne	CORAF/WECARD	Senegal
ZOUGMORE Robert	ICRISAT	Mali
ADAMOU BAYE Issoufa	INRAN	Niger
AGALYOU Alkassoum	Institutionnel de la Gestion des Questions Environnementales	Mali
AINSLIE Andrew	University of Oxford - facilitation	UK
ANGE Alain Louis	FARA	Ghana
BADJECK Marie Caroline	WorldFish Centre	Malaysia
BENINATI Noel	ICRISAT	Niger
ONILLA-FINDJI Osana	CIAT	Colombia
COULIBALY Mamadou	SAHEL ECO/CNOP	Mali
CRAUFURD Peter	ICRISAT	India
DIA Alassane	CORAF/WECARD	Senegal
DIAO BA Maty	AGRHYMET	Niger
DIARRA Daouda Zan	Nationale de la Météorologie	Mali
DIOP Chérif	Nationale de la Météorologie	Senegal
DIOP Mamadou	PROGEBE	Senegal
ERICKSEN Polly	ILRI	Kenya
GAYE Amadou Thierno	LPAOSF/ESP	Senegal
HANSEN James	International Research Institute for Climate and Society - Facilitation	USA
HAROUNA NIANDOU Abdel	Mercy Corsp	Niger
HASSANE Yaye	Agroeconomist indépendant	Niger
JALLOH Abdulai	CORAF/WECARD	Senegal
KADI KADI Hame Abdou	INRAN	Niger
KAGONE Hamade	CORAF/WECARD	Senegal
KONE Anatole Yekeminan	CORAF/WECARD	Senegal
KOUAME Nama Justin	CORAF/WECARD	Senegal
KOURESSY Mamoutou	l'Unité Agroclimatologie de l'IER/Sotuba	Mali
KRISTJANSON Patti	ICRAF	Kenya
KUISEU Julienne	CORAF/WECARD	Senegal
MARIKO Dramane	USAID	Senegal
MBOUP Papa	Interprète de conférences	Senegal
NDIAYE Cécile Edith	CORAF/WECARD	Senegal
NDIAYE Ousmane	IRI Columbia University	USA
NDOUR Ndeye Yacine	ISRA	Senegal
OUEDRAOGO Sibiri Jean	PRA/SA-LCD-Pop Dev	Burkina Faso
ROY-MACAULEY Harold	CORAF/WECARD	Senegal
SCHWEDERSKY Thomas	Process Facilitator	Germany
SISSOKO Keffing	INSAH	Mali
SOGOBA Bougouma	ONG AMEDD	Mali
SOME Leopold	INERA	Burkina Faso
SOUMARE Mamy	ICRISAT	Mali
THIAM Ibrahima	Interprète de conférences	Senegal
TRAORE Famouke	TOURE	Mali
VERMEULEN Sonja	CCAFS	Denmark
WOLLENBERG Lini	University of VERMONT	USA

Appendix B: Narratives of the Western Africa Scenarios

Cash, Control, Calories

Figure A1 Conceptual map developed by workshop participants on the key elements and relationships in the scenario.



Socio-economic context: looking for quick fixes in uncertain times

West Africa in the 2010s and early 2020s has been characterized by political instability and extractive economic activity by actors from outside the region. Significant population growth and urbanisation have driven food, energy and livelihood needs. A weak regional private sector has meant that a push for developments has been left to governments, largely working with outside actors – and these governments have been looking for quick fixes, and their precursors, fast cash. To this end, land privatization and long-term leases have been set up that mostly benefit foreign and urban interests; non-food imports have been stimulated, and water taxation has been employed. Governments have struggled to quell violence and crime connected to religion and drug trafficking in the region that saw a rise in the mid-2010s. Those seeking a safe haven under the shelter of disorder found it in West Africa. These is a looming energy crisis, driven both by a lack of local fuel wood availability and global oil scarcity.

Governments took the role of "protector states", albeit with limited resources, and prefer national sovereignty and concerns over regional integration. These governments also tended to be reactive to issues of rural poverty and food security and environmental concerns – their focus has been on quick economic development. Local resource mining has been aggressively pursued through widespread land use conversion (deforestation) for quick food and fuel. Governments were more concerned with urban stability than with rural livelihoods. In the 2010s, political instability in Azawad affected stability of the entire region; a second failure of Libyan government exacerbated this problem and so far no resolution has been reached. In 2025, violent political unrest and crime in Nigeria reached the levels where Nigeria was seen as a "failed state", further confounding regional attempt to create durably stable conditions for economic activity. The failure of Nigeria has contributed to brutal monetary shocks that affected competitiveness of West African economies and further drove urbanisation.
Water conflicts between neighboring countries over the Volta and Niger River basins and between urban and rural populations within countries (the Bani river basin) as growth in demand cannot be managed (coming from irrigation, human consumption and hydro power). Access to knowledge, technology and trade regulates tensions and interactions between governments and non-government actors. Governments' capacity to attract outside funding has grown, despite regional instability. There is a strong and successful focus on improving energy supplies.
By the late 2020, as resources have become scarce, governments have adopted policies of tactical entrenchment rather than further development, reacting to crises as necessary.

From 2030 to 2050: Post-2030, remedial action is initiated through social negotiation, under impulse from NGOs, CSOs with ECOWAS backing (20-year learning cycle).
Agriculture and food security: hectares = cash = peace

Food security in West Africa by 2030 has seen a relative increase overall, but this increase hides large spatial and temporal instability. The lack of conservation and environmental policy means that agricultural expansion and intensification as well as other types of expanding land use threaten agro-ecosystems and agro-biodiversity (though not necessarily in highly populated areas). Subsistence systems that were relatively resilient in the 2010s have struggled to cope with significantly higher demand in the 2020s.
Governments stimulated large-scale agricultural production, emphasizing quantity over quality. Policies' emphasis on urban/foreign driven "monoculture" progressively seals off transhumant corridors leading to conflicts between agriculturalists and pastoralists (exacerbated by deforestation)

GMOs are now legal in most West African Countries, since 2021. States have taken a pro-active, interventionist stance to resolve the food security problem using easiest mechanisms available: global biotechnology and local legislative power. States favored involvement of multinational giants to kick-start the commercial seed sector, yet faced powerful counter-actions from dynamic farmers' unions requiring lobbying and negotiations on both sides throughout the 2020s. The outcome of this is that farmer unions have just struck a deal with Monsanto on sorghum hybrids in 2030. Rice imports from Asia hit an all-time high in the early 2020s. Food security targets require immediate procurement of staples with rice being cheaper on international markets, and local trade operators being a "quick and dirty" mechanism to meet the growing demand, particularly from growing urban areas.
The quick push for and achievement of crop productivity increase on average is associated with lower yield stability, more vulnerability from reliance on non-seed buffer mechanisms, and conflicts over seed with commercial seed systems
A phyto-sanitary crisis in 2015 exacerbates the dependence on external solutions for food. The need for external safety nets exists at all levels, including for urban to rural cash flows. Governments' increased capacity to attract outside funding and aid flows has contributed to food security and helped mitigate some of the worst impacts of inequality of food access, but food aid dependence also slowed down development.
West Africa harbors abundant water reserves both on surface and underground, largely untapped, and returns on investments are highest in irrigated agriculture in the short term. States mobilized resources and tools for both large-scale and small-scale irrigation schemes. As a result, irrigated cropland has doubled in 20 years.
By 2030, the rapid growth in food and fuel demand driven by population increase, particularly urban has led to rapid cropland expansion and fuelwood exploitation in Sudanian and Guinean agro-ecologies home to the last dry forests for West Africa. There has been little incentive to preserve protected areas for the longer term and preference is given to agro-forestry, mixed, intensified systems.

Livelihoods and well-being: inequality grows

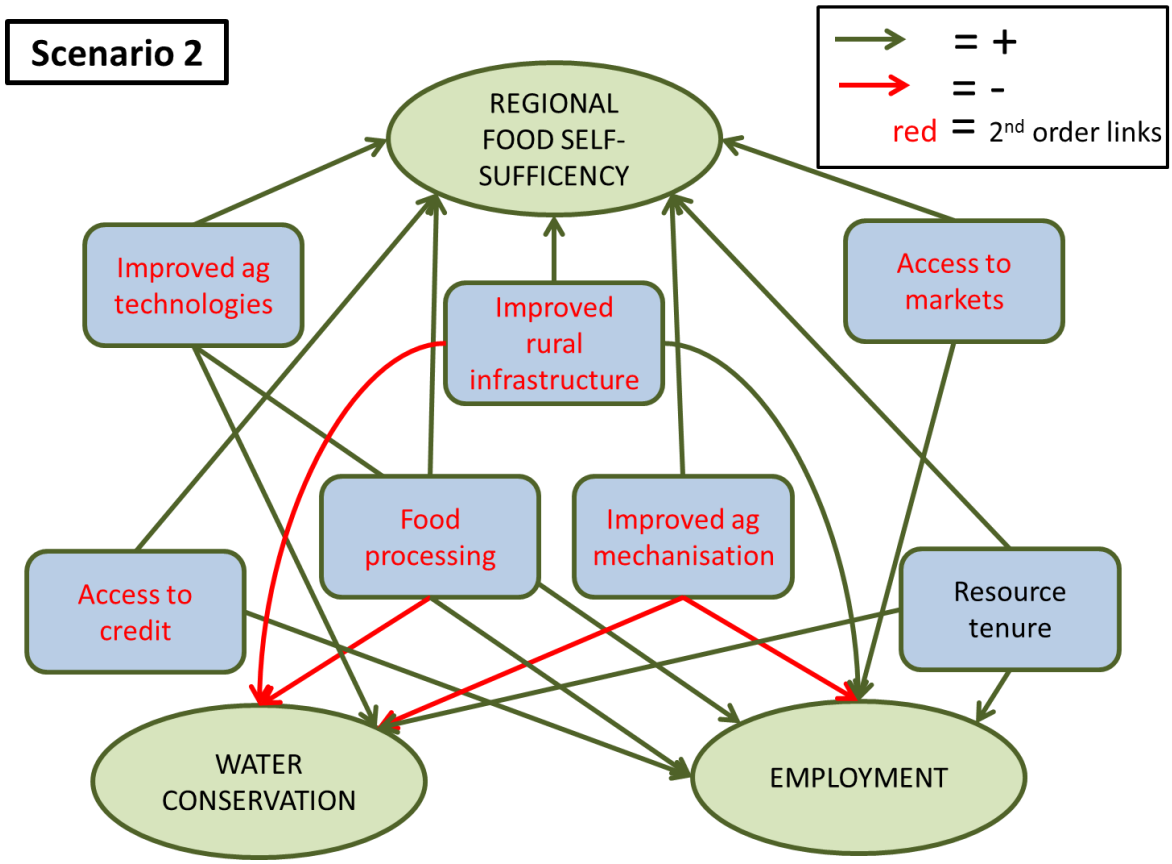
From the 2010s to the 2030s, an overarching trend in West Africa has been that problems that threaten well-being have been dealt with only after they became apparent. Structural problems of inequality remain unaddressed while governments scrambled to raise GDP. GDP development has inevitably led to some trickle-down effects for vulnerable groups in the region but these benefits have been minimal and unreliable. In fact, social and geographical inequalities in access to resources (finance, education, government support) have grown. In particular, the rural/urban divide is strengthened by the inequitable sharing of benefits from economic development, such as the crowding out of smallholder farmers.

Governments have had limited capacity and interest in fostering structural changes to lead to better education. Some effort has been put into reaching MDGs through short-term investments in the 2010s and a plan for the decentralization of education organization had been initiated but the need for resources to address security concerns trumped these plans.
Though access to health care for the middle and upper classes grows with the push for economic development in a narrow sense, little effort is put into health care improvement for the most vulnerable groups. Because of a lack of investment in education, the knowledge and skills needed for widespread, easily accessible health care are lacking. Where available, the quality of health care is questionable. Issues of shame predominate around disease and are not resolved through education. Sanitation issues arise due to increasing populations and contribute to the health problems of vulnerable communities.
The freedom of CSOs and NGOs to help vulnerable communities attain better livelihoods and well-beings has been curtailed by strict control-focused governments.
Crime is a problem for many vulnerable communities. Governments crack down on criminal activity but have not been able to deal with structural issues driving the growth of crime.
Some makeshift policies exist around social protection schemes but these have proven to be unreliable, badly implemented and largely cosmetic.
Overall, government actions to combat poverty are driven by political demand but though short-term, highly visible successes are achieved to win political good-will, these do not solve longer-term problems. No structural investments are made.

Environments:
Because governments in West Africa are primarily interested in narrow economic development and increasing food security in a very basic, productionist way, environments are badly affected.
Governments' ability to leverage the efforts of outside investors in land has meant the loss of natural environments. Land degradation has proceeded rapidly. As a result, biodiversity loss has been high as well. Dryland forests have been particularly severely affected.
Any government policies on environmental governance are largely cosmetic and are not implemented as such.
Marine biodiversity has also suffered because of massive fishing. There is algal biofuel production on the continental shelf – this activity, while producing energy, has also reduced marine biodiversity.
Pressures on water resources have further degraded natural environments.

Self-Determination

Figure A2 Main elements and relationships of the Self-Determination scenario.
Socio-economic context: together, slowly



In the 2010s, West African countries worked together to overcome regional instability in Mali and elsewhere. Investment policies in rural infrastructure, food security and agriculture and security competed for funds. Security (costly and unpredictable) and infrastructure development (high maintenance costs) proved to the main areas of government expenditure up to the mid 2010s. Toward 2020, governance conditions and infrastructure started to improve and GDP increased faster (partly due to mineral exports and increasing revenues from services), and investments in regional food security went up, as did policies to improve the livelihoods of the rural poor through services and education. The 2020s were characterized by financial and institutional integration. A second monetary union of English speaking countries was created by 2020 and later merged with ECOWAS in a union with a

common currency by 2030. Governments took the lead in economic development by inviting non-state actors in good and competitive funding schemes. Private small credit schemes were available to help boost small and medium enterprises, including the agricultural sector.

From the early 2020s on, states took an increasingly directive role in regulating local and regional markets including transport infrastructure. This changing role was drive stronger local governance due to real decentralization from the national level combined with harmonization at the regional level that took place by 2020. Subsidies were provided by the state for the production while private small schemes for credit were available for product processing, transport and commercialization. As national governments became more accountable to local authorities, regional organizations like CILSS and ECOWAS also became more accountable to countries and that led to the signature of an intra-regional trade/self-sufficiency policy with strong focus on sustainability of production systems.

A key component of new regional agreements involved the development of solar energy and hydropower to support the development in transport and industrial production chains. River Basin Organizations are successful in achieving tangible development goals, particularly in the hydropower subsector. Hydro energetic capacities of West Africa increased by 35%, though this success was marred by the regional disputes that the question ownership of this energy produced. At national scale, West African governments achieved a strong shift in institutional mind-sets with core ministries (energy, water, agriculture and environment) putting in place the right coordination mechanisms to tackle sustainable rural and agriculture development, to reduce deforestation and enhance food security in a single integrated agenda. Carbon sequestered from good agricultural practices was priced at 30 USD per ton leading to the removal of energy taxes and thus making energy cheaper and more accessible to larger proportion of the population. The 2020s did see difficulties to reduce transport costs, despite the availability of new infrastructure, due to the challenge of implementing successful inter-state conventions and regional policies on the free movement of persons, good and services, resulting in high costs for police, customs and gendarmerie checkpoints.

From 2030 to 2050:

Agriculture and food security: self-sufficient and nutritious

In the early 2010s, one third of the children under five years of age in West Africa were stunted due to micronutrient deficiencies, particularly lack of vitamin A, iron and iodine leading to high mortality rate of these children (220 deaths per 1000 live births). Overweight

and obesity were emerging problems in some urban populations and chronic energy deficiency affected 7-20% of women of West African region.

Boosted by greater political stability that allowed for higher GDP growth in the late 2010s, technologies for the fortification and improved breeding of key staple foods such as rice, maize and sorghum as well as yam, cassava and sweet potato were more effectively implemented because of harmonized policies at the regional level. In addition, food-based interventions were geared to natural food, better processing procedures including fortification processes to overcome and prevent malnutrition. All these actions contributed to improvements in physiological, mental and social development, enhanced learning potential and reduced nutritional disorders and contributed to the prevention of diet- related diseases. Community nutrition programmes were also developed for the region that promoted nutrition education and the consumption of under-utilized sources of vitamins and micronutrients. These measures helped to prevent and alleviate food deficiency disorders in 50% of cases by 2030.

Large scale regional irrigation plans have been implemented from 2018 on that additionally generate electricity for the processing of crop products. In addition to the large scale regional program, national small scale schemes of West African countries involving supplementary irrigation, rainwater harvesting or small reservoirs were also established and that brings the production close to market areas. The regional and national irrigation programs boosted the yield for the rainfed and inland valley systems by 2030 both for food staples and high-value export crops. A regional big airline, merging the small national companies, was created by ECOWAS in 2020 to ensure faster distribution of agricultural products and avoid losses. A regional railway funded by the African Development Bank and connecting costal countries (Benin, Ghana, Ivory Coast, Senegal, Togo) to landlocked countries (Burkina Faso, Mali, Niger) helped shift road freight to rail. Port facilities were also improved in costal countries for exports outside the region. The ability to communicate, share and access data revolutionized by internet and hand phones adds to the possibility to seize the most profitable opportunities and to easily commercialize the products within the west African market and outside.

Farming populations as a percentage of total populations fell steeply, from 80% to 35%, by 2030 and that translated in population redistribution in growth poles between farming and non-farming activities as well between rural and urban areas. As a consequence notable changes in diets with the shift towards a higher consumption of imported cereals (wheat and rice) were observed in the region. Remittances of people who moved out of farming sector and out of rural areas back to their origins helped those who remain there to improve their

production systems, living conditions as well as their diet habits. Successful boosts of regional production led to food aid reduction as mostly appropriate irrigation schemes were set in place in response to erratic rainfalls in the drier parts of the region. In conjunction with the change in rural population, the consumption of meat rich in iron was increased in association with that of fruit thus enhancing iron absorption from cereal and meat based food sources. However, dietary changes (increased consumption of saturated and trans-fatty acids, sugars, and salt) combined with more sedentary lifestyles did cause increases in the prevalence of overweight and obesity. Food processing was conducted in a way that improved the bioavailability of nutrients both as community level activity and as a market-oriented production to develop small and medium-scale enterprises.

The ROPPA's fight for food sovereignty prevented the states to sign economic partnerships with the EU but rather to help develop sustainable and modern family farming agriculture and agricultural businesses that have been productive and competitive both on intra-community and international markets. The regional integration of production and markets in one hand and in another the development of road systems and transportation infrastructures helped for a better distribution from poles of exceeding production areas (costal parts of the region) towards areas of low production potential for staple foods and vice versa for the meat. Indeed, the dry savanna proved more suitable for livestock production systems that also benefited from regional common agricultural and free trade policies. Livestock generally became less extensive under strict government regulations, but the intensification of production was also stimulated. In the quest for regional food sovereignty has had to grapple with strong global competition for a wide range of products.

A regional food safety policy was developed and enforced going from the production (use of pesticide, animal drugs, etc.) to the food and feed chains to avoid the consumption of contaminated products. Pre-harvesting practices, harvesting, transportation and storage practices were improved and supported by good storage capacities both at individual and community levels. Micro-financing schemes helped in acquiring storage facilities together with processing infrastructures insuring the availability of the food products and keeping the prices at a reasonable level. All these measures resulted in a reduction by 50% by 2030 of food toxins (mycotoxin, aflatoxin, etc.) and food diseases from production and storage segments. As the street food sector in the urban economy is still important in 2030 and almost all individuals regardless of their age or socio-economic status consume foods outside, actions were taken to address the poor sanitary conditions under which street foods are often prepared and sold resulting in serious food contamination and food-borne illness. Municipalities devised training activities for all operators of the sector and facilitated the establishment of hygienic facilities as well as environmental conditions for this activity. As

women are very active in that sector, they constituted the large part of the beneficiaries leading to a significant increase of their income. That allows them to have better food and nutrition security for them and their children, better health and schooling for the children.

Laws are established at the international level to recognize and reward the contribution of communities in the valuation of the organic or natural products. West Africa governments took measures to label foodstuffs containing GMOs, for the respect of farmers' rights, populations' food security and the environmental protection. Governments which decide to authorize GM products on their markets have developed a legal framework accordingly.

Livelihoods and well-being: the slow rise of a supported middle class

With rising GDP, average incomes in the region rose but because of this rise, equity decreased, following historic patterns seen in other regions. Still, boosted by a slow and late, but, by the 2020s, steady growth of education, economic development and increasing government support, the middle class in the region has grown from 34% of the population in 2012 to 50% of the population in 2030. The growth of human and social capital associated with this growing middle class has in turn started to strengthen government and non-government sectors. Consumption of domestic products in markets strongly guided by governments in the region increased with this rising middle class. As a consequence, household shares ownership increased by 20% by 2030 in national companies given them more voice. The need to diversify investments of the increasing middle-class was associated with a beginning of land grab by the new local rich forcing smallholders to sell their lands and become laborers, further adding to urbanization.

New land tenure regulations were adopted in 2020 guaranteeing land property for farmers and as a consequence conflicts between agriculturalists and pastoralists were reduced to some degree. Health centers and schools were set up in more and more rural areas over the 2020s. 25% of the rural households have access to internet by 2030. These communication tools helped farmers to be connected to market opportunities for crop products. As a consequence of better education and access to the information, farmer's organizations that are conscious of gender balance emerged around each main product, with strong negotiation power. The rapid diffusion of technologies such as mobile phones and internet to low-income consumers has given these people a stronger political voice and demonstrated the potential to provide them with universal access to basic services. But strong political voices have led to repeated demonstrations in the 2010s and in the 2020s that generated a lot of destruction of public property and private belongings. The social instability associated with these demonstrations

slowed down some of the investments that were devoted to social and production sectors including health, education, agriculture and the environment.

As local strong farmers' organizations have emerged, they have been active at national and regional levels. Under the pressure of local farmers' organization as well their regional representative which is the ROPPA, ECOWAS turned away from a European partnership negotiation in the early 2010 and focused on self-sufficiency instead. Such refusal gave more national and regional market opportunities to farmers and for their products.

Reforms in education have gone slowly, because first, funds had to be made available for investment in education, and then, educators had to be trained. West African governments struggled with finding funds and developing mechanisms for effective implementation of education development. By 2030, however, illiteracy was beginning to be reduced significantly in the ECOWAS region. Many of those getting access to education were women. The education of women particularly led to better health standards for children and the elderly.

A new land law was enacted which recognized the right for women to possess land and associated resources. Access to credit has also improved – government policies by 2030 specifically focused on a gender balance in credit access.

Health care workers became more widespread, and because of better education and working conditions there was less reason for those going into health care to emigrate. Child mortality dropped.

The greater emergence and specialization of entrepreneurs, specifically women, in processing areas added value to local products and generated more profit for producers when the power of middle men was regulated by governments. Local farmers' organizations grew in power and gave farmers better negotiation positions.

National job promotion policies based on youth (men and women) and focusing on self-employment were unsuccessful at first but once financial resources and government capacity grew in the 2020s, these were implemented with success leading to a parallel expansion of a real labor market for the region. By contrast, increased mechanization in agricultural production has reduced agricultural employment and further contributed to the shift of youth out of agriculture.

Environments:

Conservation policies in West Africa took time to develop, since there were so many connected challenges (food security, education, political security, economic development) to tackle up to the 2020s. However, with growing education and economic welfare based on long-term policy strategies, attention to environmental governance grew in the 2020s. This was urgently needed – by the 2020s, development was increasingly affecting natural areas.

Large projects such as the Great Green Wall, Regreening the Sahel picked up in the 2020s and contributed to plant cover and agriculture in rural areas.

By the early 2030s, effects of conservation and protected area policies meant that rare species began to flourish again. Eco-tourism developed.

A strong ECOWAS retracted the licenses of foreign countries such as Russia and China to fish in its territorial waters. Smaller fishermen were able to support themselves more and less encroachment into neighboring waters was needed.

In spite of the regreening observed at present in the Sahel, many rural communities are still at the mercy of the floods caused by quicksands or dunes which threaten villages and even with urban areas. The World Bank's efforts during early 2020s at conserving critical habitats and species in West Africa coastal areas have had success in their stated goals; however, this included the reestablishment of seasonal floods in the River Delta and many local populations were effected in the 2020s. Today, the region is less populated and residents have had to relocate, an expensive and upending process.

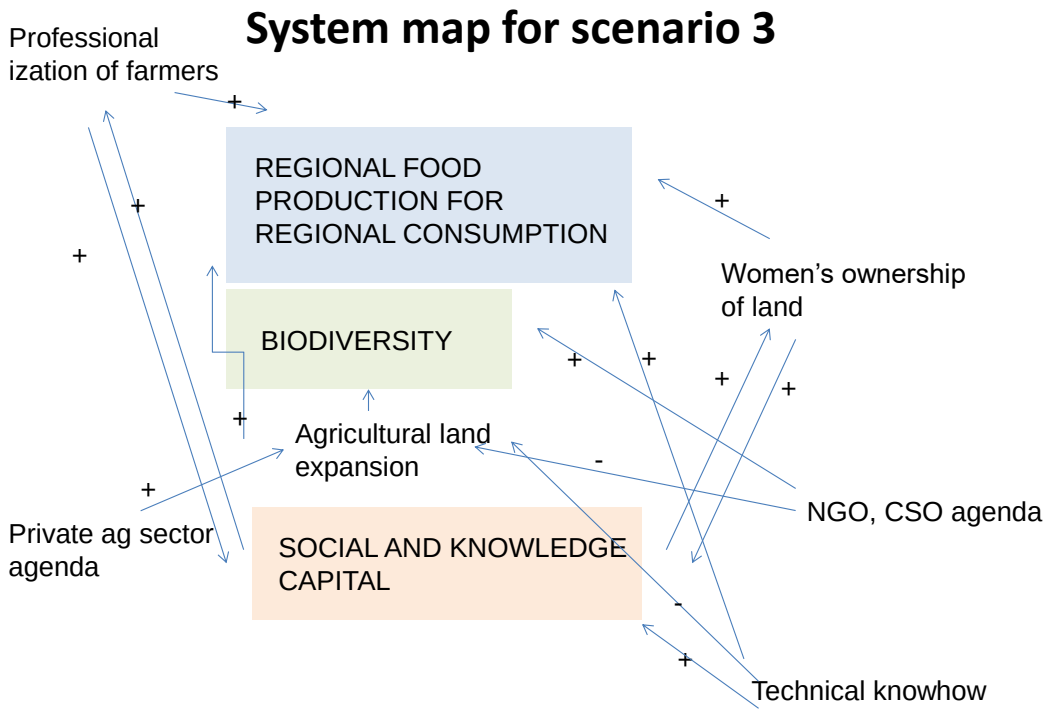
In 2030, quality of watercourses in West Africa has significantly increased. The countries have established water sector strategies and reforms at national and transboundary levels. At national level, water sector reforms include: establishing new institutions to improve the coordination of water resources development and management and creation of a common approach for water laws; decentralization and devolvement of responsibilities to the lowest appropriate level; increase investment in the water sector infrastructure, etc. The harnessing of drinking water is now often located near production units, without requiring of expensive treatments. Privatization efforts and infrastructure improvements have increased the quantity and quality of the water system through the use of water meters, pump systems, and network densification. One of the first issues that had to be addressed was the low literacy rate, the improvement of which has made water management contracts and tools available to large segments of people who were previously unable to understand and articulate such transactions. However, the high water consumption required to make water service profitable

for the private sector in rural areas presents a problem of wasteful domestic use and risks to the environment stability and depletion of underground water resources.

In 2030, a progress of afforestation is underway at the level of West African coast thanks to the programs of conservation and restoration of the mangrove swamp. After a period of decline, more than 165 protected marine areas were created offering to population a source of incomes with ecotourism, fishing and the oyster farming.
In terms of air quality, once rapid assessment techniques were implemented through Air Quality Monitoring (AQM) plans, the ability to combat health effects, such as addressing higher rates of asthma in urban centers, greatly improved. By 2025, daily particulate matter measured in many West African Cities dropped below the World Health Organization guideline value for the first time since urbanization. The establishment of national emission standard regulations was an essential part of reversing this trend. The ban against importing cars older than five years has allowed the fleet used today to enjoy the benefits of improved technology.

Civil Society to the Rescue?

Figure A3 Main elements and relationships of the Civil Society to the Rescue? scenario.
Socio-economic context: from turmoil to dynamic development



West Africa has seen a growing disparity between rather weak and passive governments and active, increasingly focused and powerful forces in both civil society and the private sector.

Private sector companies within West Africa and from outside the region have become increasingly conscious of the value of long-term investments in the region – but these investments have primarily focused on large-scale agriculture, industry and services. Civil society, in the meantime, first flourished in a relatively uncoordinated way up to 2020 and then became increasingly organized and able to rally political support and influence government policies in the interests of rural development and social equality as well as environmental management.

The period from 2012 to 2020 has also seen large economic and political instability in the region. In late 2011, the breakout of some identity-based conflicts (Tuareg rebellions), and of religious extremism (Boko Haram and AQIM) led to an influx of migrants and refugees at border areas, including those fleeing their countries because of wars and those who were sent back for peculiar reasons raised by States. This was followed with a second failure of Libya causing an influx of weapons and an economic crash in West Africa and, combined with the growing influence of extremist factions, has seen episodes similar to the coup in Mali threatening more countries in the region. This instability has further weakened governments and bolstered civil society, eventually leading to a manageable political stability. After the turmoil of decade leading up to 2020, both civil society organizations and private sector interests emerge with feasible and robust long-term goals.

Civil society in particular has gained in power due to its ability to leverage the influence of global organizations and prevent negative impacts of outside military interventions to mitigate the conflicts in northern Mali and elsewhere.

By 2030, private sector companies and powerful civil society actors are in a tense relationship while governments are a rather ineffective, unwilling tool in the eyes of both groups of actors.

Tension between NGOs and governments before 2020 leads to the governments demanding audits. The need to compete between civil society organizations and private sector is there, but there is also a need to collaborate. As a result, each actor gets more information about other actors because of the need for transparency which on occasion leads to better collaboration. The greater effectiveness of the private sector and civil society shifts power to them and away from governments in a positive feedback loop.

After 2020, GDP increased gradually and still relatively slowly because of governments' relative inability to foster investment and the aftershocks of political instability. Urbanisation is relatively slow in this last decade due to decentralization and provision of basic services in rural areas.

Sectors where it has been most clear that governments are relatively weak are infrastructure planning – civil society organizations don't have the power to invest in roads and similar big infrastructure. Developments in infrastructure sectors are dependent on only semi-coordinated private investment. Similarly, there is relatively little change in the level of corruption and crime because governments remain ineffective on these topics.

From 2030 to 2050:

Food and nutrition security: a battle for all

Private sector investments in big agriculture and civil society initiatives to increase regional food security clash but also strengthen each other. In 2015 there is pressure on farmers to become market oriented, leading to professionalization of farmers by 2020. By 2025, this leads to increased access to credit for small and medium size independent farmers, ultimately contributing strongly to yield increases and production of staple food in West Africa. Pressure from CSOs from around 2015 leads to better collaboration between researchers and farmers by 2020. By 2025, this leads to better technology adoption which results in more autonomous food production both at the level of communities and the region. The professionalization of farmers led to more compatibility with larger private sector interests. Livestock production and yields went op because of an increased demand for animal products due to rising incomes and urbanisation.

In the years around 2020, NGOs and CSOs claimed - through hunger protests and statement to the governments of those countries - steps to reduce the impacts of malnutrition on the population. Part of the statement of CSOs in countries affected by food insecurity was: *"We are exposing the lack of information on the situation of supply and demand for agricultural products, the lack of transparency on the markets, the sudden changes triggered by the situation of food insecurity in some countries".* They recommended that States adopt alternative measures to mitigate the volatility of food prices and new mechanisms to increase transparency and to manage the risks associated with new sources of market instability.

Private sector development means that there has been a gradual expansion of cropland and numerous ranches were created. There is a strong increase of export in cash crops out of West

Africa by 2030 Agricultural expansion has led to the resurgence of land-based conflicts and conflicts between users of other natural resources. Commercial farming and smallholders fight over water supply in 2015. Also, limited access to resources for smallholder farmers means that by 2025, conflicts between smallholders erupt. Local CSOs put pressure on smallholders to assert their rights, backed by global donors. This causes conflict with an increasingly strong and politically dominant export oriented private sector which is interested in obtaining land from smallholders. As a result, smallholders in 2030 are still caught in a food fight between the private sector and other civil society groups. However, the assertion of rural communities' rights has also led to an empowerment of women and their ability to own land and gain access to knowledge and resources. Increased international attention and funding of women's right from 2015 puts pressure on gender issues from NGOs, CSOs on government and communities. As a result, by 2025, women's ownership of land is increased. This has led to greater community food security in the region.

By 2025, the private sector and civil society fight and collaborate over influence in shaping agricultural policies at national and regional levels. New policies for water infrastructure that emerge from earlier disputes are mildly successful and lead to some increase in access to water for farming and livestock, also contributing to autonomous regional production. Through increased opportunities for wage labour because of private sector investment and the struggle of CSOs to turn this investment into work, there is now more cash income and thus more money to buy food in 2030.

During the 2010-2020 decade, civil society played a significant role in food security and agricultural development with an emphasis on access to social security and access to food as well as food exchange between secure and insecure regions. CSOs radicalized their struggle to draw the attention of producers on the hazards involved in access to GMOs. In 2030, rural professional organizations influence parliaments. Under pressure from non-state actors, laws and regulations are adopted at the state level to regulate the use of GMOs.

From 2020 to 2030, the rate of population growth was high in the region, leading to increased competition for resources and food, followed by increased production of livestock ensuing from the boom of forage production. The increased availability of food resources to those living in urban areas increased nutrition security for those populations, while in the years up to 2030 nutrition security has increased primarily through increased access to knowledge of nutrition in rural areas. Unsold food surpluses are increasingly directed to the processing sector (for food and feed) and marketing after packaging generates more incomes for populations to invest.

Human well-being: empowered communities caught in the middle

Abandoned by governments and limited by social stereotypes, rural communities and in particular the marginalized groups within them work to change their social status and to achieve better community representation. This leads to greater community self-organization and professionalism. Communities become more self-empowered. Women own more land. Also, by 2030, many farmers have become ICT-enabled "Techno-paysannes". Increases in social and knowledge capital are driven by and driving the professionalization of farmers and technical know-how as well as women's ownership of land. However, private sector interests function as both a pressure and a benefactor for rural communities, contributing to professionalism and community self-organization in the 2020s. Private sector investments are also heavily involved in land-grabbing, putting rural communities under pressure.

In 2010-2015, organizations (NGOs, associations and CSOs) were fighting for the welfare of the poor in vulnerable rural communities amid regional turmoil. In the years up to 2020, across the world and especially in West Africa, gender equity became a topical issue in every social forum with support from NGOs and national and international CSOs and supranational, regional organizations that worked for the advancement of women and children. In several countries this pressure has led to legislation and policy documents being adopted to address issues related to gender. On this basis the rate of girls attending primary and secondary education increased in all countries by 2030. Also, by 2020, states were required to set up laws that provide key positions (parliamentarians, business leaders, government leaders, presidents of institutions) to women, though governments' capacity to implement and enforce these laws has been rather weak. In terms of gender equality, there is effective law enforcement for the advancement of women; a redefinition of women's access to land and mechanisms are developed to enable women to combine family activities with employment. The number of women in paid non-farm employment is steadily rising because of these changes. Women's parliamentary representation (regional and state) has reached a very high level in most countries. Furthermore, urbanisation leads to more availability of education for women, as do investments by governments. Women's literacy rate is ultimately high 2030 because of civil society involvement and provision of education services. Pressures on resources and a shifting gender balance in land ownership do cause strife at the community level.

Furthermore, taking into account customs and habits led to an increase in the enrolment of children in primary schools. Many publications, debates and posters for public awareness were generated promoting national languages. Similarly, access for youth to secondary education registered noticeable progress in countries since early 2010. These allowed

children with no schooling to attend literacy programs. To refocus and begin the process of developing of the countries, new curricula were developed in schools and universities in the sub-region. The number and quality high schools and the lessons they provide lead to high success. Countering this, political instability resulted in an increase in the number of the unemployed, especially among young graduates and the situation of crisis in some states will weaken the labour market. In 2025, when political instability had calmed down, a better restructured knowledge production system, invested in by the private sector and guided by civil society demands, led to the creation of skilled employment in rural areas. Producers engaged in the private sector with the multiplication of ranches, poultry farms and gardens to meet food needs. There is an increase in the number of people/households working 8 hours a day for a salary that can pay for essentials for the household welfare.

The civil and private sectors have been investing heavily in communication. For example, the mobile phone industry has grown increasingly important in the countries, allowing access by the majority of the population to mobile and internet services even in the most remote areas.

In 2020, banks and other savings institutions are more interested in rural areas than was previously the case. Initiatives have been launched to encourage farmers to develop business initiatives and projects, with high amounts of money granted to invest in the production, processing and marketing of agricultural products. When financial resources were generated, the beneficiaries put their incomes in banks in the form of local savings. The insurance sector has in turn been increasing its attention to rural areas, providing insurance policies in case of diseases and other disasters that may occur among farmers.

Civil society organizations have focused on the development of social capital by taking into consideration traditional structures and values in dialogues to prevent and reduce community conflicts. Through NGO/CSO pressure, populations have access to information on laws through special dissemination centres created for this purpose.

While clashing in other sectors, CSOs and private companies in the health sector eventually work together to facilitate the recruitment of skilled health workers to raise the ratio of physicians/residents and village health centres. This has a moderate effect on the availability of health care - CSOs are not best equipped to deal with health care without government collaboration and the private sector is limited by its business models. Poverty goes down slowly. Malaria goes down slowly because the above, but easily deployable technology. Social protection schemes increase moderately under pressure from CSOs.

Environments: green hills and groundwater

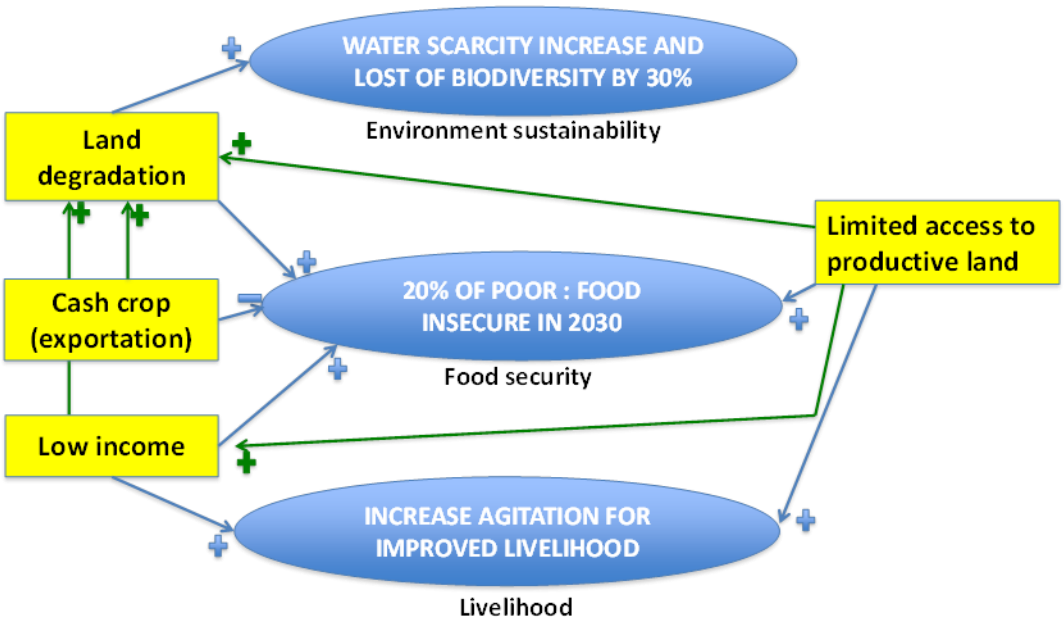
From 2012 to 2014, as population growth increases, the demand grew for energy sources (firewood, charcoal); so did the needs of rural populations for wood (building fences and shelters). This has led to excessive wood cutting. Also, this was accompanied by frequent bush fires that caused the reduction in the vegetation cover. Furthermore, livestock systems are expanded at the expense of natural land. NGOs gaining in power and pressuring governments from 2015 on has led to pro-forest policies and the rehabilitation of hills and a largely successful implementation of the Great Green Wall. Through both civil society and private sector support, environmental officers are trained and equipped to estimate the percentage of vegetation cover through GIS. It became possible to estimate the number of trees per area (measured from satellites). Large areas of land have been restored and a significant number of trees were planted. Community forests help eventually lead to integrated agriculture and agroforestry that helps return forest cover in many parts of the region. This in turn has a negative effect on livestock numbers by 2030. Replanting schemes and conservation efforts are countered by private sector-driven agricultural intensification and expansion that drives more logging. By 2020, also, private sector-driven expansion and intensification had led to increased pollution. Governments are finally driven to enforce regular inspections regarding compliance with environmental standards in 2030. On the whole, though, terrestrial biodiversity degradation was largely halted by 2030. In contrast, marine biodiversity continued to be degraded by fishery.

For usage in various sectors, from 2010-2015, water was not available or insufficient to cover the needs of the overall population. When it is found, it is on the surfaces, rivers and very deep groundwater. At the rural areas, the access rate to drinking water was very low. In response to this, some methods and technologies had been developed by the private sector, as part of their broad push for development, for groundwater management for industry and consumption. For quality, following the improvement of some rural water supply networks, analytical laboratories were available to detect impurities in water before use and this has helped to reduce exposures of population to waterborne diseases. Indeed, a number of water meters were made available in urban and rural areas, thereby increasing the number of water points for individuals and households who now have their own taps for water supply. Because of this, the poverty index for quantity and quality water has improved gradually in cities and rural areas. However, the fact that private companies controlled so much of the water infrastructure that water availability for the poorest remained limited.

Save Yourself

Figure A4 Main elements and relationships in the scenario “Save yourself”.

Socio-economic context: an unstable new world



West Africa has seen decades of economic and political turmoil by 2030. Though economic development has been strong through the activities of West African and international private companies in multiple sectors including commercial agriculture, this has not led to greater stability because of the inability of governments to harness this growth to resolve inequalities and poverty and mitigate tensions and conflicts. The extreme freedom offered to market forces in the region has led an increased regional GDP. It has also, however, led to the relative free reign of business cartels that have perverted potential benefits of this growth for vulnerable communities in the region. The private sector has operated in West Africa primarily out of interest in short-term gains and has therefore only marginally invested in infrastructure with West African governments. Government budgets have gone up and part of these new resources have been spent on infrastructure, but this has not been a priority. Illegal commerce through West Africa has also increased, including the rise of drug trade routes from Latin America to Europe – contributing to political instability and insecurity. The number of civil society and community-based organizations skyrocketed in response to relative passivity of governments and the very dynamic and forceful presence of private sector interests. This has led to mitigation of the worst consequences of the region’s chaotic dynamism in some cases and even to productive collaborations with the private sector in

sectors such as education. However, these civil society organizations have mainly been interested in their own short-term objectives and operated in a very chaotic fashion, especially up to 2025. More recently, CSOs have become more focused and organized, but the short-term perspective still dominates in 2030.

The region's corruption index has risen steeply and though attempts are made to control the most extreme cases, it is a self-sustaining cycle that neither governments nor non-state actors can break. Similarly, crime rates in the region increased steeply, and life is very unsafe with regional political instability being exacerbated by international drug cartels which has threatened to turn the most unstable West African states into all but narco-countries. There has been a high incidence of human trafficking through the most unstable countries (e.g. Mali) in the region.

The emergence of more focused and influential civil society actors impacting the governance structure has brought about some promises of change to food security, livelihoods and environments in 2030. Although some new policies look like they will pay off, there is still endemic poverty with about 8 out of every 10 persons living below the poverty line in countries like Senegal, Mali, Niger and Burkina Faso. Although poverty levels in Ghana have been decreasing there are still areas with poverty levels of above the national average of about 25 per cent. This is a consequence of the influence of private sector companies with short-term, self-directed interests in the determination of policies and the inability of policy makers to steer those interests toward public good.

From 2030 to 2050:

Food security: e-food machines and rural hunger

In 2030, rural communities in most countries in West Africa are threatened with food insecurity due to the proliferation of commercial agricultural enterprises whose sole aim is producing for the international market. Whilst these commercial entities have created some job avenues for young people, their activities have denied a substantial proportion of local producers their sources of livelihood. Today, many indigenous farmers are experiencing lower yield levels compared to those levels in 2010 due to the move to highly marginal lands that are naturally prone to high rates of degradation and low productive capacity. The situation has worsened because of increasing drought events due to climate variability. There are improved varieties of cereals, legumes and root and tuber crops that have the potential of increasing food availability locally but require high input of fertilizers and associated inputs that are inaccessible to indigenous producers because of production costs which have gone up steeply with the rising costs of resources. Though region has seen no reformative change in

e.g. infrastructure some technology improvements have become available to commercial farmers.

Due to low levels of production for local markets and strong trade liberalization policies of state governments, food imports are largely unrestricted. The government of Senegal passed a free trade and exchange law in 2021 which further increased the competition between local and imported products. Over 55000 containers of various food items from South Asia were imported through the Senegalese port alone in 2025. The quality of these food items cannot be guaranteed since there is not enough legislation to enforce food safety standards. The promotion of increased chemical fertilizer use and OGM varieties to meet was produced domestically. In northern Mali where, despite politically unstable conditions, the government leases the land to China Green Food Inc. (CGF) since 2020 food production has increased but the quality of food available to local communities has decreased as vegetables which comply with world quality standards are sold abroad in European market while the remaining food is sold locally. CGF is, by now, the top producer of vegetables sold in Europe. In Mali, 2018 saw demonstrations in Tombouctou against the newly implanted Chinese industries which produce cheap vegetables and prevent farmers to sell their goods. But the demonstration was severely reprimanded by the police as the elected mayor had some share in the enterprise.

The private sector naturally focuses on cash crops in terms of yield growth; private sector investment in yield growth has some moderate spillover effects for smallholders working in rainfed agriculture. In terms of irrigated crops, farmers themselves invested responding to rising prices, with no effective government support. Rainfed agriculture has continued to expand with population pressures, causing conflicts over land tenure across the region. Similarly, irrigated arable land expansion has initially continued, driven by the private sector. However, while the period up to 2020 sees a rapid increase in land expansion, but this increase stagnates as viable agricultural and pasture lands run out. Additionally, due to the increased pressure of growing populations on available food, important sources of domestic food from forests have been depleted.

In contrast to the dismal state of rural food security, in urban environments there is an increase of available food and an increased dietary diversity because of a veritable invasion by food manufacturers in the region. A symbol of this change in available food diversity is the e-food machine, an ICT- supported food dispenser that has many instant foods and can be found anywhere in West Africa. There are some problems with this massive scale food processing and distribution, though: there have been instances of contaminated food that have wide momentary impacts on health and even cause some casualties in the region. In Ghana, Kumasi hospital statistics show that 20% of intoxication cases have been declared to have

cause by unsafe food while in Mali the number of intoxication cases caused by unsafe food is 38%. Despite these scares, people in urban areas turn to massively produced, internationally-run instant food more and more. The older generation still remembers in the 2010s where people used to sit on a table each evening to eat in family. Since then, longer work hours have meant that those who can afford it turn to the e-food machine. With a note of ¼ West African dollar one can buy lunch and a canned tomato juice. Increased meat consumption has generated problems with obesity in the urban centres. The ratio is less severe in Burkina and Niger where people do more exercise and use bicycles in cities. In Northern Ghana where German imported cows produce meat and milk in millions of tones, cholesterol levels are very high among the middle class. In the city of Tamale cholesterol is recorded to be at dangerous levels for many young people as well as elders. Civil society organizations emerge that address concerns about obesity. In Senegal for example the association "eating better" has demanded of the government that action should be taken more taxes on junk food sold in high schools. But the government plan never passed parliament due to the leaning on the votes by the private sector. Responding to the rising demand in livestock products, livestock numbers expand largely unregulated and rangeland expansion runs into conflict with arable land expansion. There is very little long-term investment in yield increase for livestock. The over-use of N fertilizer is mitigated by the introduction of a new N-fixing Maize which helps stop land degradation. This in turn leads to a significant drop of the maize prize.

Livelihoods and wellbeing: divisions

The percentage of population in poverty has decreased somewhat with the rising GDP of the region, though this increase has been less as some have expected because they underestimated the resilience of the disparity between different societal groups – and because the middle and upper classes have seen their incomes increase the equity in West African countries has actually decreased.

West Africa has seen extremely high rates of migration to urban centres because of international companies coming in and stimulating labour in the cities. Additionally, land-grapping has moved many from their homes and has had them looking for other opportunities in the cities. The rise of the international carbon price leads multinationals to aim for short-term carbon markets in West Africa, leading to land conflicts between multinationals and smallholders. The livelihoods of most indigenous farmers who are still in rural areas have been in jeopardy because of the distortions created by such changes. Payments received from working on commercial farms are just enough for smallholders to pay for local staples whose prices have been increasing since 2010. Commercial entities have occasionally provided facilities like tap water, electricity and school infrastructure, to attract or keep the necessary

labour force for their enterprises. In most rural areas though, youth continue to leave because remunerations received are not enough. Rice cultivation in the so called now “quartier du bas fond” until 2019 used to be a profitable enterprise and major source of livelihood for an appreciable proportion of people living in Bamako, but has permanently ceased by 2030.

Employment is very uncertain for wage labourers because employers can lay off as many as they want without any trouble. The law protects employers. Those who have a job have to work very hard as much as 12 hours per day in order to be able to make it. It is rare to find middle class individuals able to support families with only one job. Small strips of land surrounding Dakar belong to civil servants working as teachers in private schools and in similar positions. Employed youths work in factories. Those who suffer the most are women who usually do very difficult jobs and small jobs in farms or selling goods. Senegal and Mali are an exception, providing fairer conditions for women as, due to civil society pressure after 2020, they were able to pass the “la loi sur la parité” which requires equality in the number of men and women in any elective position and similar rules for employment.

In terms of social protection, there is a lot of activity from private sector social security schemes in collaboration with civil society organizations, to the benefit of the many who are eligible. However, there is exclusion of the poorest and most vulnerable who are not able to invest in such schemes. Access to healthcare has suffered amid the regional turmoil. Prices have been too high, and the poorest have mainly relied on street medicine of they could afford it. The pervasiveness of fake medicaments has had damaging consequences on the health of these vulnerable groups. There has been an increasing incidence of epidemics in the region, often environment-borne outbreaks. A lack of infrastructure and facilities to reach and treat sick has crippled efforts to mitigate these outbreaks, though despite this limitations CSOs and NGOs have been able to moderate some of the impacts in a patchy fashion. Private education is available but big funds are needed and short-term CSOs concentrate on primary education, not focusing on tertiary education.

In terms of changes in the rate of literacy among women, the states have continued to do what they have done in the years leading up to 2012. Civil society organizations attempt to plug the holes, and there is some minor private sector involvement where it is deemed profitable to invest in women’s education. However, there is a measure of anarchy to these attempts. Women’s literacy rates remain highly linked to income.

Environments: paying the price

Deforestation over the last decades has occurred at very high rates – there have been huge pressures to expand other land types and even civil society has very little time for the conservation of natural environments with more pressing concerns grabbing public attention. Terrestrial biodiversity loss is somewhat hampered by a select group of active civil society organizations who protest fiercely against the loss of natural land. However, decline has been and continues to be the trend.

Water availability for multiple uses continues to decrease across the sub-region. Most of the important rivers that used to provide multiple use service have been reduced in size. The reduction in size of these rivers has been attributed to both unsustainable exploitation and climate change effects. The building of 4 dams on River Niger Sokoto has changed its course and it no longer flows through Mali. Only two bridges serve as a remembrance of former Niger River in Mali. The pollution of the Niger River is a killer. Industry producing lead is polluting the river just outside Niamey, the former capital of Niger. The association for water quality has pressed charge against the German industry recycling atomic waste south of Kumasi. Additionally, increase in the activities of small mining groups has led to the pollution of important water bodies that supply water to urban towns and cities. This explains the problem that we experience in Bamako for water supply. In Ghana the River Densu which used to supply about 50 percent of the water requirement of Accra and its environs between 2015 and 2020 is almost depleted, forcing local government authorities to turn their attention to the exploitation of underground water for both domestic and urban agriculture uses since 2023. Today, over 6 percent of potable water comes from underground water sources.

The liberalization of rice production in Senegal river valleys has been beneficial in terms of increases in productivity and production resulting a strong reduction in rice imports since 2025. This has however reduced availability of water for both domestic and agriculture purposes to indigenous people through access restrictions and pollution.

Increasing rural to urban migration has produced large urban slums with their associated sanitation problems. Urban water bodies continue to be polluted by both solid and liquid waste resulting in the ‘death’ of such rivers as Odaw in Accra. However, by 2030 a policy of the Government of Ghana to improve urban waste management through the building of infrastructure for waste conversion has paid off; over 150,000 tons of compost is being produced annually from organic waste since 2020.

Senegal has benefited financially through a private-sector oriented policy of liberating the rice production in its valley. 10% of the land around the river valley is exploited for food production by the French private company “Melon et fils”. This activity has, however, restricted and polluted the drinkable water.

Expansion and population increases have put huge pressures on water availability for agriculture. However, governments and private sector work together mostly effectively to increase water availability. Access to water is being targeted by CSOs as well, because governments and the private sector do not focus on vulnerable rural communities. A technology for desalinizing sea water is being piloted in Ghana in 2030 which looks hopeful in its ability to increase water availability in most coastal towns and cities. Burkina still buy water from Niger from December to May and has intensified its cloud seeding experiment through private sector funds, the effects of which allow for enough water until November. In the meantime, marine biodiversity is strongly reduced because there are no attempts to mitigate fisheries and pollution.

Intensified agriculture has led to degradation of the soil. The increasing use of marginal lands by rural communities has resulted in increased land degradation in almost all countries. Today in Ghana, the northern savannah zone has lost much its forest cover compared with 2010.

The increasing destruction of vegetative cover coupled with high rates of erosion has resulted in the siltation of rivers and streams rendering them seasonal. There is also increased occurrence of flush floods due to the reduction in carrying capacity of most streams and rivers. Soil degradation has converted to faster runoff which has further increased flooding.

Appendix C: Semi-Quantitative Indicators

The tables below (1 to 4) provide semi-quantitative information about the developments of a number of indicators for economy and governance, food production and food security, livelihoods and environments for the four scenarios for Western Africa. In discussion with stakeholders, care was taken to specify the direction of change in each variable, and provide logic driving the change. Capturing the logic behind each change helps interpret further analyses using the scenarios as well as the quantitative model outputs.

The consistency between indicators was also reviewed with the stakeholders while developing these assessments of directions of change.

Table C1: Cash, Control, Calories Semi-Quantified Indicators

Indicator	2010-2020	2020-2030	Logic for change	2030-2050	Logic for change	Volatility
Gross Domestic Product	++	=	Initial boosts are not sustained as long-term growth	+	Periodical boosts and plateauing; reactive	Highly volatile
Women with higher education	+	+	urbanisation - schools/high education institutions nearby; more focus on primary education (school feeding programs); business schools	+	trend continues	high difference between years
Yields for rainfed crops	+	-	more rainfed area expansion under low-input with lower concern for sustainability. Effects of land degradation, climate change, low intensification	-	Lack of long-term thinking, hard to repair once degraded	Very high

Yields for irrigated crops	+	+	conservative estimate as yield gap lower in irrigated crops	-	Lack of long-term thinking, hard to repair once degraded	Very high
Area for rainfed arable land	+++	+++	No concern or policies for informal expansion by governments	++	Rural populations looking for lands because they are crowded out; leads to conflicts	Highly volatile
Area for irrigated arable land	+	+	Short-termism prevents heavy investment in irrigation infrastructure	+	Same trend	Slow
Livestock numbers	+	+	Animal feed available (through irrigation) - increased demand (population growth/urbanization)	-	More focus on imports	Unstable
Livestock yield change	+	+	New breeds, new inputs but no structural investment	=	Veterinary services decrease	Unstable
Access to potable water	+	+	Government investment, focusing on a short-term issue; debate for privatization will be high	=	Failure of long-term insight into population growth	Unstable
Forest cover	---	--	population increases - cropland encroachment in rangelands and forest due to increased land demand - urbanisation - extension of land areas - deforestation (fuelwood); some funds from mitigation donors implemented	-	Interest from governments only with regard to climate adaptation on the short term	Relatively slow

Farmer input prices	++	+	Some buffering, politically motivated by governments who need to stay in power, periodical	++	Same as before	Unstable
Urbanization	++	++	urbanization - state services provisions. States provide housing, motivated by political campaigns	++	Highly urbanised, dependent on import	
Transportation infrastructure	+	+	Some fast investment into infrastructure for big rural development and food exchange between secure and insecure regions	+	Low quality investment; local companies for the cheapest deal;	Slow
Dietary diversity	+	+	Urban consumers will drive change; consume more that is not produced domestically; sugars, edible oils and fats	+	Further openness of markets; diverse food with poor quality	Unstable
Reports of contaminated food/ food borne diseases; aflatoxins	+	=	Massive increases in livestock production; food cooked - increased use of chemicals in a controlled way; imported fish from Chinese fisheries; purchasing power is the problem	=	Trade liberalization continues but government regulation is also rather strict	Unstable

Marine species biodiversity indicator	--	--	Government action but very hard to implement, effects beyond national waters; in 20 years dwindling of fish stocks in the coastal areas; algal biofuel production on the continental shelf	--	Trend of decrease continues	Gradual
Terrestrial species biodiversity indicator	--	--	Overall decrease; some minor government control	--	Trend of decrease continues	Gradual
water availability for agriculture	-	-	Increased technology support for increasing water efficiency but very high pressures on water availability (population, industrialization) - states compete for consumption	=	Very unstable water availability - short-term remedies	Unstable
Existence of social protection schemes; percent population covered	+	+	Makeshift policies, unreliable	=	Each new government brings in new plans to get voters - but no consistency - mostly concerned with urban work force, little attention to rural social protection	Unstable
Number of community based organizations	+	+	moderated by government - decentralization + community organizations	=	Number will be the same; number of active CSOs will decrease; government pushes for federation	Unstable, follows political change

Crime rates	+	+	Short-term focused government will crack down on crime; but cannot deal with structural issues	=	Reactive policies to get rid of problems of that day - but new problems emerge constantly; unemployment	Very volatile
Corruption index	+	+	International crime, funding for equitable development redirected to other areas; big money to be made in big deals	+	The trend of previous decades continues; culture of selfish business	Unstable
Access to health care	=	+	Government and private sector investments are limited, knowledge capacity limited, slow, quality questionable	+	Trend continues; population overwhelms available health care; capacity to deal with some emergencies does exist; governments can leverage donor funds well.	Unstable
Prevalence of malaria	+	+	Shame related to disease - sanitation issues due to increasing population	+	Governments are able to cure but not prevent	Pervasive
Percent population in poverty	-	-	Government action on poverty driven by politics, but no structural investments	-	Will keep decreasing slightly driven by momentary action	Poverty peaks and falls regularly
Equity	-	-	rising GDP, following historic trends	-	not too much because of government work on worst poverty	Unstable

Table C2: Self-Determination Semi-Quantified Indicators

Indicator	2010-2020	2020-2030	Logic for change	2030-2050	Logic for change	Volatility
Gross Domestic Product	+	+	Some countries already involved in long-term transformation. Others will have to make an effort. Minerals exported/divide between countries, artificial way of changing GDP through services	++	Transition into services and secondary industry, agricultural production; processing	Volatility decreases
Women with higher education	+	+	Time lag in education; focus on vocational education	++	This generation reaps the benefits of earlier investment in education	Slow variable
Yields for rainfed crops	+	+	Capital investment takes time; Strong government will but few resources; market signals drive yield investments supported by governments. Backup irrigation systems implemented.	++	After period of trial and error, institutions are now strong enough, and capacitated enough to cause real improvements; governments are investing in research and development	Variability decreases somewhat
Yields for irrigated crops	+	+	Water a limiting factor but may be available at a continental level; technology a limited factor; new tech needs strong organization; better management; cultivars; hybrids; better water management; two crops per year	++	Once irrigation schemes are widely implemented, yields can increase strongly	Medium instability

Area for rainfed arable land	++	++	Growing population but land use planning for sustainable management starts to become effective	+	Effective land use management policies; higher yields	Slow variable
Area for irrigated arable land	++	++	Planning mitigates increase; regulated water pricing; sustainable water use; medium-sized farms with government support	+++	Once institutional capacity and political will is there, small irrigation schemes are easy to apply widely; sensitized by climate change concerns	Slow variable
Livestock numbers	++	++	Responds to demand and government planning	++	Demand continues and government support remains	Unstable as much as affected by inputs
Livestock yield change	++	++	Government planning to support yield increase	++	Trend continues	Affected by inputs
Access to potable water	+	++	Access for whom? Government willingness, but limiting factors are technology, pollution	++	Investment in infrastructure; pressure from population; pollution by irrigated agriculture; climate change	Relatively unstable

Forest cover	--	--	Government mitigates some deforestation but overall huge pressures on forests; Increase energy prices; some climate change effects	-	Policies focusing on replanting schemes as incentives for smallholders and medium cash agriculture in marginalized area; green economy; incentives from carbon business (secondary benefits) and ecosystem services	Relatively slow
Farmer input prices	+	+	Fossil fuel prices increase, but government organizing price drops for fertilizer, seeds, subsidies, manpower	+	Trend continues, but dampened by big and smaller renewable energy projects in the Sahel	Relatively unstable
Urbanization	++	++	Smaller towns or big cities? Peri-urban agriculture; food policies to support rural areas - consequences of government action rather than government control, land tenure	++	Follows previous trend	Unstable because of short-term work migration
Transportation infrastructure	+	+	Pressure to invest in infrastructure but democratization process means that this will take time; limited resources; more recurrent costs for maintenance; world bank loans; hydro-power leading to conflicts of interest; costs for cross-boundary security and customs	+++	This period reaps the benefits of previous investments	Slow variable

Dietary diversity	++	++	Urbanization will drive increase of dietary diversity – further driven by proactive government policies	+++	Markets and policy driver further diversity, but rural areas affected by food insecurity through climate change	Unstable
Reports of contaminated food/ food borne diseases; aflatoxins	+	+	Massive increases in livestock production; food cooked - increased use of chemicals in a controlled way; imported fish from Chinese fisheries; purchasing power is the problem	-	Capacities are built; animal numbers are reduced; improvement of veterinary services; less overuse of drugs; less chemical residues; more regulations	
Marine species biodiversity indicator	--	--	Government action but very hard to implement, effects beyond national waters; in 20 years dwindling of fish stocks in the coastal areas; algal biofuel production on the continental shelf	-	Policing and monitoring of marine resource uses becomes easier through technologies	
Terrestrial species biodiversity indicator	--	-	Decrease slowed down	-		
water availability for agriculture	+	+	Increased technology support for increasing water efficiency but also increasing competition from other sectors	+	Government capacity increases but challenges also increase	Moderately unstable; partly buffered

Existence of social protection schemes; percent population covered	+	++	Proactive policies	++		Some instability with regard to how this is executed
Number of community based organizations	+	+	no need for strong growth in civil society because of stronger government	+		
Crime rates	++	++	International crime, resourcing of funding to other areas	+	Up with increasing population; economic activity, conflicts	
Corruption index	+	+	The struggle for institutional change opens up new opportunities for corruption; increasing wealth	-	Corruption goes down with increasing equity	Slow variable
Access to health care	+	+	Slow improvement through government policies	++	Institutional, knowledge and technical capacity have developed	Stable
Prevalence of malaria	+	+	No change at first	--	Vaccine supported by government policy; education; better water infrastructure; sanitation	
Percent population in poverty	-	-	Slow to decrease - policy change takes time	--	Reaps benefits from earlier changes	Relatively stable
Equity	+	+	First equity will decrease as certain groups are lifted out of poverty and other remain	-	Better distribution of wealth through policies, taxes	

Table C3: Civil Society to the Rescue? Semi-Quantified Indicators

Indicator	2010-2020	2020-2030	Logic for change	2030-2050	Logic for change	Volatility
Gross Domestic Product	+	+	Increasing regional stability and strong civil societies stimulate investment, but governments are not able to facilitate investments well.	+	Population pressures increase; puts a pressure on education; without governments it is difficult to bridge the growing gap between poor, middle class and rich. Climate change makes things worse for the poorest.	Fairly high because of absence of effective government policies; climate change, challenges with population growth.
Women with higher education	+	+	Those who can afford some cheap education are well supported ; the very poorest miss out	+	Increases but challenged by increased population	Smooth development
Yields for rainfed crops	+	+	The professionalization of farmers supported by social enterprises and CSO is combined with more effective communication tech ; though benefitting largely those who already have some capacity for yield increase	++	Adoption of new strategies through comms, agricultural technology etc. Big multinational GMO - two responses: 1. resistance and alternative farming; 2. "home-grown" responsible GMO technologies.	Volatile because of economic inputs and climate change
Yields for irrigated crops	+	+	Conservative estimate as yield gap lower in irrigated crops	+	same assumption as for rainfed; small schemes can be set up by private sector, but no big government investment in irrigation	same assumption as for rainfed

Area for rainfed arable land	+	++	Increase in demand drives expansion; desire for livelihood improvement	+	Two drivers: 1. population and increased demand; 2. intensification through technology availability and dissemination decreases pressure on land expansion	Slow
Area for irrigated arable land	+	+	Expansion of commercial agriculture	++	Same as above; but some rainfed land converted to irrigated land	Slow
Livestock numbers	+	+	increased demand of animal products (focus on quality rather than quantity)	+	Assumptions continue; more demand for meat, better intensification; global competition for production of livestock products	Relatively volatile
Livestock yield change	+	++	Demand for meat drives private sector investment. Social entrepreneurs work with professionalized communities.	++	Trend continues as before – demand grows.	Unstable
Access to potable water	-	+	Private and civil society intervention and collaboration	+	Technology increases, but population pressures and CC impacts also increase	Volatile because of climate change and private sector activities
Forest cover	-	++	more mechanisms for protection and replanting of forests, intensification of agroforestry practices on both small-scale and large-scale land ownership	++	In the absence of strong pressures on land, reforestation continues, supported by agroforestry and new technologies	Slow

Farmer input prices	+	+	Rising input prices are unmediated	+	Fuel prices increase; technology has a cost; but renewable technologies become more and more available	Very volatile because of global prices
Urbanization	+	+	long term perspective - civil society and private sector involved in development priorities, provisions of basic services - decentralisation and responsibilities at local level; but also large-scale agriculture in some places that excludes vulnerable rural populations and drives some urbanization	++	Population pressures increase beyond the capacity of the rural areas to absorb it - this means a relative increase in urbanization; additionally, urban centres will expand into rural areas. Agriculture in peri-urban areas will expand.	An increase in short-term travel between urban and rural areas.
Transportation infrastructure	+	+	Civil society and private sector actors don't have the means and power to invest in roads beyond targeted investment; governments make some investments	-	Lack of effective government support means that infrastructure is degrading generally; exceptions are made when there is specific private sector interest in developing roads etc.	Slow variable
Dietary diversity	+	+	increased sources of food in urban, increased awareness for nutritious value in rural	++	Education, literacy of women, technology will greatly increase dietary diversity	Because of disasters, poor roads etc. dietary diversity is volatile
Reports of contaminated food/ food borne diseases; aflatoxins	=	-	Better policy to some degree but also more activity	-	Better technology but even more activity in terms of production, processing, distribution etc.	Outbreaks

Marine species biodiversity indicator	--	--	No substantial policy on marine biodiversity	--	Trend continues	Steady decline
Terrestrial species biodiversity indicator	--	--	Relative preservation of habitats due to controlled deforestation	-	Lack of land pressure and increased reforestation	Steady decline
water availability for agriculture	=	=	Water harvesting and other SLWM technologies and irrigation compensate for cropland expansion; but little overarching policy	-	Population pressure, uncertain climate change, mitigated by more effective water use technologies	Unstable
Existence of social protection schemes; percent population covered	+	++	Civil society and private sector push government; but government is weak	+	Earlier protection schemes have failed because of lack of government support; donor fatigue	Unstable
Number of community based organizations	+++	+++	Lack of government drives civil society	++	Organization and federation of civil society	Unstable to more stable
Crime rates	=	=	Crime is not dealt with by governments	+	Private security does not help	Unstable
Corruption index	=	=	No real change – governments do not possess the capacity to deal with corruption issues.	+	Government does nothing and corruption flourishes though civil society watchdogs moderate	Unstable

Access to health care	=	+	CSOs not best equipped to deploy health care infrastructure; private sector invests but not available for the poorest	+	Technology increases health care for middle and upper classes, but not for poorest - tech still costs money	Relatively unstable; depends on markets
Prevalence of malaria	-	-	easily deployable technology by CSOs (impregnated mosquito nets etc.)	---	Vaccine available - but not for everybody	Steep decline when vaccine is introduced
Percent population in poverty	=	-	Social enterprises and civil society programs lift some out of poverty	+	More population - more ok, more poor	Unstable for middle classes and relatively less poor, but stable for the poorest
Equity	-	-	Equity decreases with increasing GDP and no government control	-	Trend continues	Unstable

Table C4: Save yourself Semi-Quantified Indicators

Driver	2010-2020	2020-2030	Logic for change	2030-2050	Logic for change	Volatility
Gross Domestic Product	++	++	Open market competition with little state interference, but also forming of cartels, society overall is worse off	++	Dynamic growth continues to build though resources have become a constraint; large informal economies	No control of the situation - volatility increases and affects political stability - only the strong benefit
Women with higher education	=	+	Private education available, big funds needed, short-term CSOs do not focus on tertiary education.	+	Inequality in education increases	Slow variable
Yields for rainfed crops	+	+	Private sector will focus on cash crops; farmers lobby for food production; private sector some investment but not significant	+	increases only for those rainfed crops that are economically viable on a large scale like biofuels; staple foods suffer	Unstable because of climate change and input prices

Yields for irrigated crops	+	+	Private sector focus on cash crops; farmers lobby to improve food production	+	Increases only for those rainfed crops that are economically viable on a large scale (e.g. biofuels); staple foods suffer	Unstable because of climate change and input prices
Area for rainfed arable land	++	+++	No mitigation of population-led pressure, conflicts ensue over land	=	All easy land expansion has happened by now;	Slow variable
Area for irrigated arable land	++	=	Price to pay, waste, pollution; depleting water; no government support for infrastructure; rapid increase but taildives as depletion happens	+	Irrigation expansion will happen only in areas that are already suitable to be converted	Slow variable
Livestock numbers	++	+	No government mitigation, population pressure; conflict with increasing arable land	=	No more room for expansion of numbers	Relatively unstable
Livestock yield change	=	=	Very patchy investment, no government planning; no veterinary control; current trend= decrease	=	No improvement	unstable
Access to potable water	=	+	Some investment when profits can be made	+	Water is available when profitable	Unstable
Forest cover	---	---	Huge pressures and no mitigation, only slightly by NGOs	---	Continuing decline	Slow variable
Farmer input prices	+++	+++	No reformative change, some tech improvements	+++	Continues to follow global prices	Unstable
Urbanization	+++	+++	International companies coming in, stimulating labour in the cities, land-grabbing	+++	This trend will continue	Unstable due to short-term migrations

Transportation infrastructure	+	=	Private sector comes in for current gains; some government investment in infrastructure initially through private sector influence	=	With new hyper-flexible transport tech formal infrastructure is no longer necessary	Slow variable
Dietary diversity	++	++	Invasion by the food manufacturers - e-food machine in urban areas; low diversity in rural areas	++	Synthetic meat - mostly focusing on urban diets; rural areas still lag behind	Unstable
Reports of contaminated food/ food borne diseases; aflatoxins	+++	+++	Problems are not balanced or mitigated	+++	Some control by new medical tech, but also much more activity	Crises
Marine species biodiversity indicator	---	---	Not mitigated by policies	---	The trend continues	Slow variable
Terrestrial species biodiversity indicator	--	--	Forest cover reduced; somewhat mitigated by NGOs	--	More NGO focus but not very successful	Slow variable
water availability for agriculture	---	---	Huge pressures on water availability	---	Infrastructure degraded; climate change; rising demand	Unstable
Existence of social protection schemes; percent population covered	--	--	Private sector social security schemes increases, but exclusion as well. Government social schemes decrease	0	Civil society puts pressure on private sector through government	Unreliable
Number of community based organizations	+++	+++	Out of necessity, state is not there, chaotic	-	The best organized NGOs/CSOs will survive and become more powerful	Unstable but increasingly stable as survivors emerge
Crime rates	+++	+++	Corruption spreads with no policies to stop it; cartels control governments	+++	No change in the trend this time period	Unstable

Corruption index	+++	+++	international drug crime cartels (narco-countries?); human trafficking through unstable countries	++	Organized crime nations, links between formal and underground private sector	Pervasive
Access to health care	-	-	Prices too high, street medicine, fake medicaments	-	New technologies available but these do not reach the majority	Unstable
Prevalence of malaria	++	++	Moderated by non-state, environment-borne diseases, lack of infrastructure/facilities to reach sick	++	Civil society slightly better at dealing with outbreaks but largely continues	Seasonal
Percent population in poverty	-	-	Poverty is reduced as GDP grows and provides some income through secondary effects and informal economies; enclaves of poverty persist	-	Gap between rich and poor will increase; mechanisation will increase unemployment	Unstable
Equity	---	---	Large differences between incomes	---	See above	Unstable

Appendix D: Categorization of Western Africa within the SSP drivers

Table D1: Fertility grouping (Kc & Lutz, 2014)

Benin	High fertility countries (TFR > 2.9)
Burkina Faso	High fertility countries (TFR > 2.9)
Côte d'Ivoire	High fertility countries (TFR > 2.9)
Gambia	High fertility countries (TFR > 2.9)
Ghana	High fertility countries (TFR > 2.9)
Guinea	High fertility countries (TFR > 2.9)
Guinea-Bissau	High fertility countries (TFR > 2.9)
Liberia	High fertility countries (TFR > 2.9)
Mali	High fertility countries (TFR > 2.9)
Niger	High fertility countries (TFR > 2.9)
Nigeria	High fertility countries (TFR > 2.9)
Senegal	High fertility countries (TFR > 2.9)
Sierra Leone	High fertility countries (TFR > 2.9)
Togo	High fertility countries (TFR > 2.9)
Cape Verde	Low fertility countries (TFR ≤ 2.9)

Table D2: World Bank Definition of income groupings

(http://data.worldbank.org/about/country-and-lending-groups)

Country	2000	2010
Benin	L	L
Burkina Faso	L	L
Gambia, The	L	L
Guinea	L	L
Guinea-Bissau	L	L
Liberia	L	L
Mali	L	L
Niger	L	L
Sierra Leone	L	L
Togo	L	L
Cabo Verde	LM	LM
Côte d'Ivoire	L	LM
Ghana	L	LM
Nigeria	L	LM
Senegal	L	LM

Table D3: SSP drivers not explicitly included in the narrative or storyline of CGIAR scenarios

carbon intensity
energy intensity
energy tech change
fossil constraints
technology development
technology transfer

Appendix E: Area and Yield growth by crop and scenario

Figure E1 Millet average annual growth in production from FAO statistics (FAOSTAT, 2015) and CCAFS scenarios from 2010-2050 the growth in production is allocated to either expansion of area or improvement in yields

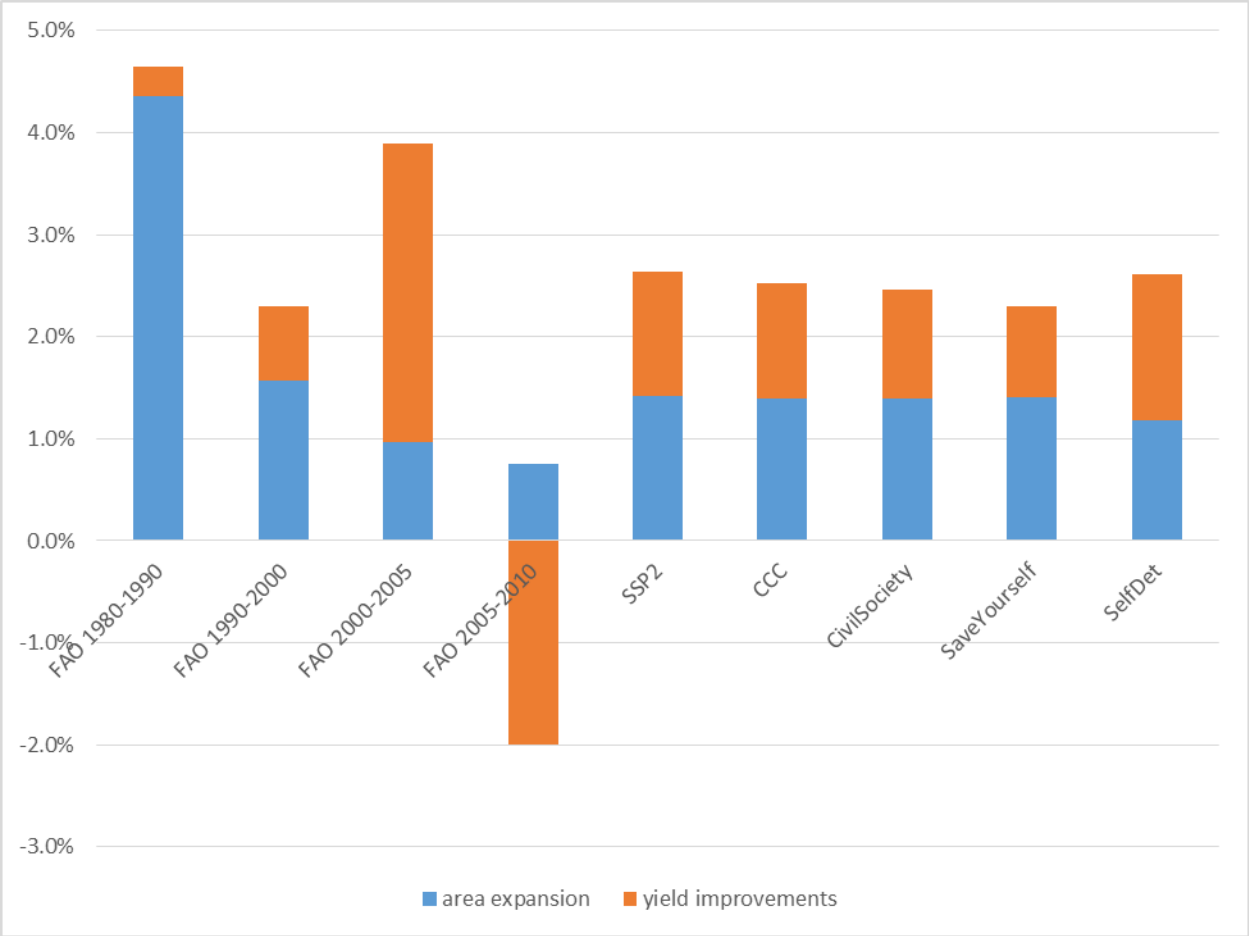


Figure E2 Sorghum average annual growth in production from FAO statistics (FAOSTAT, 2015) and CCAFS scenarios from 2010-2050 the growth in production is allocated to either expansion of area or improvement in yields

Figure E3 Maize average annual growth in production from FAO statistics (FAOSTAT, 2015) and CCAFS scenarios from 2010-2050 the growth in production is allocated to either expansion of area or improvement in yields

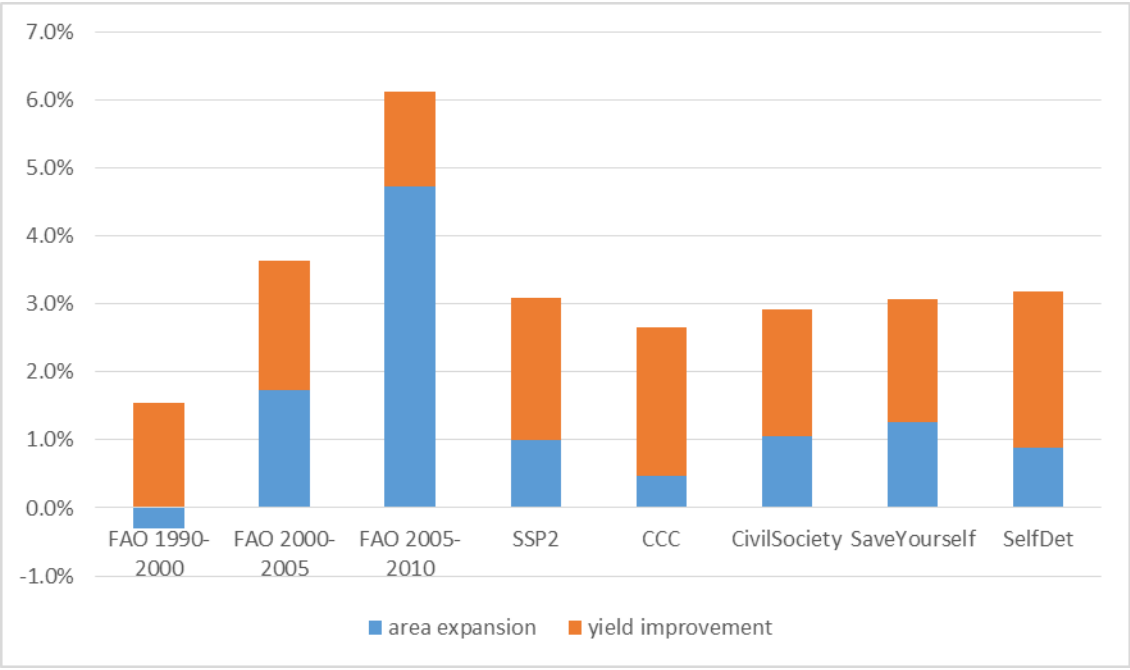
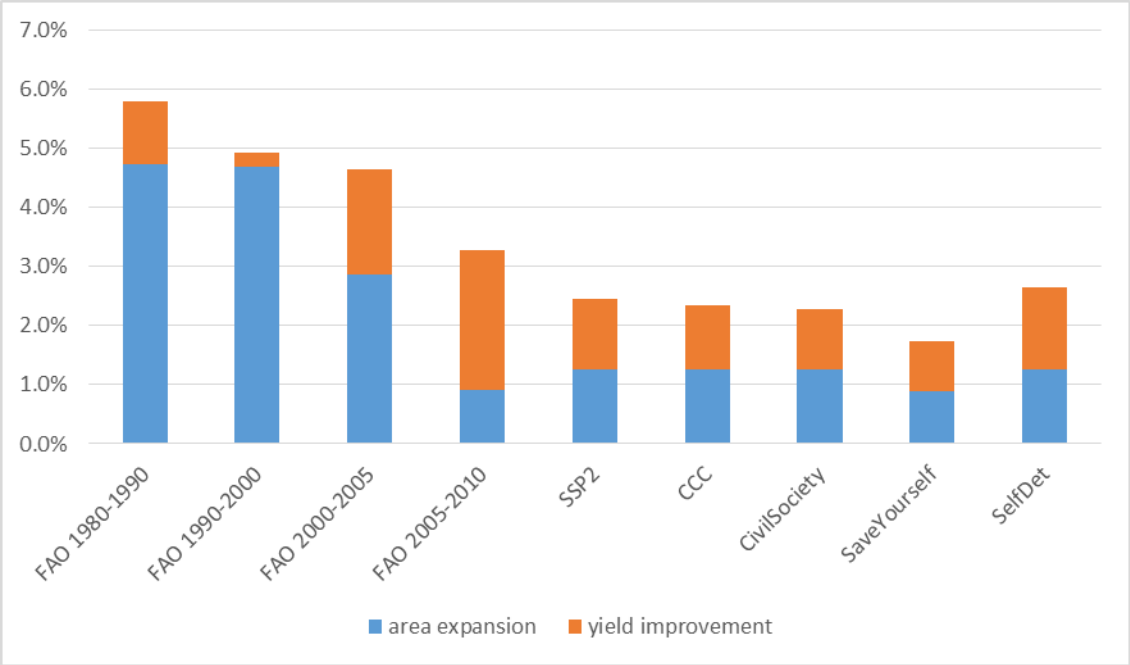


Figure E4 Cassava average annual growth in production from FAO statistics (FAOSTAT, 2015) and CCAFS scenarios from 2010-2050 the growth in production is allocated to either expansion of area or improvement in yields



RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security

CGIAR

CCAFS

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is a strategic initiative of CGIAR and Future Earth, led by the International Center for Tropical Agriculture (CIAT). CCAFS is the world's most comprehensive global research program to examine and address the critical interactions between climate change, agriculture and food security.

For more information, visit www.ccafs.cgiar.org

Titles in this Working Paper series aim to disseminate interim climate change, agriculture and food security research and practices and stimulate feedback from the scientific community.

CCAFS is led by:

CIAT

Strategic partner:

futureearth
research for global sustainability

Research supported by:

CGIAR Fund

Danida

European Commission

IFAD

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Agency for Development and Cooperation SDC

IICT

UKaid from the British people

Australian Government
Australian Centre for International Agricultural Research

Irish Aid
Government of Ireland
Rialtas na hÉireann
Ireland's commitment to a world without poverty and hunger

Ministry of Foreign Affairs of the Netherlands

Government of Canada
Gouvernement du Canada

NEW ZEALAND MINISTRY OF FOREIGN AFFAIRS & TRADE
MANATŪ AORERE