The FSEC-SSPs: Shared Socio-economic Pathways for global agricultural production and their implications for on-farm management decisions

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Contributed Paper prepared for presentation at the 96th Annual Conference of the Agricultural Economics Society, K U Leuven, Belgium

4 – 6 April 2022

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Abstract

The Shared Socio-economic Pathways (SSPs) are qualitative descriptions of five equally plausible, potential future scenarios related to climate change mitigation and adaptation. The FSEC-SSPs extend the SSPs framework and contribute to this literature by focusing on the global agricultural production level as its scope. We examine the drivers determining future on-farm management decisions and their outcomes regarding output and productivity, profitability, and environmental impacts. We apply a qualitative approach using semi-structured interviews and expert workshops, with its results to be implemented as a baseline in Integrated Assessment Modelling exercises. The storyline elements and the associated storylines are defined by an international group of experts in agricultural economics from both FSEC (Food System Economics Commission) and various other research institutions. Besides, bio-physical and locational factors of the farm, especially the structure of the agricultural system of the particular country and the political environment, are predicted to be significant drivers of future development. However, demand for various product groups, the availability and use of specific technologies, and the market structure are additional forces to impact production decisions. The description of typical farms for each SSP in different world regions will support the qualitative storylines.

Keywords Shared socio-economic pathways, storyline development, agricultural production, food system, future scenarios

JEL code Q110, Q160, Q190, D580,

1. Introduction

In the context of the IPCC's 5th Assessment Report (Dellink et al. 2017; O'Neill et al. 2017), the international research community, together with governments and NGOs, developed the Shared Socio-economic Pathways (SSPs). These pathways describe five equally plausible, potential future scenarios linked to climate change mitigation and adaption, focusing on socio-economic developments, such as demographics, human development, economy and lifestyle, policies and institutions, technology, and environment and natural resources (O'Neill et al. 2017). Following this initiative, various studies have been published describing individual SSPs (e.g., SSP1 by van Vuuren et al. (2017), SSP5 by Kriegler et al. (2017))) or implementing SSPs on the global level (O'Neill et al. 2017), regional level (SSP narratives for agriculture in Finland by Lehtonen et al. (2021)), or sector-specific level (land use in SSPs by Popp et al. (2017), Eur-Agri-SSPs by Mitter et al. (2020)).

Storylines and scenarios can provide assumptions for Integrated Assessment Models (IAMs) to measure the narratives and their outcomes quantitatively. Additionally, storylines help interpret IAMs results, but they can highlight aspects and interlinkages modeling cannot display. Both can be utilized by researchers in informing governments and supporting policy design (van Vuuren et al. 2012; Mitter et al. 2020).

We extend the basic SSPs and contribute to this literature by focusing on the agricultural production level as its scope. In the FSEC-SSPs (Food System Economics Commission), we examine the drivers determining future on-farm management decisions and the outcomes regarding output and productivity, profitability, and environmental impacts.

This paper proceeds as follows: first, we give some background on the role of scenarios and the SSPs framework. After introducing the method used for the storyline development, we present the defined storyline elements. In the next section, we describe the next steps before concluding the paper.

2. Background on Shared socio-economic Pathways

Role of scenarios

Scenarios and narratives describe the development and future states of various factors (van Vuuren et al. 2012; O'Neill et al. 2014; 2017). In the design and assessment of scenarios, it is crucial to not only focus on the most likely development but to rely on a wide range of assumptions resulting in contrasting scenarios. A set of coherent and consistent assumptions

supports the descriptions of plausible, even though probably unlikely, developments according to today's state of knowledge (van Vuuren et al. 2012).

However, scenario development does not serve its own purpose but plays an essential role in science and policy (O'Neill et al. 2017; Mitter et al. 2020). The scientific community uses qualitative narratives and assumptions to feed in IAMs. Results can be incorporated in informing governments and policy design. For the larger society, narratives can initiate discussions on preferred futures and ways to achieve them.

Basic Shared Socio-economic Pathways

In an international effort, the science community engaged in climate change mitigation and adaptation developed the framework of SSPs (Ebi et al. 2014; O'Neill et al. 2014; 2017). The basic SSPs are qualitative narratives that describe five equally plausible but distinctive futures linking socio-economic and environmental developments. The five SSPs are classified according to their level of challenge for mitigation and adaptation efforts. They provide a broad description of future conditions in terms of demographics, human development, economy and lifestyle, policies and institutions, technology, and environment and natural resources. However, climate policies to cope with mitigation and adaptation are not considered. In the following, we will give a short overview highlighting selected characteristics. For a detailed description, see O'Neill et al. 2017.

SSP1, named *Sustainability – taking the green road* depicts a sustainable world with low challenges for both mitigation and adaptation. With an emphasis on equality and inclusion, the economy focuses on "green" and sustainable growth. Collaboration among (international) institutions, the private sector, and civil society encourages stable governments and positively influences governance quality. Increasing investments in education and health lead to decreasing global population. The *Middle of the road* described in SSP2 follows many aspects, such as technology, population growth, educational level, and the deployment of different energy sources, historical trends. In this storyline, the world experiences moderate challenges to mitigation and adaptation.

SSP3, as *Regional rivalry – a rocky road*, proposes a world fragmented world. Countries revive nationalism and back domestic production instead of expanding and supporting international trade. Limited international collaboration leads to weak institutions and unsteady cooperation in addressing global environmental issues. Focus on national interests increases the danger of international conflicts. Further characteristics are reduced investments in education, slow economic growth, and increased poverty and population. This world exposes high challenges to both climate change mitigation and adaptation.

Inequality – a road divided is the name of SSP4, which portrays a highly unequal world. While selected people in a society follow the sustainable pathway in education, technology, or opportunities, others are characterized by low education and income, high poverty, and unskilled labor in low-tech economies. Over time, disparities expand, which leads to a concentration of power and increasing conflicts due to decreasing social cohesion. In terms of

climate change, this world experiences low challenges for mitigation and high challenges for adaptation.

Finally, SSP5, *Fossil-fueled development – taking the highway*, illustrates a world with rapid technological progress and a thriving economy based on fossil fuels as a major energy source. Investments in education, health, and institutions lead to stable population size. However, reliance on fossil fuels and limited collaboration in addressing environmental issues lead to high mitigation challenges but low adaptation challenges.

In the years following the presentation of the SSPs framework, many papers have been published, using (IAMs to test the described storylines quantitatively. Some studies concentrate on specific aspects, such as demographic development (Kc and Lutz 2017) or economic development using GDP projections (Dellink et al. 2017). Others model various factors of one particular SSP, e.g., SSP1 by van Vuuren et al. (2017) or SSP5 by Kriegler et al. (2017). Often in comparison with SSP2. Yet others expand the basic SSPs and focus on specific sectors, which are usually only described in a limited way and selected indicators in the initial storylines. Examples are the SSPs for the land-use sector (Popp et al. 2017) or the European agricultural sector (Mitter et al. 2020).

3. Storyline development

Our study applies the qualitative scenario development approach described by Mitter et al. (2019). In their paper, they portray nine steps of storyline development. Storyline elements are defined after defining key characteristics and setting up a stakeholder group. The storyline elements are the basis for the first draft of storylines. In several rounds of review consistency of the storylines is monitored. Further, presentation formats for the storylines are developed. In a round of oral and written feedback, the stakeholder group provides final feedback before publishing the storylines. As the last step, the authors propose an evaluation of the collaboration.

Following this proposal, we defined the core group and an expert panel as stakeholder groups. We invited FSEC-internal experts together with external experts in agricultural economics from various international research institutions to discuss future developments in agriculture. The expert panel consists of 16 international agricultural experts. In their description of qualitative scenario development, Alcamo and Henrichs (2008) introduce an approach that is designed to ensure the incorporation of views of various stakeholders with different fields of expertise and background. As we attempt to develop consistent storylines for future agricultural production, we invited researchers considering the gender balance and their knowledge from various continents and world regions. In doing so, we try to capture the heterogeneity in global agriculture. Table 1 shows selected characteristics of the expert panel in terms of gender, career stage as well as geographical focus of their research.

Table 1. Gender, career stage, and geographical focus of research of expert panel

Gender		Geographical focus of research	
Female	8	Global	2
Male	8	Europe/North America	5
Career stage		Africa	4
Junior researcher	4	Asia	2
Senior researcher	12	Latin America	1
		Middle East	1
		Oceania	1

In a first step to identify the storyline elements, we used semi-structured interviews combined with expert workshops and an extensive literature review to gather information on drivers of change for future agricultural production. All drivers were constantly reviewed and revised by both the expert panel and the FSCE-internal core group to ensure consistency. These drivers are translated to storyline elements and will be presented in the next section of this paper

In a next step, along with these elements, dynamics, and directions for all five SSP storylines (SSP1: Sustainability – taking the green road, SSP2: Middle of the road, SSP3: Regional rivalry – a rocky road, SSP4: Inequality – a road divided, SSP5: Fossil-fueled development – taking the highway, see O'Neill et al. 2017) are described, displaying different possible futures for the agricultural sector on a global scale until 2050. In contrary to the basic SSPs, we plan to develop storylines with and without climate policies. Several iterations of review and revision in the expert group as well as in the internal core group are established to ensure consistency and plausibility of the FSEC-SSPs. In an attempt to capture and display the diversity of global agricultural production and highlight differences between the single storylines, we plan to generate a limited number of typical farming examples per SSP in distinctive settings and with exemplary farm types.

4. Storyline elements

After collecting information on drivers of change for global agriculture, applying semi-structured interviews, expert workshops, and literature review, we developed a list of 66 storyline elements assigned to ten groups. All groups and elements can be found in Table 2.

In the first group, *Population and human development*, we describe general socio-economic developments already described in the basic SSPs (O'Neill et al. 2017). Besides demography, such as population growth, we include GDP development (average GDP and GDP per capita), educational level, or urbanization rates. Additionally, we look at income distribution as a proxy of poverty, intra-national and inter-national migration, and national labor regulations. Governance quality and stability, equality, e.g., in terms of gender, ethnicity, or religion, and impacts of conflicts are also named in this group.

Demand patterns lists demands for multiple agricultural products. Besides demand for food, feed, biomass, and bioenergy, we incorporate changes in dietary habits and food waste here to summarize consumer preferences. However, explicitly excluded in the basic SSPs, we define a distinct group *Policy* referring to the agricultural sector. Instead of listing individual policies

and regulations, we identified the element of targets of agricultural policies. Examples of targets can be regulatory policies, farm support, or rural development policies. Because of its importance for the agricultural sector, we list trade (including regional and international trade, multilateral and bilateral trade policies) as an independent storyline element. This group is completed by standards, regulations, certification, international agreements, and financial instruments and regulations.

To the fourth group, *Markets and value chains*, we assign storyline elements such as local to international value chain integration, concentration and power structure in the value chain, and the price development for inputs and outputs. In *Technology,* we distinguish a number of types of technologies: digital technologies (e.g., sensors, robotics, early warning or forecasts, traceability technologies), intensification technologies (e.g., vertical agriculture, irrigation expansion), replacement of food/feed (e.g., insects, seaweed), genomic technologies, nutrient, and resource efficiency (e.g., soil management, breeding) and non-agricultural food production (e.g., artificial or soilless products). Since not only the availability of technologies themselves is a major driver of change in the agricultural sector, we add the elements of the pace of diffusion and adoption to account for local adaptation, integration and inclusion, and the element of public acceptance and regulation.

Structure of agricultural sector incorporates common and shared aspects of the agricultural sector in a given country or region. Public infrastructure describes not only roads and transportation but also water infrastructure. The farm structure can be based on several indicators, such as size or ownership. Rural services and the provision of agricultural education serve as a proxy for the sector's capacity. Property rights and tenure system can be interpreted as tradability and tenure security regarding land, pasture, and water. The group is completed by the societal perception of farming, the social safety system for farmers, cooperation and collaboration in the sector, and R&D and the role of institutions.

On the very farm level, we define four groups: *Production system, Biophysical factors on-farm, Farm inputs and assets*, and *Farmer's characteristics*. In the group *Production system,* we describe what, how, and for whom farmers are producing. Elements among others are the produce (crops, livestock, fishery/aquaculture, agroforestry), commercialization, intensity level, practice, diversification on-farm, irrigation system, labor types; Also, secondary activities on the farm beyond farming or the decision structure. Capturing biophysical characteristics of a farm, we use climate, biodiversity, soil quality, and water availability in terms of quality and quantity. *Farm inputs and assets* include elements such as machinery, other capital (e.g., physical amounts of seeds, fertilizer, pesticides), the amount of labor available, and storage facilities. The land is not only defined as land size but also as field size and (dis-)aggregation of land on-farm. The last group, *Farmer's characteristics,* incorporates elements describing the farmer her- or himself. Besides socio-economic factors such as gender or age, we included off-farm activity and risk perception. Training in this group is meant as any type of individual education, skill, or experience either in agriculture or non-agricultural. Lastly, we consider family structure as a storyline element.

Table 2. Storyline elements

Population and human development	Demand patterns	Policy	Markets and value chain	Technology
Population development and demography GDP development Income distribution Educational level Urbanization Migration Equality Governance quality & stability Labour regulations Conflict	Demand for food Demand for feed Demand for biomass and bioenergy Change in dietary habits Food waste	Targets of agricultural policies Trade Standards, regulations, certification International agreements Financial instruments and regulations	Value chain integration Concentration and power structure Price development	Pace of diffusion and adoption Public acceptance and regulation Digital technologies Intensification technologies Replacement food/feed Nutrient and resource efficiency Genomic technologies Non-agricultural food production
Structure of agricultural sector	**Production system**	**Biophysical factors no-farm**	**Farm inputs and assets**	**Farmer's characteristics**
Public infrastructure Farm structure Rural services Provision of agricultural education Property rights and tenure system Social safety system Societal perception of farming Cooperation, collaboration and connectivity R & D, institutions	Produce Commercialization Practice Diversification Food loss Irrigation system Labour type Energy production Secondary activities on-farm Decision structure on-farm	Climate Biodiversity Soil quality Water availability	Machinery Other capital Labour Storage facilities Land	Gender Age Off-farm activity Training Family structure Risk perception/aversion

5. Conclusion

Our study shows that besides farm and farmer's characteristics, such as biophysical factors, availability of farm assets, or education, external factors play a significant role in influencing an individual's decisions on-farm management. We distinguish between various aspects of demand patterns (e.g., demand for food, change in dietary habits), markets and value chains (e.g., value chain structure, price development), policies and institutions (targets of policies, role of institutions), the structure of the agricultural sector (e.g., rural services, social safety net), and technology (e.g., digital technologies, the pace of diffusion and adoption). The FSEC-SSPs are embedded in overarching population and societal developments, such as demography, GDP development, urbanization, or governance quality. While all elements individually influence the future of agricultural production, interlinkages and uncertainties are considered just as well. As general population development estimated for each SSPs impacts demand for food, dietary habits are influenced by policies, substitutes for traditional foods, or prices, among other factors. Each of these elements needs to be considered while developing storylines on agricultural production in 2050. These storylines will be drafted, and presentation formats developed in the next step.

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