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A Short Review of Global Scenarios for Food Systems Analysis

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Abstract:

While global environmental change (GEC) clearly affects agricultural production, it is likely that GEC will also increasingly affect other determinants of food security such as food accessibility, food utilization and the stability of food supply. The questions of what impact future possible GEC dynamics could have, as well as how current decisions about GEC mitigation options and food system adaptation strategies might affect future food security are therefore emerging as crucial for decision-makers and scientists alike. Plausible futures/scenarios analysis has developed over the last decades as a tool for creatively and systematically thinking about the future of complex systems in order to inform decision-making. A number of scenarios exercises carried out over the last decade have either addressed food security or GEC issues. This paper reviews six important global scenarios and projection exercises as to their coverage of food systems and food security related variables to help guide further research on the future of GEC-food security interactions. Results show that the coverage of food systems and food security variables varies greatly between the exercises, as only two of the exercises specifically focused on agriculture and food, while the others addressed more general development or GEC issues. Variables related to food production and food availability were covered most comprehensively. Food accessibility and utilization parameters as well as direct GEC-food systems links were addressed to a lesser extent. This shows the need for further scenarios analysis in the area, which could deepen the insights gained from existing exercises.

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1. Introduction

Human-induced changes of the environment have emerged as a serious concern for scientists and decision-makers around the globe. Though climate change is currently the most talked about aspect of Global Environmental Change (GEC), changes in other environmental factors such as nutrient cycles, land cover, global fisheries or species numbers are among others that are increasingly gaining in attention (Millennium Ecosystem Assessment 2005, Vol 1). The implications of these changes for natural as well as human systems are so far only poorly understood, although a number of international research and assessment efforts are under way to investigate and assess our current knowledge on these linkages (e.g. Millennium Ecosystem Assessment, GEO-4, IPCC AR4).

One important outcome of human managed systems that is likely to be heavily influenced by current and future GEC is food security, which not only depends upon the production of food but also on food access and utilization. All of the mentioned environmental changes will of course affect agricultural and other food production systems and therefore food availability. But certain GEC components are likely to also influence food accessibility by changing, for example, the affordability of food. In addition the stability of the food supply, another important component of food security, is likely to be affected. Our understanding of the manifold interactions between GEC, food systems and their activities and food security is still limited. Improving our knowledge in this area is crucial to be able to maintain and improve food security now and especially in the future with its many uncertainties and unknowns.

The Global Environmental Change and Food Systems (GECAFS) Project is an international, interdisciplinary research effort to broaden the current understanding of the links between GEC, food systems and food security. In addition, the program aims to provide tools for enhancing policy discussions of possible adaptation options to GEC and to evaluate management strategies and their trade-offs to reduce the vulnerability of food systems to GEC. GECAFS was jointly launched in 2001 by the International Geosphere-Biosphere Programme (IGBP), the International Human

Dimensions Programme on Global Change (IHDP) and the World Climate Research Programme (WCRP).

As GECAFS aims to inform decision-making concerning GEC and food systems issues, the questions of what impact future possible GEC dynamics could have, as well as how today's decisions on GEC mitigation options and food system adaptation strategies might change future food security levels need to be addressed. GECAFS research therefore includes a specific research component on plausible futures/scenarios development. This approach was chosen because it provides a structured way for thinking about the future and its many uncertainties through a combination of qualitative and quantitative tools. In addition, this method has gained in importance over more predictive approaches in a number of global environmental assessments over the last 20 years, because it allows for including surprises and unexpected developments outside of currently existing boundary conditions.

The scenarios component of GECAFS addresses a number of issues related to the future of global and regional food systems. For this three key questions were developed:

(i) What are plausible changes in environmental and socioeconomic conditions that will affect food systems?

(ii) Which elements of existing global scenarios are most important for regional-level food systems analyses?

(iii) How best can global scenarios be linked to the regional scale so as to capture regional-level factors relevant to food systems?

These questions frame conceptual as well as methodological research in this area, but also set the stage for scenario development in GECAFS regional studies.

This paper focuses on a specific area important for the scenarios component of GECAFS - evaluating the relevance of previous global scenario studies for food systems analysis. A number of global scenario studies, many of them with a special focus on GEC issues, have been carried out in recent years. These include, to varying degrees, an analysis of plausible changes in food system parameters and their implication for food security outcomes. This paper reviews which relevant food system variables were actually addressed by six major scenarios or projection studies

in order to assess the utility of these exercises for further scenario development for food security-GEC interactions. It should be noted from the outset that, with the exception of IFPRI's 2020 scenarios and FAO agricultural projections up to 2030, none of these efforts have explicitly addressed food systems and food security variables. The author does not aim at a detailed analysis and comparison of scenario result with respect to food variables based on varying assumptions for the future, but rather wants to provide a basic review of the food variables coverage. For this, the paper first provides a short overview of the main food systems and food security variables used in the GECAFS research. Then the scenario approach is briefly described and the main assumptions of the global scenario and projection exercises are laid out. Then the analysis of which food systems and food security variables are covered by these exercises is presented and conclusions drawn for further GECAFS research in this area.

2. Elements of food systems and food security

Various definitions of food systems and food security have been developed over time, which reflect the particular world views held by economists and food security analysts at varying stages of the research. Analysts have shifted from a focus on agricultural production towards including the question of access to and affordability of food into the notion of food security. Today both food utilization and the stability of food systems are also recognized as determinants governing the food security status of a household or a nation (Maxwell 2001, Ericksen, forthcoming). For the purpose of its research, GECAFS reviewed the evolution of the thinking on food systems and food security and developed a conceptual framework to guide the scenarios work on food systems and GEC interactions. In this framework all food systems activities as well as the food security outcome variables that GECAFS focuses on are listed. A detailed review of each of the variables can be found in Ericksen (forthcoming). In addition the framework describes various driving forces that influence GEC as well as food systems and lays out their interactions. A detailed description of the whole framework can be found in Zurek and Ericksen (in preparation).

The variables selected for the review of global scenarios exercises with respect to their treatment of food systems and food security issues can be found in Table 1. The global scenarios exercises were reviewed for their coverage of these variables either

Table 1: Food systems and food security variables (adapted from Ericksen, forthcoming)

Food system and food security variables		Explanation
Food systems activities	Producing	activities involved in raw food production, incl. crop, livestock and fishery production
	Processing and packing	activities involved in transforming raw food for retail
	Distributing and retailing food	activities involved in moving food from one place to another and marketing it
	Consuming food	deciding on what to buy and when, preparing and eating food
Food security outcomes	Food availability – Production	which types of and how much food are produced by local production and how much
	Food availability – Distribution	how much food is available, when, in what form and to whom
	Food availability – Exchange	how much food is exchanged through trade, barter, purchase etc.
	Food accessibility – Affordability	purchasing power of households relative to the price of food determines if food can be afforded
	Food accessibility – Allocation	mechanisms governing when, where and how food can be accessed
	Food accessibility – Preference	social and cultural norms and values that influence the demand for certain types of food
	Food utilization – Nutritional value	how much of the daily requirements of calories, vitamins, protein and micronutrients are provided by the consumed food
	Food utilization – Social value	social and cultural aspects of food consumption
	Food utilization – Food safety	all aspects associated with eating food so that is not a health hazard because of contamination or its nutritional value
	Stability	stability of food supply over time

Source: adapted from Ericksen (forthcoming)

in the scenario storylines themselves or their result sections. In addition, wherever possible it was assessed whether the exercises dealt with the respective variable in a qualitative manner (e.g. qualitative assumptions were made based on key driving forces, for examples, changes in food preferences under each scenario) or if they were modelled by using simulation or projection models (e.g. production estimates for a specific crop were simulated under different scenario assumptions).

3. Review of Recent Global Scenario Exercises

Over the last decade scenarios analysis has become an important, integral part of many environmental assessments. Scenario development as a tool for dealing with complexity of and uncertainty about the future was first developed about 40 years ago as part of strategic planning exercises for cold war planners (Kahn and Wiener 1967). It has been used since then under a variety of circumstances, including for developing so-called 'Future Studies' to investigate long-term consequences of natural resource use under different population growth rates and consumption pattern pathways. Scenario studies developed both along quantitative lines, employing ever more complex mathematical models (such as for the Club of Rome study, Meadows et al. 1972), as well as qualitative stories describing various futures (Kahn et al. 1976). In parallel with the scientific community, the business community, under the leadership of Royal Dutch/Shell International, began to extend scenario analysis as a tool to boost creative thinking about future change and the development of robust business strategies to prepare for it. Scenario analysis has now also become part of a number of environmental assessment processes, such as the IPCC, GEO-3 and GEO-4, the Millennium Ecosystem Assessment. For this often more qualitative approaches to storyline development that allow for creative, "out of the box" thinking are combined with modelling efforts that 'ground truth' the underlying assumptions made in the stories.

Scenarios have been described as "plausible and often simplified descriptions of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces and relationships" (Millennium Ecosystem Assessment 2005, Vol 2) or "plausible descriptions of how the future may unfold based on 'if-then' propositions" (European Environment Agency 2005). Scenarios are basically a set of stories about the future, each of which highlights specific developments that could take place and their consequences. Developing more than one story about the future allows for exploring various possible pathways. Once internally consistent, logical stories are developed, the comparison of outcomes across the set allows, for example, the assessment of various policy measures or analysis of similar or differing trends in specific output variables. Scenarios are neither predictions nor forecasts nor projections. In contrast to these other methods for

describing the future, scenarios do not necessarily assume that the world will remain within today's boundary conditions in the future. They are, in fact, often based on the assumption that the boundary conditions will change, and each scenario in a set follows the path of a different set of boundary conditions. Scenarios are today utilized in various ways, but their main purpose has historically been either more related to scientific exploration and information dissemination or to inform on-going decision-making and strategic planning processes.

A number of scenarios and projection exercises have been carried out over the last decade which focus on GEC issues and also include an important component on the future of agriculture, food systems or food security. For the purpose of this review five important global scenarios studies were selected. These are the scenarios of the Special Report on Emissions Scenarios (SRES) developed by the Intergovernmental Panel on Climate Change (IPCC) (Nakicenovic et al. 2000), the Global Environment Outlook of UNEP scenarios (GEO-3) (UNEP 2002, UNEP/RIVM 2004), the scenarios of the Millennium Ecosystem Assessment (MA) (Millennium Ecosystem Assessment 2005, Vol 2), the Global Scenario Group scenarios (GSG) (Raskin et al. 1998) and the scenarios of the IFRPI 2020 Global Food Projections (Rosegrant et al. 2001), which all use a qualitative/quantitative methodology. In addition, one important food projection exercise, the FAO AT 2015/2030 agriculture and food projection (FAO 2003), was included in the review as it provides comprehensive information on various food security variables.

All of the reviewed exercises have developed their assumptions about a number of globally important driving forces of change for the future and their scenarios storylines independently. Nevertheless they also have quite a number of similarities. As a detailed description of assumptions made in the reviewed scenarios and projection exercises is beyond the scope of this paper, the author used a classification proposed by Westhoek et al. (unpublished) to group scenarios with similar overall assumptions into so-called scenarios families. This classification system is used to provide a short overview of the reviewed exercises. Table 2 groups similar scenarios (their names are given in the cells) of the reviewed exercises into so-called scenario families, such as the 'Economic optimism' or the 'Global sustainable development' families (the author added the IFPRI and GSG scenarios to the original table of

Westhoeck at el). Table 3 describes the main assumptions made within scenario families for some of their main driving forces; the names of the scenario families are given in the first row (e.g. 'Economic optimism'), while the first column describes the important driving forces of the exercises (e.g. economic development or population growth). Thus all scenarios in the 'Economic optimism' scenario family (such as the IPCC-SRES A1 or the GEO-3 'Markets first' scenario) assume, for example, an overall rapid economic development, low population growth rates and a more reactive attitude of decision-makers to environmental problems in the future. The details in the actual scenario story might differ a bit though.

Table 2: Overview of different scenario families (scenarios family names given in the first column, Scenario exercise names in the column headings, scenario names in each cell)

	IPCC-SRES	**GEO-3**	**Millennium Ecosystem Assessment**	**Global Scenarios Group**	**IFPRI 2020**	**FAO**
Economic optimism, market liberalisation	A1	Markets First	*Global Orchestration*	*Conven-tional Worlds*	*Optimistic scenario*	
Reformed market scenario		Policy First	*Global Orchestration*	*Conven-tional Worlds*		
Global sustainable development	*B1* (B1-450)	Sustainability First	*Techno-Garden*			
Regional competition, low growth	A2	Security First	Order from Strength	Barbariza-tion	*Pessimis-tic scenario*	
Regional sustainable development	*B2*		Adapting Mosaic	Great Transition		
"Business as usual" (medium scenario)	*B2*				baseline projection	AT2015/ 2030

(Italics are used to indicate that scenarios are not completely consistent with the group in which it is categorised.)
Source: modified after Westhoeck et al. (unpublished)

All reviewed scenario exercises make a number of qualitative assumptions about plausible changes in driving forces influencing food production and demand and use simulation models to project land-use changes, food production, and demand for food under each scenario. In some cases, such as the IPCC-SRES, different models for land use change were used and their results compared. The Millennium Ecosystem Assessment, which utilized five global simulation models to calculate changes in various ecosystem services including food, used the IFPRI IMPACT model to do the

specific calculations for the food variables. The results differ from the IFPRI 2020 food projections as the basic assumptions in both scenario exercises differed a lot.

Table 3: Overview of common characteristics in scenario families (Scenario family names given in column headings; key drivers in first row)

	Economic optimism	**Reformed markets**	**Global sustainable development**	**Regional competition**	**Regional sustainable development**	**FAO**
Economic development	Very rapid	Rapid	Slow-rapid	Slow	Slow/medium	Medium
Population growth	Low	Low	Low	High	Medium	Medium
Technology development	Rapid	Rapid	Medium-Rapid	Slow	Slow-medium	Medium (Rapid in some regions)
Main objectives	Economic growth	Various goals	Economy, Environment, Equality	Security	Local sustainability	-
Attitude towards env. protection	Reactive	Pro-active – reactive	Pro-active	Reactive	Pro-active	Medium
Trade	Globalisation	Globalisation	Globalisation	Trade barriers	Trade barriers	Globalisation
Policies/institutional development	Policies create level playing fields for markets	Policies help reducing market failures	Strong global governance	Strong national governments	Local steering; local actors	

Source: Westhoek et al. (unpublished)

4. Coverage of food systems and food security variables by global scenario exercises

The previous sections provide an overview over the food systems and food security variables considered by GECAFS as well as a short presentation of six global scenarios and projection exercises covering GEC and/or food issues. Table 4 describes how each of the reviewed exercises deals with the food related variables.

Analyzing the coverage of food related variables across all reviewed scenarios and projection exercises, shows that not all variables are covered completely by any of the exercises (though both the IFPRI and the FAO work cover almost all of them) and the coverage varies across the exercises. This variance in coverage was to be expected as only the FAO and the IFPRI work was built specifically around food systems. But neither of those two exercises includes an analysis of the impact of GEC. This shows that there is a need for new work that addresses plausible futures for interactions between various GEC factors and food systems. This work should not only deal with

Table 4: Variables describing food systems activities and food security outcomes and their coverage in global scenarios and food projection exercises

Food system and food security variables		IPCC-SRES	GEO-3	Millennium Ecosystem Assessment	Global Scenarios Group	IFPRI 2020	FAO AT 2015/2030
Food systems activities	Producing	■ □ (land use change)	■ □	■ □	■ □	□	□
	Processing and packaging						
	Distributing and Retailing food		■	■	■	■	■
	Consuming food	■ □ (indirect)	■ □	■ □	■ □	□	■ □
Food security outcomes	Food availability – Production	■ □ (implicit in land use change)	■ □	■ □	■ □	□	□
	Food availability – Distribution		indirect	indirect	indirect	indirect	□
	Food availability – Exchange		■ □ (mainly trade)	■ □ (mainly trade)	■ □ (mainly trade)	□ (mainly trade)	□ (mainly trade)
	Food accessibility – Affordability		■ □	■ □		□	□
	Food accessibility – Allocation		■ □ (market functioning)	■ □ (assumptions about market functioning)		□ (market functioning)	indirect
	Food accessibility – Preference			■	■	■	■
	Food utilization – Nutritional value			■ □		■ □	
	Food utilization – Social value						
	Food utilization – Food safety			■			■
	Food systems stability		indirect	indirect	indirect	indirect	

Legend: ■ = addressed qualitatively, □ = addressed quantitatively, if a variable is assessed both qualitatively and quantitatively this often means that a number of qualitative assumptions had to be made in order to then simulate a specific quantitative indicator

variables related to food production but take a wider approach to include other food security determinants as well (Ericksen, forthcoming).

In addition, the analysis shows that, while the scenarios exercises simulated various indicators related to future food security (such as area of crop land, amount of a certain crop traded or the number of malnourished children), they could not describe specific determinants of food security outcomes *per se*. The indicators were aggregated and interpreted in order to assess possible food security conditions under each scenario. So the interpretation of, for example, how easily people can get access to food in a region depends on the kind of indicators that were calculated. The indicators vary between exercises based on their qualitative storylines and the employed models. The coverage of food security determinants by the available indicators was thus not comprehensive, but rather selective, which explains a number of the gaps in the coverage of all food security variables.

Food production activities and the related food security outcome, namely food availability, are covered quite well by all exercises. They all modelled various production indicators, such as yields for various crops, area under certain crops, input use or exchange mechanisms. Also the consumption side of the food system, how much food is demanded in each scenario and how consumer preferences could change, is addressed through modelling food demand in all scenarios. Only the IPCC-SRES calculations are a bit different from the others as they focus on land use change, which implies that food production as well as possible food demand under each SRES scenario had to be simulated as well in order to calculate long term land use changes. The SRES report though only reports the land use change variables. In summary, it can be said that the basic food availability variables are addressed by the reviewed scenarios in a rigorous, quantitative manner. Nevertheless, food security depends not only on whether enough food can be produced to cover caloric requirements but also if and how food can be accessed by people, which requires a more disaggregated analysis.

The coverage of the various other determinants governing food security outcomes in the reviewed scenarios and projections is less complete than for food production. Some of the factors influencing food accessibility were addressed by simulating food price changes for the different scenarios. Also assumptions about allocation of food through markets are made indirectly under different scenarios via assuming whether and how well markets and governance systems function. Food preferences are usually covered in a more qualitative manner through assumptions made about changes due to various cultural and economic factors.

The area that is the least covered by the reviewed scenario exercises is food utilization. The IFPRI and MA exercises calculated the number of malnourished children under each scenario, which serves a very basic indicator of hunger and whether nutritional standards are met. But nutritional outcomes under varying diets and their possible changes are hardly addressed. Only little, if anything, is said in any of the exercises (including the MA and IFPRI scenarios) on food safety issues or the social value of food, which could both have important consequences for food preferences. The MA does however quantitatively assess certain health indicators which could be used to give a further indication on the nutritional status of people in the various scenarios.

This analysis shows the need for further in-depth research on some of the specific food systems variables and their changes in the future, specifically for those related to food utilization as well as a number related to food accessibility. In addition, our understanding of the various linkages of the food systems and food security determinants with environmental changes is in some cases only developing now. To include these into global and regional scenarios analysis could add additional value to the debate on how best to adapt food systems to GEC.

5. Conclusions

The analysis of the coverage of food-related variables by six global scenarios and projection exercises shows that there are some important differences in how the various

elements of food security and food systems activities are analyzed. Food availability is covered quite well by all exercises as are plausible developments in food demand. However, to analyze food demand, various, and often implicit assumptions are made about, for example, food distribution or trade. Variables more specific to food accessibility are less covered. Food accessibility is mainly addressed via food price simulations and assumptions are made about market functioning. Food utilization variables are addressed, if at all, via qualitative assumptions about for example food safety issues, while the nutritional value of the consumed food or its social value is rarely addressed. The scenario exercises also only deal indirectly with food supply stability as assumptions are made for example about conflicts and wars, societal breakdowns etc. But no direct assessment of food supply stability over time is carried out.

Furthermore, none of the scenario and projection exercises reviewed deal specifically with GEC – food systems interactions. Possible impacts of environmental change are assessed, if at all, mainly via impacts on food production variables. But other interactions (for instance the impact of increased risk of flooding on food accessibility, or how increasing desertification could influence labour migration and with that food systems stability), are only addressed indirectly by some of the scenarios (e.g. MA, GEO-3). But as these exercises focus not specifically on food systems but on a whole suite of the interactions between GEC and human systems, the analysis of interactions with the food system could be deepened. This would help to improve some of the simulation modelling employed in this area, as a more rigorous analysis of assumptions made in the models would help to improve their results.

The presented analysis did not aim to compare the outcomes for various food-related variables arising from similar or differing assumptions about driving forces of change. This kind of comparative analysis could be helpful to decide on which scenarios assumptions to build upon and how best to learn from previous exercises.

In summary, it can be said that in order to assess future possible impacts of GEC on food systems and food security, developing scenarios that focus particularly on food

interactions can be useful. These scenarios can be built on existing exercises, taking for example some of their results or proposed driving forces trajectories into consideration, but the GEC-food systems scenarios are also likely to produce new insights into the complex connections between issues such as food systems stability or changes in food utilization and certain long-term environmental changes that we can already foresee.

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