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Sustainability assessment and climate change resilience in food production and supply

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Abstract

To improve food security a conceptual integration beyond the scope of production in the agricultural sector due to examination of critical supply chain system compartments and levels of services ("integrated food production and supply systems") is proposed. For creating systematic results, a platform integrating various perspectives of experts has been established following the principle of triple helix stakeholdership (business practice, public management/policy and also science). During a series of workshops, the main actors, success factors, challenges and communication strategies have been identified for shaping sustainable food supply chains under use of systems thinking and the application of Participatory Systems mapping (PSM). In this line, the paper presents how "system maps" based on the method of PSM are used to gain insights into sustainable logistics services facilitating sustainable consumption patterns, enabling participatory considerations and the productive exchange of knowledge.

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Keywords: Integrated Food Production and Supply Systems; Sustainable Supply Chain Management; Climate Change Resilience; Sustainability Assessement; Logistics Services; Sustainable Consumption; System Dynamics; Participatory Systems Mapping

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1. Introduction

The human society is facing complex and interrelated problems of unsustainability. An essential threat represents the ongoing destabilization of regional food systems' capacities due to a mix of interacting factors, such as climate change, population growth, overuse of resources, change of consumption modes, governance failures and problems in fair resource allocation and distribution under the increasing pressure and uncertainty. Currently 1.4 billion of the global population is living on less than 1 Euro a day, unable to adapt to an upcoming crisis; one billion of them is living in rural areas where agriculture is the main source of livelihood [14]. The 'green revolution' in agriculture, especially starting from the 1950s, increased agricultural productivity and contributed beside general economic growth in some regions of the world to reduced poverty rates, even if this progress is still patchy across countries. Stable improvement is heavily depending on local as well as international governance and investment policies as well as the implementation of fair economic trade rules in the globalized food and agriculture market. However, achievements were received without considering environmental externalities, leaving e.g. soils degraded and groundwater depleted, and have been undermining the ecological resource base. Moreover, many of the achievements sthrengthend the dependency on fossile energy and have led into less resilient production systems because of reduced crops diversity.

These underrepresented issues become more relevant in times of climate change and its regional impacts on agricultural systems. Taking into account two decades of underinvestment and vague innovation policies in agriculture, coupled with the growing competition for land and water and rising input prices, agricultural systems are now becoming more vulnerable then ever [6]. Therefore, it is expected that due to the world's demographic development in its global differentiation, together with the significant effects of global climate change and resulting shifts for all organic production systems (agriculture, forestry, use of natural or semi-natural ecosystems), rural regions will undergo severe pressure in terms of their economic and ecological productivity, supply effectiveness of the population and the general societal prosperity in the next decades. From a systems perspective the situations also bears enourmous risks for the globally expanding urban centers, because of their restricted selfsufficient food production capacities and critical dependencies on the already affected rural areas, with which they stand in a source-sink-relationship.

Sustaining the agricultural system is dependent not only on shaping sustainable production ways. The entire food supply chain must be analyzed systematically considering also further downstream and also upstream stages of the supply chain, industrialized combination of ingredients and further processing of food products, and in particular, their distribution, including the strorage/ turnover and transportation to retailers and the consumer as well as the consumption phase and waste disposal [5]. In this context, logistics services are continuously expanded and adapted. Hereby, logistics service providers support in coordinating cross-company activities in a supply chain [9]. In the last years, social issues of sustainability (health and safety issues as well as employee income in developing and emerging countries) are increasingly questioning the producer and distributor business relations with the logistic industry and their Key Performance Indicators (KPI) after scandals and public debates were significantly raising the consumers' awareness. Thereby, a sustainable lifestyle (closely related to logistic services) is vitally important, because it favors reduction of resource consumption together with implementing technological and business innovations [12].

Up to now the main objective of logistics services is to co-ordinate activities in a way that meets customer requirements at minimum cost [1]. In the past, this costs have been defined in terms of the internal operations invest within the supply chain. As concern for the environment rises, companies must take more account of the external costs of logistics associated with climate change and further damage to the environment, e.g. due to various emissions and massive resource consumption [11]. Supply chain capacities to reduce environmental externalities represent a powerful lever to enhance ecological resource efficiency across the whole lifecycle of a food product and is finally a more commanding means than just the ecoefficient optimization of the production phase [8].

Thus, this paper contributes to exploring ways of reduced externalities and to achieving a more sustainable ratio between economic, environmental and social objectives considering the operational functions of logistics. Through a better understanding of the interaction of consumer behavior and logistics services, the paper gives insights about relevant factors with regards to alternative last mile distribution modes as well as supply chain transparency by taking into consideration new forms of business models, such as the Sharing Economy [11]. Facilitating this aim, a

platform was established to improve understanding among experts who make decisions on or contribute to a secure food supply system. Following the triple helix strategy the platform integrates business practicioners as well as policy makers/ public managers as well as science representatives and serves to understand the ways of minimizing the climate change impacts on food production and supply systems, organizing the agri-food supply chain in a sustainable way and, at the same time, providing long-term profitability.

In a future step, it is intended to develop innovative, integrative business models and concrete measures for sustainable economic activities based on the results of this paper.

2. Methodology

To understand the linkages between innovative logistics services and sustainable consumption/lifestyles, a systems thinking approach for integrating complex social, environmental and economic issues is required and applied [7][10]. The main idea of systems thinking is that changes of an element can inevitably lead to changes in the other elements in the system, which makes the connections between system components explicit [2]. To operationalize systems thinking the method of system dynamics modeling (SD) has a rich tradition not only in environmental and sustainability contexts, but also for decades in supply chain management (SCM). One option of a first implementation of SD is the development of Causal Loops Diagrams (CLD), which represent the general picture of a complex system [13]. In the particular context of the given study the proposed key points "Choice of the Distribution Channel", "Sharing Economy", and "Transparency in the Supply Chain" served as entrance gates into the further system mapping process. The CLDs comprise a set of nodes and edges, which represent a set of variables connected by arrows. These arrows denote the causal interrelations among the nodes. These relationships can be “positive” or “negative”. A positive relationship means that if the cause increases, the effect increases above what it would otherwise have been, and if the cause decreases, the effect decreases below what it would otherwise have been. On the other hand, a negative relationship means that if the cause increases, the effect decreases below what it would otherwise have been, and if the cause decreases, the effect increases above what it would otherwise have been. Due to mutual interaction of combined functional relationships an emergent (sub-)systems behavior based on feedbacks can result into simple reinforcing or balancing loops. Here, further specific combinations their feedbacks emerge into known “typical” SD archetypes of system behavior related to subsystems or the entire observed system. Such SD archetypes can be used for the diagnosis of a system.

Generally CLDs are very useful not only for capturing the feedback mechanisms among various system elements, they are also a good basis for information gathering and communication of the relevant issues and hypotheses in the system. To systematically gather all the relevant parameters, a series of workshops with experts have been conducted. The main purpose of these workshops was to define the actors, success factors, challenges and strategies to implement sustainable logistics in integrated food production and supply systems.

During the platform workshops the method of Participatory Systems Mapping (PSM) [10] was used to apply the principles of systems thinking in a collaborative manner in terms of the production of CLDs. PSM is effective to receive information about relevant variables from experts that are connected to the system in various but concrete ways. The resulting CLDs served finding relevant interconnections between logistics infrastructures, services and consumer behavior, in particular for the key points "Choice of the Distribution Channel", "Sharing Economy", and "Transparency in the Supply Chain".

3. Results and Discussion

3.1. Choice of the Distribution Channel

The focus of the workshop was narrowed on food supply chains as well as on the last mile logistics, since the last mile serves as important “matching point” of logistics services and consumer behavior, where interaction is intense and alternative options could be directly applicable. Moreover, the workshop participants were making a differentiation between two consumer lifestyles resp. groups of actors. The results of the workshop with regards to the choice of the distribution channel are shown in Figure 1.

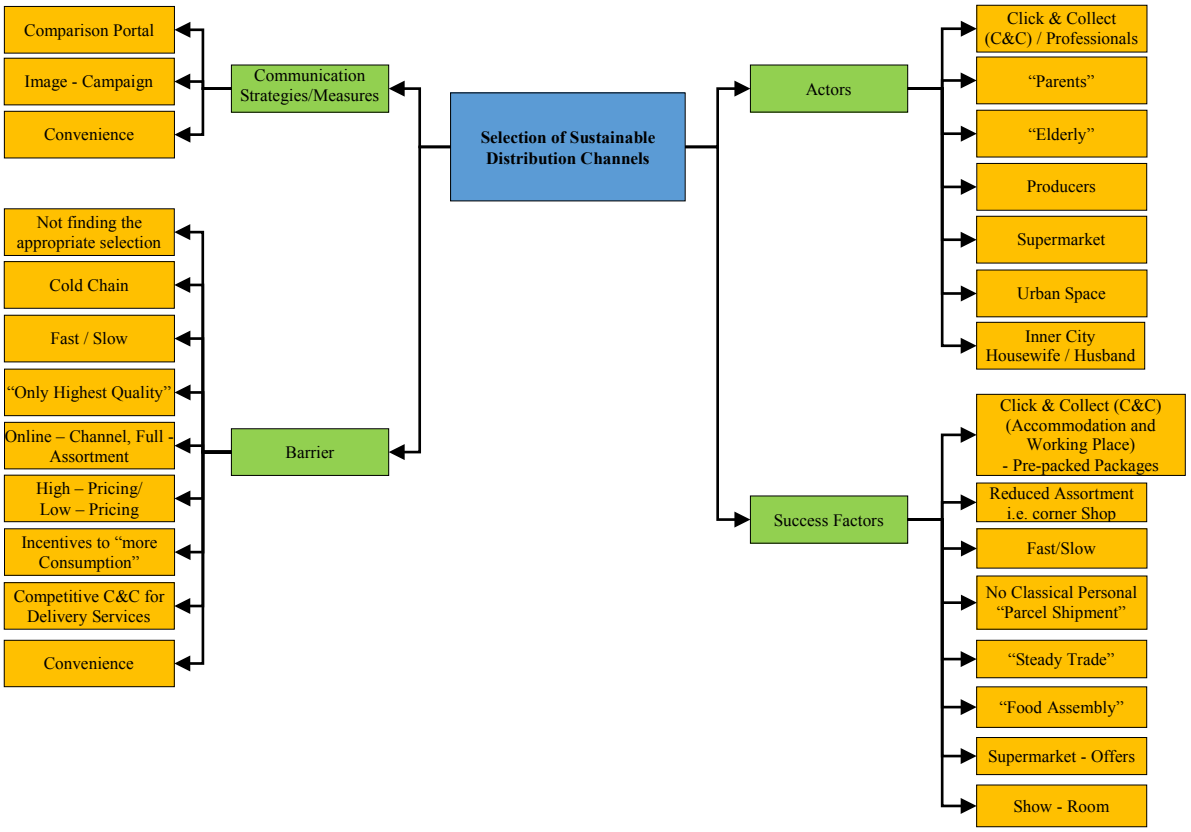

Fig. 1: PSM Results of the workshop "Choice of the Distribution Channel

The first lifestyle was defined to be the *group of consumers who are working full-time and have limited time for grocery shopping accordingly* (for instance young and employed parents). Thus, they need to plan their shopping activities carefully. In this context, the workshop participant considered E-Food distribution channels, like "Click & Collect" and direct home shipments as very attractive for this actors group, mainly due to time savings. Within online retailing, logistics service providers have the best opportunity to interact directly with consumers. Vice versa consumers can place their demand for more sustainable last mile configurations more easily. Moreover, the participants claimed that the classical parcel delivery at home is not sufficient for food products, such that more personal delivery services including the handling of complaints should be offered, which could be coupled with Sharing Economy solutions. They also warned that parcel pickup concepts like "Click & Collect" present a business model to bypass the challenges in the last mile to the consumer. Here, the performance with regard to sustainability depends strongly on the mobility preferences of the consumer.

The second lifestyle was defined including *consumers not investing time in pre-consuming, but rather in shopping itself seeking to be inspired from the product offers in the market* (e.g. elderly people). Conventional "brick and mortar" retailers seem to be still the most relevant distribution channel for this consumer group. The participants argued that communication about sustainable mobility patters is very important for these lifestyles. Thus, including the consumers' consumption and mobility preferences in the configuration of distribution channel, also for conventional channels, is crucial to achieve a better sustainability performance in the last mile.

3.2. Sharing Economy

From the interviewees' point of view, the concepts of Sharing Economy have potential for a more sustainable configuration of supply chains in general and the last mile in particular. A changed value perception, which

highlights the trust in the others, meanwhile ranking the "using value" higher rather than "owing value", is the basis for Sharing Economy consumption patterns. In this context, consumers, logistics service providers, retailers and local authorities were identified as most important actors in accomplishing sustainable Sharing Economy solutions in the last mile. The participants named trust, reputation mechanisms and a localization of the services, e.g. local delivery services with low prices as important success factors. In contrast, major challenges are the type of the product (food is critical due to freshness and hygiene), spatial limitations (rural areas are hard to reach), and missing digital know-how (elderly people have difficulties in accessing digital applications). Further barriers were identified to be the limited size of assortment, legislative boundary conditions and limited flexibility. The detailed results of the workshop are included in Figure 2.

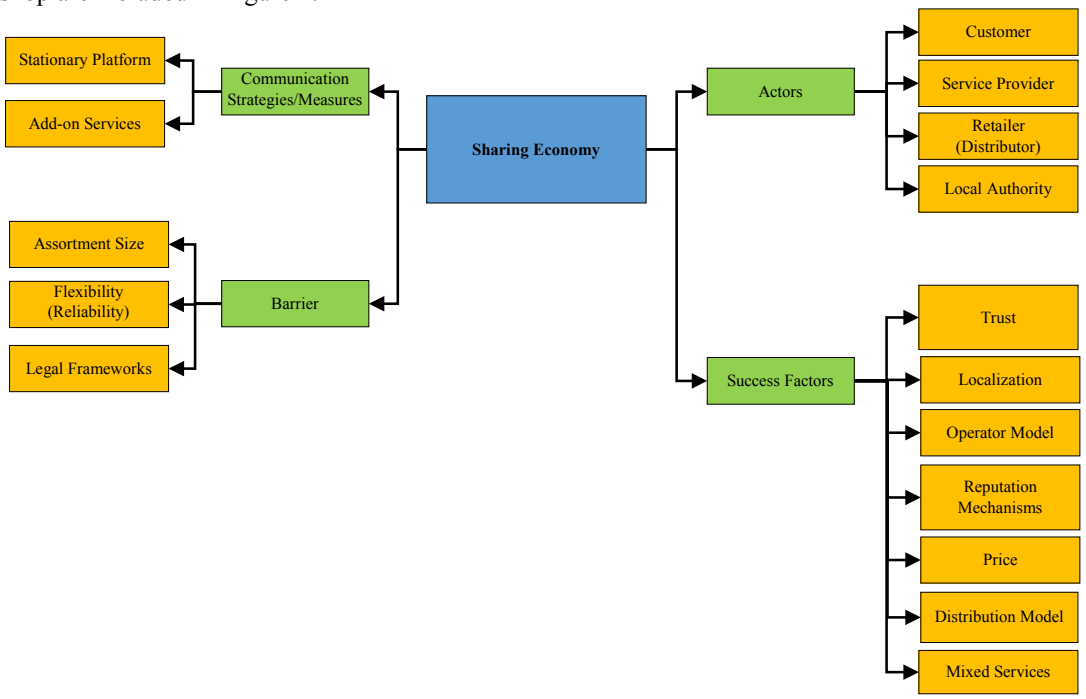

Fig. 2: PSM results of the workshop: "Sharing Economy"

3.3. Transparency in the Supply Chain

The detailed results of the workshop considering the "Transparency in the Supply Chain", namely actors, success factors, challenges and communication measures are included in the Figure 3. The relevant actors are the consumers, logistics service providers, producers, retailers, NGOs, political decision makers, researcher, local authorities and media companies. Here, the readiness to pay for sustainable products was defined as a success factor, but simultaneously as a challenge. It was considered that a consumer, who is ready to pay more for sustainable products, will be possibly ready to pay more for sustainable logistics services, too. On the other hand, this was also considered as a challenge by the workshop participants, since a consumer has limited financial resources and once paying for the sustainable products, he/she will be left less money for affording sustainable logistics services.

In order to communicate sustainability aspects in the logistics, these aspects of sustainable logistics must be clearly defined to achieve measurability. Such a measurability would make it much clearer for the consumer to make an informed choice. On the other hand, it was also mentioned that too much information could be a challenge overburdening the consumer. Nonetheless, providing sufficient information about logistics services and their sustainability impact was considered to be predominantly positive. Here, information is tightly connected to transparency, which was also considered as a success factor. In this context, labeling sustainable supply chain of a product was identified to be a possible communication strategy. It was also clearly stated that this might be a

challenge, not only because of the "over-information" for the consumer, but also that the sustainability along the entire supply chain might be too hard to measure.

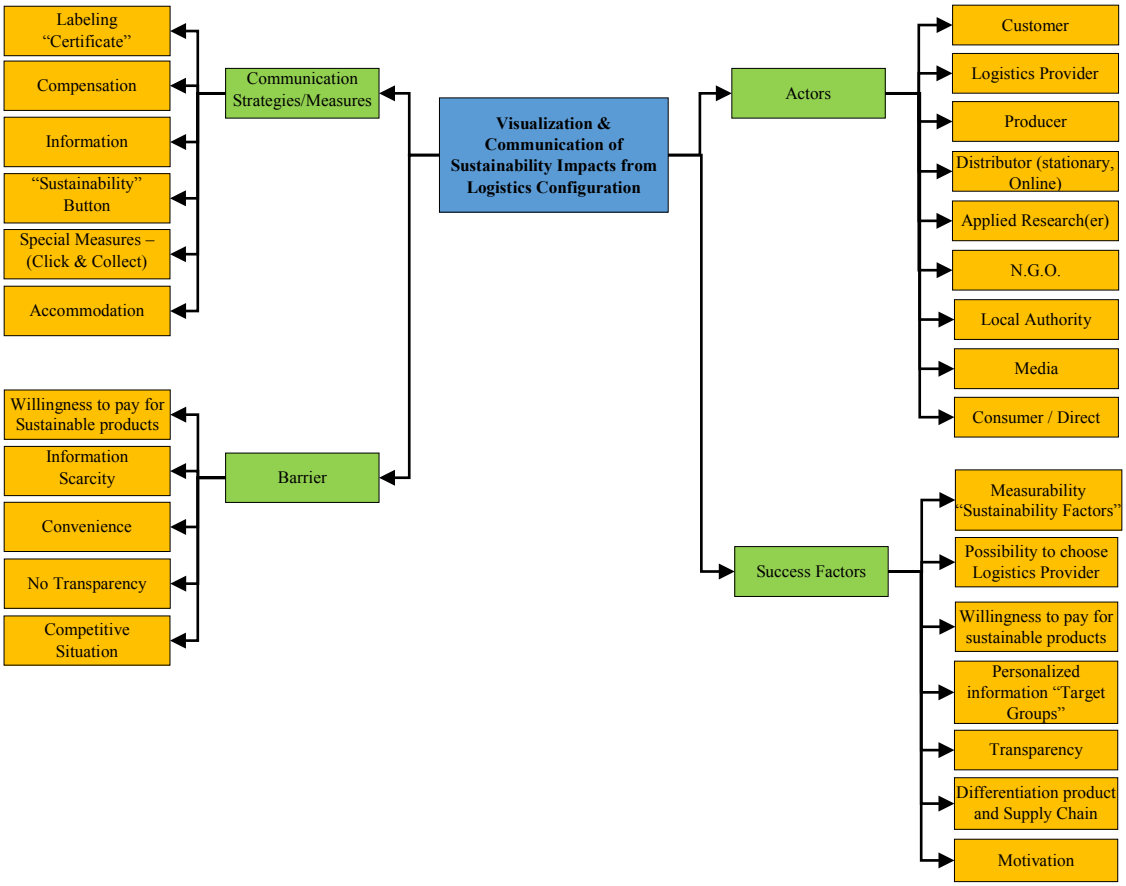

Fig. 3: PSM results of the workshop "Visualisation and communication of sustainability impacts from Logistics Configurations

3.4. Causal Loop Diagram for Sustainable Logistics

Summarizing the results of all workshops, Figure 4 presents the CLD using all parameters highlighted by the participants linked with logical feedback mechanisms. As shown, there are six feedback mechanisms, which influence the dynamics of the system. The "Willingness to pay" feedback loop describes the stabilizing interconnection among the willingness to pay, performance and price of a sustainable logistics service in dependence on the consumer income. The feedback loop "Investment in infrastructure" shows the positive impact of demand in sustainable logistics service on investments in logistics infrastructure in dependence on available resources. The choice between the use of a private car and using logistical services is clarified with the feedback mechanism "Choice of the distribution channel". "Sustainability image" shows that the image of the firm is very important for the supply of sustainable products. All the feedback mechanisms are summarized in the main feedback loop, which connects the awareness of sustainability in logistics service (thus also willingness to pay for that) with the image and reputation of the firm and thus supports sustainable consumption patterns.

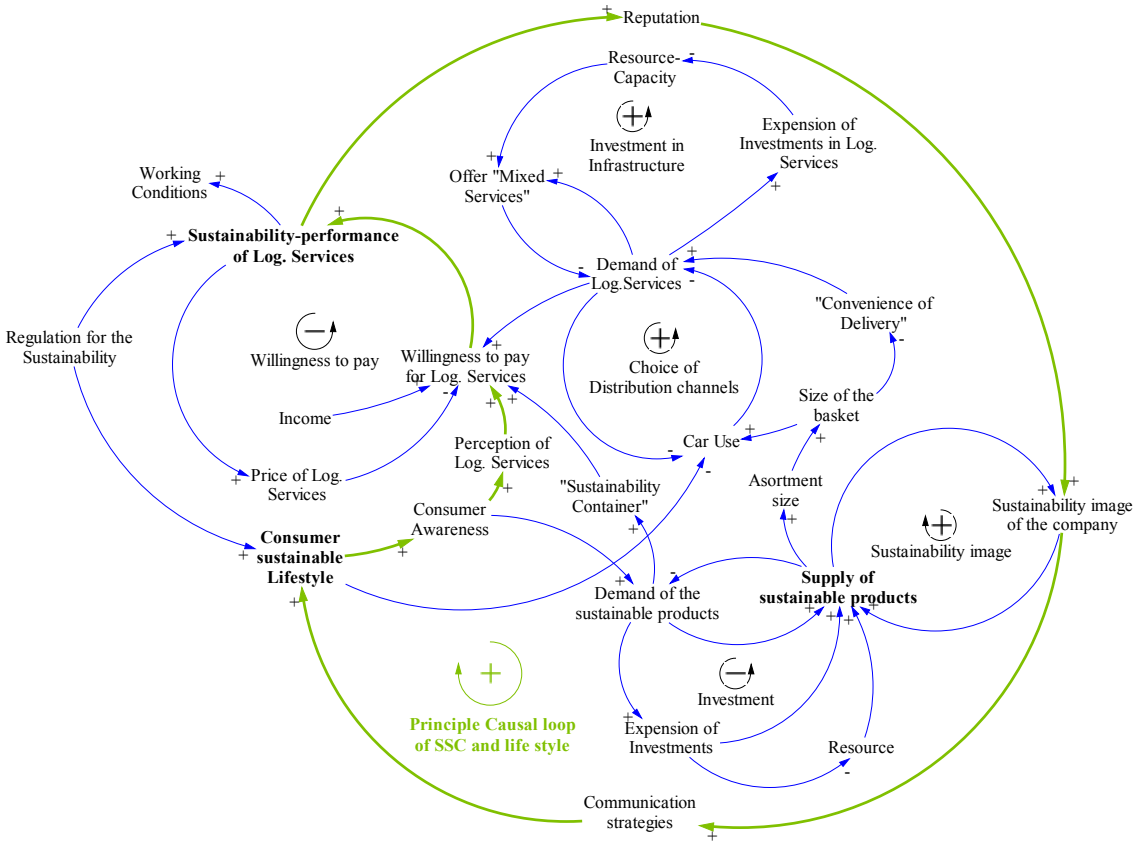

Fig. 4: Causal Loop Diagram on Sustainable Logistics generated from all three workshops

Conclusions and Outlook

The paper has shown that more sustainable options in food production and supply, particularly with higher climate change resilience and resource efficiency, necessitate a systems thinking approach to integrate all vitally included components. The needed integration can be guided by principles Sustainable Supply Chain Management (SSCM) applied to the food sector. The processual cascades of food supply, starting from production grounds across the entire supply chain structures and operations to finally the end consumer and modes of consumption can be displayed as an *integrated food production and supply system*.

On the way to identify sustainable system alternatives with respect to environmental and social externalities of food supply chains, the study has shown the significance of an approach that considers system thinking (A) in terms of understanding of system behavior and the applied methods, but (B) also under the integration of available system knowledge of experts "from the field" through a participatory approach. This combination produced system maps of integrated food production and supply systems based on the perceptions and implicit knowledge stocks of the actors participating. A key issue for sustainable alternatives is represented by the interplay of logistics services from the sphere of the supply chain and consumer behavior from the sphere of lifestyles.

CLD which describes the relevant parameters and their logical feedback mechanisms, provides starting points for several next steps of future research. Thus, the CLD will be transformed into a Stock and Flow diagram, in order to simulate various scenarios using System Dynamics. The conversion of the CLD into a simulation model has the purpose to acquire a basic knowledge of stocks and flows as a modelling alternative by displaying the dynamic behavior of the system. Following the *principle of accumulation* within a System Dynamics simulation, this will provide a strong foundation for understanding the connections between CLDs as well as stocks and flows and add a

methodical structure to an often chaotic process.

Furthermore, the process strengthens the stock and flow way of thinking by underlining the difference between information and material flows, and giving unit consistency throughout the model. The end result of the conversion process will be a computer model that can be used to experiment with different policies for a sustainable food production and supply system and see how the system might respond to different variables modifications. Based on the completed steps of work the model will allow the important integration of feedbacks between the production and supply sphere and the consumption and lifestyle sphere and could offer more integrated solutions than available until now in scientific literature. Accordingly, the simulation will provide further insights into the system, for instance into necessary pricing schemes for sustainable food production and supply systems, explicitly taking into account the consumer lifestyles as a main driver.

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