

Article

Structured Mental Model Approach for Analyzing Perception of Risks to Rural Livelihood in Developing Countries

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Abstract: This paper presents the Structural Mental Model Approach aimed at understanding differences in perception between experts and farmers regarding the various livelihood risks farmers are confronted with. The SMMA combines the Sustainable Livelihood Framework with the Mental Model Approach and consists of three steps: (i) definition and weighting of different livelihood capitals; (ii) analysis of livelihood dynamics, and (iii) definition of the social capital by means of agent networks. The results provide a sound basis for the design of sustainable policy interventions such as communication and educational programs which consider farmers' priorities and viewpoints.

Keywords: mental models; sustainable rural livelihood; livelihood risks of farmers; developing countries

1. Introduction

This paper provides a methodological approach to analyzing differences in risk perception between farmers and experts in developing countries. The approach combines the Sustainable Livelihood

Framework (SLF) [1] with the Mental Models Approach (MMA) [2], allowing greater understanding of: (1) farmers' risk perception in the context of their livelihood, (2) the differences in risk perception between farmers and experts, and (3) priorities and trade-offs of risk strategies selected by farmers.

Sustainable development of small-holder farmers in developing countries depends highly on their ability to cope with several risks affecting their livelihood [3,4]. First, they have to deal with environmental risks such as climatic risks (rainfall in rainfed agriculture), soil erosion, and pest infestations [3-6]. Second, they are also confronted with health risks, such as malnutrition due to an imbalanced diet, and neurological impairments, nausea, blurred vision, *etc.* resulting from the improper application of pesticides (lack of protection, quality and quantity of the products chosen) [7-10]. Third, they have to deal with financial risks, that is, with the proper marketing of their products, regional and national price volatilities, and access to credit [3,11]. Finally, a further often-neglected risk is the loss of social networks, that is, loss or change of social status, loss of friends or family [3,5].

Several authors have emphasized that for developing sustainable risk coping strategies, the risks small farmers in developing countries are confronted with have to be studied in relation to their livelihood [12-14], even if the focus is only on specific risks such as environmental risks, e.g., soil erosion [3-6]. One approach that has been developed to provide a more systemic and holistic perspective on farmers' strategy selection is the SLF [1]. The framework states that farmers' livelihood depends on their knowledge and ability to use their assets in such a way that the family can make a living, meet their consumption and economic needs, cope with uncertainties and respond to new opportunities [15,16]. Typically, human, physical, financial, natural and social capital are considered when studying farmers' livelihood [1]. The stock of capitals is specific for each farmer, constraining or enabling his/her decisions and actions [12]. The latter, in turn, impinge on the stock of their capitals, creating a feedback loop. According to Scoones [17] "a livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resources base". Please note that Scoones *et al.* utilize the term natural resources base as a synonym to natural capital base. The results from livelihood analyses have been used for evaluating and developing sustainable rural development programs at a micro level [1,16,18-20].

Several methodologies for assessing farmers' livelihood have been developed by different research groups as well as international agencies [1,16,18,20,21]. In most of the methodologies, farmers assets and capabilities are investigated through a set of participatory tools (interviews, focus groups, [19] leading to an assessment of farmers livelihood situation. However, the SLF [1] and the developed methodologies have two problems in common.

First, the SLF [1] and related methods do not include the link between farmers' assets and their decision-making in their analyses, neglecting to some extent farmers' local knowledge and their view on their own livelihood. Even though the livelihood approach would suggest that farmers with the same set of assets would take similar strategic decisions, de Haan and Zoomers [16], found that this was not the case. The knowledge of farmers' assets proved not to be sufficient to understand their decision-making on the allocation of their capitals and thus to provide a basis for developing strategies for a more sustainable livelihood. There are two explanations for these findings. On the one hand, de Haan and Zoomers argue that variables such as geographical settings and access to markets might

affect the allocation decisions and propose the study of trajectories to foster the understanding of current decisions based on former ones. On the other hand, psychological studies show for cases of reflective decisions that, the prioritization of the assets, the way farmers see their interaction, and the risks perceived might significantly affect their decisions and the potential livelihood pathways [22]. That is, the way farmers perceive their livelihood, and how they conceptualize the livelihood dynamics has a direct influence on their decision-making and behavior [21]. Furthermore, their knowledge of the system and their perception of specific risks is likely to significantly differ from the one of experts. This issue has been largely investigated with respect to soil management and local soil characterization systems [23-27]. Müller-Böcker [23], for example, found that local farmers in Nepal characterized and evaluated soil quality according to its agricultural relevance, while scientists would primarily focus on morphogeneric criteria. Abdulai and Binder [28] showed for the case of Nicaragua that farmers' decisions on the amount of pesticides to be applied significantly depended on earlier managerial decisions taken, such as burning or not burning the crop residues on the field. Thus, farmers do have a specific system knowledge from which they draw their conclusions and balance their risks, and in which they embed their decision-making. This knowledge and its relationship to decision making has rarely been included into farmers' livelihood analysis. Furthermore Schoell and Binder [29] showed that differing risk perceptions and priorities among the various capitals of farmers' livelihood between experts and farmers might lead to misunderstandings and failure of educational interventions. Feola and Binder [30], additionally showed that social norms are a key factor affecting farmers' decision whether to use or not use protective equipment when applying pesticides. These results imply that for an intervention to be successful on the one hand criteria as land tenure, education, technical assistance, are relevant. On the other hand, farmers' perceptions, their system understanding as well as the social norms prevalent in the region have to be considered.

Second, it has been shown that social capital can play an important role with respect to the access to individual capitals (e.g., natural or financial capital) [21]. For example, farmers with a higher integration into a social network are able to develop out of poverty, where as others are not as successful [16]. Still, the social capital has not been analyzed separately and in depth within the livelihood approach and to our knowledge the differences of how experts see the social network farmers are embedded in and how farmers themselves see their network, as well as the consequences of these differences have not been investigated so far.

Therefore, relevant research questions are: What is farmers' understanding of their livelihood? How do they conceptualize and balance the different risks and dynamics of their livelihood? How does their system understanding diverge from that of experts? What role does social capital play in the eyes of experts and farmers?

The analysis of mental models (MMs) has proven useful for understanding the underlying thinking of persons and in determining the difference between laymen's and experts' risk perception [2,31]. MMs are defined as intuitive theories or tacit maps which people construct and hold in their long-term memory. These theories are used in the everyday decision-making process to interpret new situations and react accordingly, and to make predictions or develop scenarios on future developments [22,32-35].

Drawing on the concept of MMs, Morgan [2] developed the Mental Models Approach (MMA). The main goal of the MMA is to (i) analyze differences in risk perception among experts and laymen

(e.g., identifying differences in how experts and laymen understand and interpret exposure, effect and mitigation processes [36]); (ii) identify misconceptions in system understanding [2,37] and (iii) develop adequate and successful risk communication tools [2,37].

The MMA has been applied in diverse fields of research, such as risk communication [2,37-40], system dynamics [8]; and environmental decision-making [41,42], as well as comparisons of shared and team mental models in organizations [43]. However, two main limitations of the MMA have been identified which might be particularly relevant if this approach is to be used to understand the differences in risk perception between experts and farmers in developing countries and develop sustainable intervention strategies [44,45].

First, the system boundaries are often set too narrow. Researchers often investigate experts' and laymen's MMs with respect to their perception of a specific risk, neglecting its relation to other risks prevalent in the system laymen live in. Therefore, the focal consequences are mostly discussed (*i.e.*, the immediately apparent consequences), whereas indirect consequences are not studied [45]. In the case of farmers, the different types of risks they are confronted with make it necessary to broaden the system boundaries to allow for including the different livelihood capitals and the analysis of risk trade-offs and thus allow for a more holistic design of strategies [6]. Furthermore, Murphy and Gardoni [45] suggest to use assets and capabilities as a means for communicating possible consequences of risk management strategies to lay-people.

Second, the individual contexts, motives, and values are rarely included in the analyses. When expert and layman risk perceptions are compared, their differences are related mostly to differences in knowledge and expertise, whereas, individual contexts, motives, values, or even traditions are not included either in the analysis or the interpretation of the results [44,45]. In the case of farmers in developing countries, this issue is important, as in rural areas of developing countries differences in risk perception are likely to be related to or induced by cultural beliefs and traditions [23-25,46-48].

In this paper we propose a methodology, the Structured Mental Model Approach (SMMA), which combines the SLF [1] with the MMA [2] to analyze the differences in risk perception between farmers and experts in rural areas in developing countries. With this methodology we aim at building a base for designing strategies for more sustainable rural livelihoods. In particular we aim at contributing towards:

1. Understanding farmers underlying mental models and perceptions. In particular, understanding the relevance of perception of a specific risk in relation to farmers' livelihood.
2. Comparing the mental models of experts to the one of farmers for identifying potential misunderstandings.
3. Analyzing the sources of potential misunderstandings between experts and farmers.
4. Supporting the development of intervention strategies, considering farmers' mental models and their differences to the one of experts.

The paper is organized as follows: First, we present a conceptual framework which combines the psychological factors with the socio-cultural factors involved in farmers' decision making. Second, we show how this conceptual framework can be operationalized, taking account of the different degrees of literacy between experts and farmers in developing countries. The operationalization and implementation is illustrated with a case study about pesticide management risks in the highlands of

Colombia, South America and a case study on soil conservation measures in Nicaragua. Finally, we discuss the implications of the presented approach and conclude.

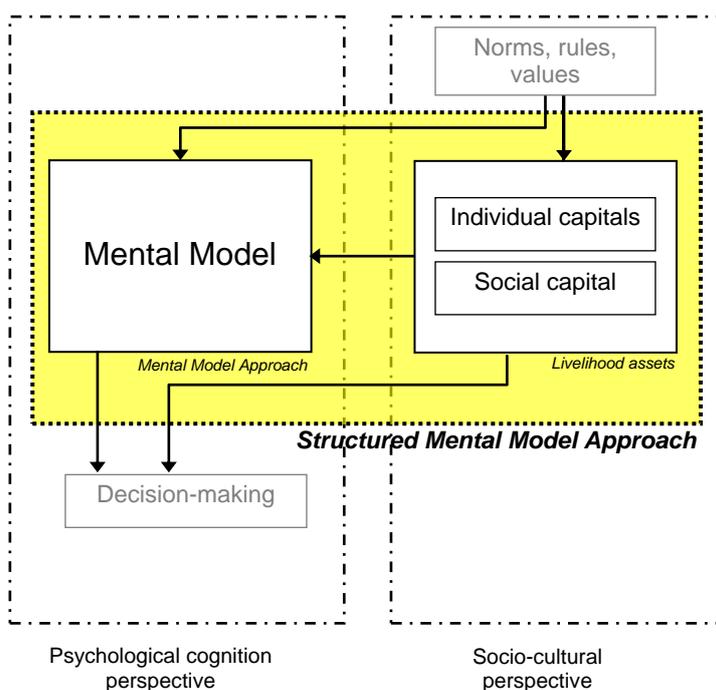
2. Conceptual Background

From a conceptual point of view the SMMA combines concepts emerging from psychological cognition perspectives as is the MMA with socio-cultural perspectives as is the SLF. The conceptual framework (Figure 1) of the SMMA provides a systemic perspective for relating farmers’ MMs to their livelihood, social structure, and decision-making. It depicts on the one hand the factors affecting farmers’ mental models and consequently his/her decisions. On the other hand the models integrated in the SMMA are presented.

2.1. The Psychological Cognition Perspective

On the left, the contribution from cognitive psychology is depicted. The perception of the livelihood, an intervention or a specific risk to farmers ‘livelihood is part of farmers’ MMs [2,49]. These MMs feed together with other variables, such as land size, access to credit, *etc.*, into farmers’ decision-making. Please note that the MMs represent the way in which farmers perceive their livelihood and do not have to be identical with what one would objectively measure. That is, farmers with the same assets can have a different view on them being wealthy or poor.

Figure 1. System border of the MMA and the SMMA (left: psychological cognition perspective; right: socio-cultural perspective; Individual capitals consist of human, physical, financial, and natural capital).



2.2. The Socio-Cultural Perspective

On the right, the components of the conceptual framework (Figure 1) related to socio-cultural research are shown. Socio-cultural research considers that cultural assumptions and normative values (components of the social structure) across social groups are important bases for forming the ideas about livelihood, its risk and risk management [49]. Hereby we base ourselves on the concept of the “risk society” as described by Giddens [50], in which he investigates the impact of culture and cultural change at the individual level. Giddens structuration theory [51] states that individuals are influenced by social structure (e.g., social norms, values and rules) in two ways. First it affects them directly as individuals within their human capital as they are part of a culture and have culturally specific traditions (in Giddens terms: signification [51]). Second, it affects the way farmers perceive their livelihood and hence their MMs (see above). Similarly Smith and Collins [52] state that the social context shapes the cognition of individuals and so their MMs.

The SLF provides an analytical approach to structure farmers’ livelihood assets. Individual capitals as part of farmers’ livelihood are defined as the assets and capabilities farmers have access to. They impact on their thinking and perception given the social structure they are embedded in [1,21,53,54]. In our approach, the individual and social capitals are constituents of the MMs built for analyzing risks. Therefore, the relevance of each individual capital for farmers’ livelihood, their interactions, and their relation to the selected risk should be studied. Based on the SLF [1], we suggest on including human, natural, physical, and financial capital in the analysis (Table 1).

Table 1. Definition of the four individual capitals and social capital and their relation to risks small-holder farmers are confronted with.

Capital type	Definition	Related risk
Human capital	People and their ability to be economically productive. It includes educational level, skills, experience, knowledge, creativity and innovativeness [16] Education level and health status of individuals and populations [55]	Health risks
Natural capital	The natural resource base available for pursuing an agricultural activity. It includes land and soil quality; access to water, <i>etc.</i> [1]. Natural resource base (land, water, trees) that yields products utilised by human populations for their survival [56]	Environmental risks
Financial capital	Stocks of cash that can be accessed in order to purchase either production or consumption goods, and access to credit might be included in this category [56]	Financial risks
Physical capital	Assets brought into existence by economic production processes, for example, tools machines and land improvements like terraces or irrigation canals [56]	
Social capital	Process and condition of social networking among people that lead to accomplishing a goal of mutual social benefit, usually characterized by trust, cooperation, involvement in the community, and sharing [57,58]	Loss of social status and network

Alternatively, one could consider of dividing the human capital into human capital (only related to education, tradition, *etc.*) and health capital to be able to determine effects between education and health as suggested by Schöll and Binder [29].

In contrast to the SLF, in the SMMA we look at social capital in a different way as at individual capitals, as:

- it includes relations between people rather than property owned by people
- it can usually be considered a public good shared by a group of people
- it is created by mutual effort over time of different people

Social capital is thus defined as the process and the condition of social networking among people that leads to accomplishing a goal of mutual social benefit, usually characterized by trust, cooperation, involvement in the community, and sharing [57,58] (Table 1). It is a product of culture and social norms within a society.

In the SMMA we specifically look at social capital in a relatively narrow sense, considering linkages, one form of social capital, which includes the relations between social strata, and reflects power relations [59]; see [57,60] for detailed definitions on social capital.

2.3. Considering the Different Literacy Levels in Less Developed Countries

In less developed countries one often has to deal with illiterate farmers or farmers with only a few years of education. We designed the SMMA so that the different levels of schooling and capacity of abstraction can be accounted for. Furthermore, the mental models elicited differ in their complexity as follows [32]:

Monadic models and set-theoretic models [32], aim at representing differences in the definition of the livelihood capitals

Two relational models [32] lead to (i) an influence diagram [2] of the interrelations between the livelihood capitals, and (ii) an agent network of the agents influencing farmers.

3. The Structured Mental Model Approach (SMMA)

In the following the specific procedure of the SMMA is described. In each section specific results are presented and their contribution to risk reduction and intervention planning is shown.

The SMMA is divided into three parts (Table 2):

Part I: Definition and weighting of the Individual Capitals

This part aims at understanding whether the definition of the livelihood capitals is the same for experts and farmers and how each group prioritizes one livelihood capital over the other.

Part II: Analysis of the Livelihood Dynamics

This part aims at understanding the way farmers perceive the dynamics of the system they are embedded in. The understanding of farmer underlying logic is essential for explaining them, what the

contribution of a specific technology to their livelihood might be. The comparison to experts view makes potential misunderstandings explicit.

Part III: Definition of the Social Capital

This part depicts the agents' network of farmers. The closer the farmer views the intervening institution relative to other agents, the higher the probability of a successful intervention might be. The results provide furthermore the basis for selecting collaboration partners.

Table 2. The assembly methods utilized in the SMMA.

	Experts model of farmer's livelihood	Farmers' model of their livelihood
	Influence diagrams of system elements and agents	Open-ended questions of system elements and agents
Part I	<ul style="list-style-type: none"> • Listing of relevant capital group elements • Weighting of the capitals 	<ul style="list-style-type: none"> • Grouping of the elements assembled by the experts in four capitals • Weighting of the capitals
Part II	<ul style="list-style-type: none"> • Showing how the elements are related 	<ul style="list-style-type: none"> • Answering open-ended questions on the relations found by the experts
Part III	<ul style="list-style-type: none"> • Listing the relevant system agents • Designing an agents network 	<ul style="list-style-type: none"> • Designing an agents network with the agents listed by the experts

In the following, we present the general approach. It is illustrated with results of two case studies in Latin America. One deals with pesticide management in Boyaca, Colombia [29]. The other studies the implementation of Canavalia as an erosion minimizing and fodder plant in Nicaragua [61].

3.1. Selection of Experts and Farmers

In order to cover all the perspectives of farmers' livelihoods, experts with different fields of expertise, e.g., agricultural economists, agronomists, *etc.* as well as experts of the specific risk analyzed should be selected. It is essential that experts' areas of expertise overlap, so that the robustness of the developed expert mental model can be guaranteed (Table 3).

Table 3. Example of selection of experts depending on their specialization (one expert can cover several capitals).

Human	Physical	Natural	Financial
Agronomist	Agronomist	Agronomist	Agronomist
Local technical assistance	Local technical assistance	Environmental engineer	National economist
Regional technical assistance	Regional technical assistance	Toxicologist ^a	Local economist
Medical doctor ^a			Pesticide seller ^a
Toxicologist ^a			
Teacher			

a: specific experts concerning pesticide risk analysis.

For the selection of farmers a purposeful sampling has to be carried out. Thereby, farmers with different levels of human, natural, physical and financial capital, have to be selected. This will allow us to analyze the variance between farmers' mental models and to understand whether the differences between farmers and experts are larger than the ones among farmers (Table 4).

Table 4. Examples of possible capital states of the interviewed farmers.

Capital	High (state)	Low (state)
Human	<ul style="list-style-type: none"> • Education: at least finished primary education • Health: no severe health problems 	<ul style="list-style-type: none"> • Education: no formal education • Health: severe health problems
Natural	<ul style="list-style-type: none"> • Soil: fertile soils • Slope: low • Forest: owns land with natural forest 	<ul style="list-style-type: none"> • Soil: low soil fertility • Slope: high • Forest: does not own any natural forest
Financial	<ul style="list-style-type: none"> • >10 ha of own land • Good access to credit 	<ul style="list-style-type: none"> • Landless farm worker • No access to credits
Physical	<ul style="list-style-type: none"> • Access to paved road, irrigation system, machinery 	<ul style="list-style-type: none"> • Geographically isolated farmer, no agricultural machinery
Social	<ul style="list-style-type: none"> • Status: community leader 	<ul style="list-style-type: none"> • Status: isolated member of the community

The size of the sample depends on the amount of interviews required until a drop off new concepts is encountered. Applying the MMA typically 20–30 interviews are conducted within a population group with relative similar beliefs [2]. Maharik [62] experienced that the number of new concepts encountered in mental model interviews often increases rapidly for the first 10–15 interviews approaching an asymptote around 20–30 interviews. During the farmers' interview in the case of Schöll and Binder [29] for Colombia and Mosimann [61] for Nicaragua, a drop-off of new concepts was observed after 4–5 farmer interviews. Therefore, if the characteristic drop off of new concepts is encountered after 5 or 10 interviews, a sample size of 10 or 20 persons is recommended, respectively.

3.2. Implementation of the SMMA

The interview is carried out in four steps. Introduction to the research; Part I: Definition and weighting of farmers' individual capitals; Part II: Interaction and dynamics between the capitals; and Part III: Social capital.

3.2.1. Introduction to the Research

The introduction to the research includes the following steps: (i) presentation of the interviewer and research, (ii) recording of their personal working background (experts) or socioeconomic situation (farmers), and (iii) overview of the interview.

3.2.2. Part I: Definition and Weighting of Farmers' Individual Capitals

The goal of this part is (i) to ascertain how farmers and experts define and weigh farmers' individual capitals and (ii) to analyze the differences between these definitions. Differences in capital definition between farmers and experts already provide insights into potential origins of misunderstandings when developing a risk communication strategy or implementing a new technology. Differences in the ranking of the capitals provide an indication on the divergent perception of the importance and consequently the perceived risks to farmers' livelihood capitals. We hypothesize that the higher the weighting of the capital is, the more farmers/expert will do to avoid risks to that specific capital.

Interview

The expert interview. In the expert interview, first, experts are given a definition and two example elements for each of the four individual capitals. Then they are asked to determine additional elements that will complete the set of elements of each capital group. The result is a set-theoretic model for each type of capital [32]. Finally, experts are asked to weight the capitals considering their relevance for farmers' livelihood. We suggest using a simple rating procedure, in which the experts interviewed are asked to rate the capitals between 1 and 4 (e.g., 1: most important to 4: least important capital group; see Table 5 for an exemplified interview). A more time-consuming and sophisticated option would be to perform an Analytical Hierarchy Process (AHP). AHP is an approach for weighting criteria in multi-criteria decision-making analysis, which is based on pair-wise comparisons of two criteria [63]. AHP requires that weighting criteria be defined and has the advantage that it encourages people to make clear statements on trade-offs between the criteria. An advantage of AHP is that it also provides an inconsistency check, which makes it possible to identify persons who were not able to perform the weighting correctly.

Table 5. Examples of questions posed in Part I of the expert interview (example for pesticide related health risks).

Part of the interview	Examples of questions
Definition of the capitals	Here are the four capitals chosen to define farmers' livelihood. They are defined as follows (see Figure 2). Please complete the elements belonging to each type of capital.
Ranking of the capitals	What role do the capitals play regarding farmers' use of pesticides? Please rank the capitals with respect to their relative relevance for farmers and explain. (1 = highest relevance; 4 = lowest relevance) Please consider their short- & long-term relevance.

The farmer interview. As preparation for the farmers' interview, we suggest taking photographs representing the region-specific pooled elements elaborated by the experts (Table 6). In a Latin

American context, we recommend photographs over pictograms or cartoon-like figures as farmers do not necessarily relate pictograms to their everyday reality.

Table 6. Example of an element consolidation and its photographic representation (example from case study Vereda la Hoya, Schöll and Binder, 2007).

Elements named by experts	Consolidated element	Regional relation	Photograph
<ul style="list-style-type: none"> • Religion • Ideology • The prayer 	→ Religion	→ Visualization of religion in Vereda la Hoya	<p>Communal church farmers go to</p> 

The farmer interview contains one step more than the expert interview. First, the capitals are defined by utilizing the same examples as in the expert interview. Second, farmers are shown the photographs of the elements and asked to define what they see in each picture (obtaining a monadic model [32]). Then they are asked to place the photographs in the four explained capital groups, obtaining a set-theoretic model (Table 7). For each placement they are requested to justify their choice, so that potential differences between experts and farmers can be explained. Finally, farmers are asked to rank the four capital groups in order of importance (e.g., 1: most important to 4: least important capital group) regarding the sustainability of their livelihood. If an AHP is to be applied, it has to be taken into account that illiterate people in developing countries are more likely to give inconsistent answers than people in developed countries [64].

Table 7. Examples of questions posed in Part I of the farmers’ interview.

Part of the interview	Examples of questions
Definition element Photographs	<p>Here are the four capitals chosen to define your livelihood in four groups. They are defined as follows...</p> <p>Please sort the following photographs into these four groups, commenting first on what you see in the photograph and second explaining why you chose to place the photograph in a specific group.</p>
Ranking of the capitals	<p>What role do the capitals play regarding the <i>specific risk</i>?</p> <p>What role do the capitals play regarding your livelihood?</p> <p>Please rank the capitals with respect to their importance for you and explain. (1 = highest relevance; 4 = lowest relevance)</p> <p>Please consider their short- & long-term relevance.</p>

Analysis

The expert interview. In a first step, the elements named by the experts to define the individual capitals are analyzed and multiple mentioning and synonyms summarized. This leads to a consolidated

list of region-specific pooled elements for each capital group, which builds the expert part of the capital definition. The elements could be presented as in Table 8 where the capital characterizing elements named by experts are sorted and marked in grey.

Regarding the ranking, it is aimed at obtaining one expert ranking. If deviations between experts emerge they should be discussed. Persisting deviations should be noted and considered when interpreting the differences in ranking between farmers and experts.

The farmer interview. In analogy, for farmers' interviews, the statements of what the farmers recognized on the photographs are consolidated. Subsequently, the total number of naming of each element to define each capital is inputted into the capital definition table (Table 8). The rankings of all farmers are summarized by counting the number of votes for each capital being placed to a specific rank. The capital with most votes for the nth rank is ranked on nth position.

Table 8. Example of capital definition by experts' and farmers' allocation of the elements to the capital groups (Fields in gray indicate expected placement by experts) adapted from [61].

Experts	Element	Farmers' element allocation to capital group			
		Human	Physical	Natural	Financial
Human capital	Technical assistance	2		6	2
	Nutrition	2	5	3	
	Politics	5	2		3
Physical capital	Pesticides		2	6	2
	Fertilizer		2	5	3
	Seeds		3	6	1
Natural capital	Canavalia		5	2	1
	Maize harvest		5	3	2
	Livestock		2	3	5
	Soil	1	4	5	
	Bean harvest			6	4
Financial capital	Bank		1	4	5
	Tobacco		3	2	5
	Costa Rica	1	1	1	7

Results and Interpretation. Table 8 shows exemplarily results obtained when analyzing the capital definition of experts leading and farmers participating in a soil conservation project [61]. One of the differences found, was that experts allocated technical assistance as being part of the human capital, since the activities of technical assistance should increase farmers' human capital. Farmers, instead, used this element to define natural capital. Their explanation was striking: the technicians were telling them exactly what to do and how to work with their soil, but they were not teaching them anything, suggesting a paternalistic type of intervention [65]. This example shows very clearly that the definition

of the capitals and moreover the differences between farmers and experts give indications on potential weaknesses within the intervention.

Results from Schöll and Binder [29] showed that experts interviewed weighed the human capital highest and the health capital the lowest, whereas farmers had the opposite weighting scheme. This implies that if experts invest in increasing farmers' human capital, which was weighted lowest by farmers, their intervention might not lead to the expected result as farmers weigh health above human capital. Thus farmers were not interested in increasing their human capital but were concerned about their health care system instead. This finding is confirmed by the fact that in the study most of the educational programs (also health related ones) have had no or little effect.

3.2.3. Part II: Interaction and Dynamics between the Individual Capitals

The goal of this part of the interview is, first, to obtain a pooled experts' influence diagram or a relational model of the interactions among the different individual capitals within farmers' livelihood. Second, it is to gain first insight into the dynamics of the livelihood system with respect to the specific risk analyzed. The model obtained is then used for designing farmers' interviews.

Furthermore, in the interview, farmers and experts have to explain the types of dynamics they consider relevant to the particular risk analyzed. That is, differences between experts and farmers will point to differences in priorities, risk balancing and views on trade-offs among the capitals. The dynamic perspective also provides insights into the origin of misunderstandings and miscommunications, as a similar interpretation of the past and a similar view of potential future development are key aspects in designing strategies in which experts and farmers' strive towards the same goals [66,67].

Interview

The expert interview. We suggest that experts be given a figure depicting the different individual capitals (Figure 2). Then, in the form of guided interviews they are questioned, always starting from a different type of capital,

- to analyze what a change in one capital state would have on the other capitals states, considering the specific risk analyzed;
- to depict the effects of one capital on another capitals with arrows in the diagram;
- to explain the depicted changes utilizing the elements they used to define the capitals.

For each new set of questions (and capital from which the questions start) a new diagram should be used. This approach structures experts' knowledge from the beginning of the interview (Table 9). We expect that, depending on expertise, the expert will depict and explain the interactions between the capitals with a different degree of detail.

The farmer interview. As a preparatory step for the farmers' interview, one "expert diagram" should be derived from the influence diagrams of all experts depicting both the general characteristics of system most of the experts mentioned and the detailed subsystems for which the different expertise provided specific inputs. From this, open-ended questions for the farmers' interviews should be designed, focusing on specific types of interactions among the capitals, always related to the risk

analyzed. The questions have to be asked in random order and have to include the interaction among the capitals as well as their dynamics consisting of sequential capital influences (for an example see Table 10).

Figure 2. The four capitals (left). Experts have to depict the interaction among these capitals with arrows showing the type and direction of the interaction (right).

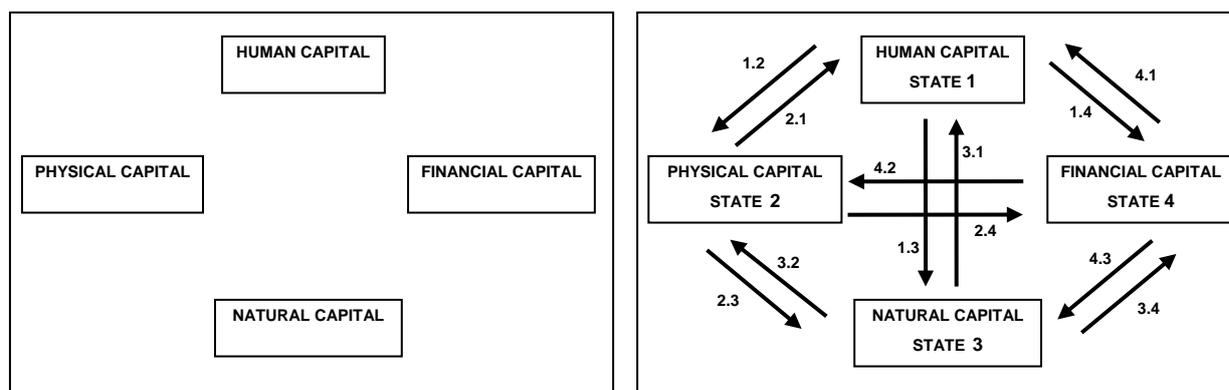


Table 9. Examples of questions posed in Part II of the expert interview.

Part of the interview	Examples of questions
System dynamics	<p>Please comment on farmers’ livelihood system considering the interaction among the capitals.</p> <p>To what extent and how does farmers <i>risk management</i> influence their capital states and respective elements?</p> <p>How does the level of capital state (e.g., high or low wealth, education) influence farmers’ perception and decision-making with respect to <i>risk</i>?</p>
Influence diagram	<p>Assume that, e.g., farmers’ financial capital increases. How will this change affect the other capitals? Please illustrate your statements within this figure. (Figure 2)</p> <p>For example: Increase of human capital → safer use of pesticides → increase in health → higher labour capacity → improved livestock → increased profits → higher financial capital → can buy less toxic, more effective pesticides</p>

Analysis

The expert interview. In order to obtain a common experts’ system dynamic model, all resulting experts’ graphs have to be combined into one single graph. The experts’ graphs and their comments are analyzed separately considering two system dynamic aspects: (1) capital state S (*i.e.*, S3 = natural capital state) and (2) capital effect, *i.e.*, effect of one capital on the others (e.g., 1.3 = effect of human on natural capital) (Figure 2 right). Multiple mentioning is summarized; deviations of experts’ statements are noted and considered in the interpretation.

Table 10. Examples of questions posed in Part II of the farmer interview.

Capital group	Examples of questions
Human	Did your parents also cultivate potatoes? What other crops did they cultivate? Have the cultivation techniques changed with respect to the ones your parents used? If yes, how?
Human	How did you learn to confront the pests (with pesticides, types of pesticides, biologic crop protection)?
Human	What do you do if you feel sick? (e.g., nausea after applying pesticides)
Physical	What kind of agricultural machineries are you using via a common village organisation?
Natural	How do you judge the quality of your soil? Has it changed since you cultivate potatoes/ carrots?
Natural	What effect do you think have pesticides on plants? ...on the soil? ...on natural abundance in the fields (biodiversity)? ... water?...your health?
Financial	What is the current price of potatoes/carrots? What do the prices depend on?
Financial	What would you do if you had more/less money?

The farmer interview. The summarized statements of the experts' interviews are used to develop the 10 open-ended questions which farmers are asked. Each question targets either specific capital states (1, 2, etc. (Figure 2)) and/or capital effects (1.2, 2.4, 3.1 etc. (Figure 2)). Farmers' answers are summarized with respect to the targeted aspects, by counting how many farmers' gave the same or a similar statement.

Results and Interpretation. At the end of the analysis for each capital-state and each capital-effect, the statements of experts and farmers are compared applying the qualitative interpretative approach [2]. The effect statements are then analyzed and interpreted to identify the person's risk-related perception of the mentioned effect. For doing so, each statement is rated on a four-level-perception scale measuring the significance of the statement in terms of risk perception, where:

- Score 0: no effect perceived
- Score 1: effect perceived
- Score 2: effect perceived and explained
- Score 3: effect perceived, explained and stated to be risk related

All experts' and all farmers' statements scorings are summarized in an expert and a farmer impact matrix (Table 11) to obtain a comparable overview of the scoring.

For example (* in Table 11), in the case of pesticide risks in Colombia, experts did not mention any effect of natural on human capital (0), while farmers attributed this relationship a value of 3, as they stated to learn from their observations of nature (a perception score of 3). Farmers answered the question "What effect do you think pesticides have on plants?" with "when dosage of pesticides is high, the growth and the strength of the plant is affected" and "when pesticides are overdosed, burning of leaves is observed". When asked how they derived these interactions, farmers commented that experts never taught them about the effect of e.g., overdose but they had observed it and thus learned this

interaction by experience. For farmers learning by observations from effects perceived in nature means, that nature had taught them these effects.

Table 11. Theoretical example of an impact matrix of experts vs. farmers' risk perception.
* = example explained in the text (adapted from Schoell and Binder [29]).

	Human Capital (E/F)	Physical Capital (E/F)	Natural Capital (E/F)	Financial Capital (E/F)
Human Capital		2/1	3/3	0/0
Physical Capital	1/0		0/1	0/2
Natural Capital	0/3*	2/0		1/1
Financial Capital	3/2	0/3	1/1	

This example shows that differences in the perception of how the capitals are interrelated and how risks to one specific capital might affect the dynamics of the system indicate sources for misunderstandings between experts and farmers. Another example from our application in Colombia showed that experts believe that if farmers had more money they would invest in improving their pesticide management leading to a reduction of health risks, but farmers, in contrast, considered they were sufficiently healthy and would rather invest in producing a different product. That is strategies designed by experts to, e.g., increasing farmers' income for improving their health might not lead to the desired goal.

3.2.4. Part III: Social Capital (Agent Network)

The goal of this part is to identify the social networks farmers are involved in. Of particular interest is not only to whom farmers are connected, but to what degree they feel that different agents are close to them and might influence their decision-making.

We suggest combining the following approaches in the interview (see also Binder [54]): Snowball principle to identify the relevant (direct and indirect) agents [68], and relation mapping through functional and production-consumption interactions [69,70].

Interview

The expert interview. Experts are first asked to name all the agents they consider relevant for the farmers. Then they are requested to illustrate the agent network in a diagram. Thereby the farmer should be placed in the center and the connections to the other agents should be recorded with lines depicting the distance of the farmers to the named agents. Experts are solicited to consider both direct and indirect interactions of the agents with the farmers.

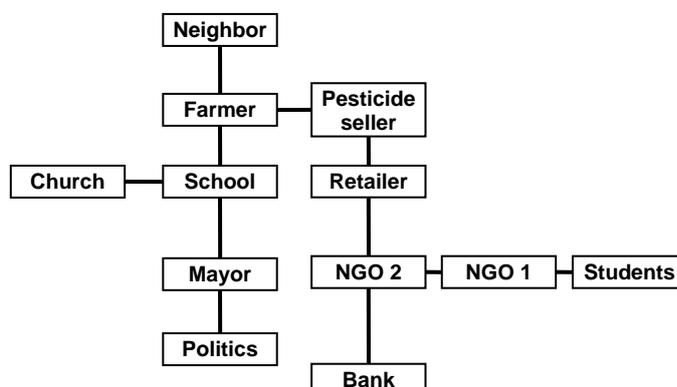
The farmer interview. In a preparatory step, the agents named by the experts are again be categorized and photographs of agents related to the region taken. As in Part I, farmers are first asked to name the agent on the photograph. Then they are requested to build their own agent network by

placing the photographs closer or further away from themselves with respect to their importance for their livelihood and to the specific intervention or risk studied (Table 12). Photographs of the agent models as developed by farmers should be taken and the relative distance between agents, *i.e.*, between the farmer and the different agents should be measured and included in the analysis (Figure 3).

Table 12. Examples of questions posed in part III of the farmer interview.

Topic	Examples of questions
Agents network	Who is the agent depicted in this photograph?
Agents network influence diagram	<p>If you were here, place the agents recognized on the cards around you by considering how close you feel to every agent compared to the others</p> <p>(1) If you feel that Agent 1 and Agent 2 are equally close to you, then place both cards around you</p> <p>(2) If you feel closer to Agent 1 than Agent 2, place the card of Agent 1 closer to you than the card of Agent 2</p> <p>(3) If you feel Agent 2 is leading you to Agent 1 then place Agent 2's card between you and Agent 1</p> <p>(4) If you look at the final placement of the cards given to you, are any agents missing?</p>

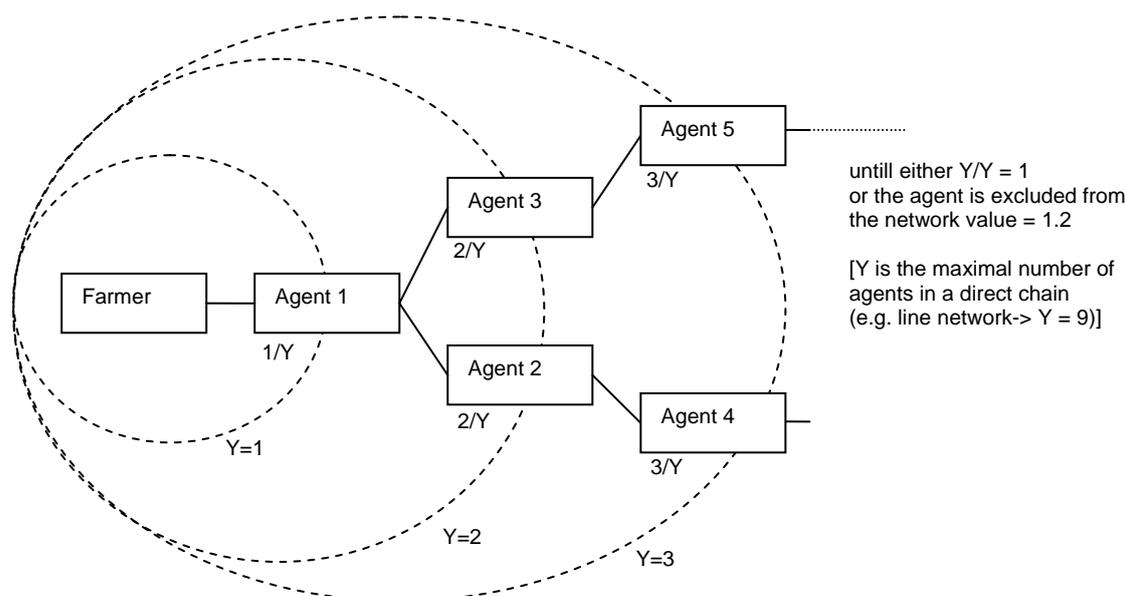
Figure 3. Example: agent network constructed by a farmer and its graphical representation (adapted from Mosimann [61]).



Analysis

The expert interview. The agent networks of the experts are summarized and the most frequently named agents by all experts selected. Subsequently an expert agent network is constructed and validated with experts. Finally the obtained network is represented as a line network. The position of the agent on that network is found by calculating the distance of the agents to the farmers as shown in Figure 4.

Figure 4. Example: agent network analysis.



The farmer interview. In analogy, to analyze the farmers' agent networks the elicited agent network structures are analyzed and are represented in a line-network as shown in Figure 3. Additional named agents by the farmers are noted down and have to be considered when interpreting the analyzed data.

Results and interpretation. The agent network analysis provides first information about how close experts and farmers see specific agents to be related to farmers. Farmers' explanations regarding the perceived closeness of agents within their network might pinpoint issues such as trust. Differences between experts and farmers might additionally elucidate why interventions by specific agents might not be as successful as expected.

Second, the structure of the elicited networks (e.g., a straight line *versus* a spider type network) can be analyzed and compared. The type of structure characterizes the embeddedness of the farmer in his/her social surroundings and provides first insights into their access to other capitals through the social capital available. Furthermore, for experts, the knowledge of farmers' views on agents' networks might be of relevance when looking for partners to implement change programs.

5. Discussion

This paper presents a method, the Structured Mental Model Approach (SMMA), for analyzing diverging system perspectives between experts and farmers regarding the perception of farmers'

livelihood, related risks and potential utility of interventions in the rural areas of developing countries. Specifically, the SMMA:

- (i) structures the interviews to first understand farmers' perception of their livelihood and livelihood risks and potential gains.
- (ii) allows for comparing farmers' perceptions to the ones of experts
- (iii) supports the analysis of potential sources of misunderstandings, and thus
- (iv) supports the development of sound intervention strategies

In the following specific gains from applying the SMMA are highlighted, followed by the need for further research.

5.1. Insights Gained with the SMMA

5.1.1. Understanding Farmers' Local Knowledge and Individual Motives and Values

The SMMA supports the understanding of farmers local knowledge, their motives and values as claimed for by de Svenson [22], Walters *et al.* [71], and Haan and Zoomers [16], as follows. First, the analysis of farmers' mental models makes the underlying logical thinking structure (local knowledge) explicit, supporting the understanding of the role of livelihood capitals for farmers' decision-making. Second, the comparison to experts' mental models enables for pinpointing specific differences between experts and farmers in the definition, prioritization, and dynamics among the livelihood capitals and supports thus the development of appropriate communication techniques.

The utility of the SMMA becomes evident when looking at the results of capital definition and weighting in the case of Vereda la Hoya, Colombia [29]. Example 1 (Table 13) shows the case where the element definition and the weighting were different between experts and farmers. In this case, the expected farmers' decision by experts is likely to be the same than what farmers would do, but the underlying logic of experts and farmers is completely different. Example 2 (Table 14) illustrates the case in which the weighting of the capitals is the same but the definition of the capitals is not. In this case even if farmers and experts would apparently talk about the same capital weighting (financial over natural), if experts would design measures to improve the natural capital, they might instead be fostering the financial one.

These results suggest that for designing interventions and communication campaigns three issues have to be considered: First, how farmers define the capitals, second, how they rank them, and third, how they perceive the interaction among them.

Table 13. Example 1 for Vereda la Hoya, where the same expected action by experts and farmers is due to different element definition and weighting.

	Technical assistance placed in	Ranking	Potential outcome
Farmer	Financial capital	Financial > Human	Same expected decision but different capital definition and weighting
Expert	Human capital	Human > Financial	

Table 14. Example for Vereda la Hoya, where apparently same capital weighting leads to different expected actions if the capital definition is not elicited.

	Pesticide management placed in	Ranking	Potential outcome
Farmer	Financial capital	Financial > Natural	Apparently same capital weighting leads to different expected decisions if the capital definition is not elicited.
Expert	Natural capital	Financial > Natural	

5.1.2. Accounting for the Role of Social Capital and Access to Individual Capitals

In SMMA, to understand the social network farmers are embedded in, their agent network is analyzed. The agent network describes the closeness of different agents to the farmers and allows for analyzing the access of farmers to e.g., human capital (e.g., technical assistance), or financial capital (e.g., closeness to and experiences with banking or credit institutions). This insights are essential for designing intervention strategies to improve the sustainability of farmers' livelihood. For example in the case study of pesticide management in Vereda la Hoya, we found that the perceived closeness to local markets affects the decision on how farmers produce potatoes (e.g., input use) which in turn affects the financial capital. The obtained results suggest that a separate analysis of the social capital, specifically, farmers network, might give significant insights into the role and influence of different experts on farmers from which the key agents can be selected and cooperated with.

5.1.3. Systemic Embedding of the Intervention Planned or Specific Risk to be Studied

Interventions or risks farmers are exposed to, have to be seen within farmers' livelihood, as each intervention or each risk assessed is always in relation to other parts of farmers' livelihood or risks [45]. With the SMMA we provide an approach to investigate the trade-offs between the different livelihood capitals as seen from an expert and a farmer perspective.

In the case of pesticide management in Colombia, we found that improving the communication and education of a specific e.g., health risk, it would not be sufficient to improve the health situation of farmers, as farmers do not see any connection between knowledge and health related risks. However, looking at the whole picture suggests that the best way to support farmers in improving their health situation is to consider their faith and the influence of their faith on decisions concerning health protection [29].

5.1.4. Identifying Potential Origins of Misunderstandings

The results from the SMMA provide a basis for identifying origins of misunderstandings between experts and farmers. In the first step, the capital definition, differences in the definition of capitals already provide preliminary insights into potential sources of misunderstanding (Table 15). Having the same definition and understanding of a term is the basis for successful communication. When weighting the capitals, the priorities of farmers and experts are clearly defined. Communication based

on a different type of weighting is likely to fail, since the common denominator is missing and messages may easily be misinterpreted. The differences in capital interaction and system dynamics, elicited in the second step, show the interpretation of past incidences and allow assumptions on to future behavior. In the third step, the farmers' agent network, aspects such as trust and confidence impact on how farmers see their closeness to different agents. From this step, it is possible to deduce which agent is likely to be effective with his/her interventions and which not.

5.2. Policy Relevance

We consider that the results that can be obtained with the SMMA provide a sound basis for the design of interventions, communication and educational programs. Risk communication is more effective if it is related to the whole system affecting the subjects' lives [45]. In the SMMA this is assured through the inclusion of the system dynamics of the different capitals of farmers' livelihood in the mental models. The mental models obtained, thus, on the one hand, allow for a thorough scientific analysis of the differences between experts and farmers, and on the other, open the door for an effective risk communication and development of educational programs [2]. The embedding of the mental models into the context of farmers' livelihood, furthermore, allows for the design of holistic policies which consider the views of farmers on their own livelihood, as well as the perception of their own problems. Thus, the way in which farmers "balance" the risks of the different capitals and see the trade-offs between the different capitals can be made explicit.

In addition, experts' understanding of the embedding of e.g., pesticide risks in farmers' livelihood allows them to develop strategies and options for change that consider farmers' priorities and viewpoints. This allows for developing strategies in expert-farmer teams.

Considering the different literacy levels in less developed countries

The SMMA was designed to include different levels of systemic abstraction as discussed by Johnson-Laird [32]. We used monadic, set-theoretic and relational models. In a first trial in Vereda la Hoya, Colombia [29], experts had no problem using and relating to these different types of models. For farmers the case was slightly different. Farmers related well to the monadic models, *i.e.*, they recognized the photographs, could define them properly, and were able to relate them to an abstract concept. This was even true for photographs depicting different parts of the health care system in Colombia [29]. This suggests that, in the context of Latin America, photographs are a good way of testing the ability of farmers to build monadic models. In other cultural backgrounds, alternatively painting on a sandy soil [21] or weighting with stones [72] might be considered.

Farmers were also able to conceptualize a set-theoretic model. Our first experiences suggest that the consistency of farmers with experts' allocation (of elements to capitals) decreased with decreasing level of human capital. Finally, the building of relational models was handled well by farmers suggesting that, first, the approach to build the relational model by using open-ended questions about relations described by experts is adequate in this cultural setting. Second, farmers can easily relate to a systemic context also considering interactions [28]. This insight is relevant for developing measures to reduce a specific risk, implying that educational programs should always encompass both information on the whole system and the interrelationship to the specific risk to be reduced.

5.3. Critical Issues, Validation and Need for Further Research

5.3.1. Critical Issues

A few caveats to this approach should be noted. First, a theory driven approach might bias the results obtained, as people are guided in their thinking with respect to a specific framework. That is, even though at each step experts and farmers are asked if important aspects are missing, relevant system features might not be included in the mental models. In the Colombian case this was the case, for example, for gender issues.

Second, experts' mental models are taken as the basis for analyzing farmers' mental models. That is, one underlying assumption is that the expert models are the "correct" or "objective" ones. This is one issue that has also been criticized in the MMA [6,45,46,47]. This might lead to a neglect of specific topics or issues. In our approach this issue is slightly minimized through a specific theoretical background. When applying the SMMA for analysis of the future, we reversed the order of the questioning. This led to higher focus on farmers' viewpoints concerning farmers' future [35].

Third, an issue when such a complex system is analyzed is the consistency of the expert model. In both case studies we chose experts from different fields, to assure a proper representation of the system. In the Colombian case, where Colombian experts were chosen, expert mental models merged nicely to one expert model [29]. In the Nicaraguan case we included also experts from Switzerland. Here it was much more difficult to merge the different models [61]. In future research, the robustness of the expert models in dependency of the degree of specialization should be studied.

Fourth, the time required for performing an SMMA in the field is approximately two weeks; farmers interviews lasting two hours each. This implies that earlier contact with the farmers is required to build trust. In the Colombian case, the University we have been collaborating with had been performing projects (mostly schooling projects) in the study area during the last 5 years building trust with the population. One of the main contact persons accompanied the researcher in her field visits and performed part of the interviews. Thus, farmers were comfortable with and trusted the research team.

Fifth, if the approach is to be applied to another research area, a sound theoretical and conceptual background, as in our case, the livelihood approach, is required. This implies that some research on the general system characteristics should already have been carried out to be able to build on existing systemic knowledge.

5.3.2. Validation

In contrast to environmental process models, mental models are rather difficult to validate. In the case of the Colombian case study, an anthropological study was carried out in the same study area, also analyzing farmers' perception and behaviour regarding pesticide management [73]. The specific systemic information obtained, and also elicited with the SMMA, e.g., perception of farmers' livelihood, risks, was the same with both approaches. That is, the information obtained with the SMMA on farmers' perceptions is adequate. As mentioned above, in the ethnological study additional issues were looked into as gender aspects, labour distribution within the household. This gives additional insights about the system, which were not aimed for in the SMMA.

5.3.3. Further Research

The SMMA opens the room for further research in several directions:

First the link between mental models and current behaviour could be analyzed. The next envisioned research step is to derive with the SMMA the mental models and with a survey the current behaviour of two farmer groups within one region (one control group). Based on the analysis, interventions for improving farmers' livelihood are designed. After two years the analysis is repeated to obtain longitudinal data on the mental models and farmers behaviour. Optimally this analysis should be repeated periodically. We performed a pre-test of such a study, comparing intervened and non-intervened farmers with similar characteristics in neighbouring regions in both case studies. The preliminary results suggest that the type and potential effectiveness of intervention is reflected in the change/non-change of farmers' mental models. In the Colombian case we found differences in the mental models between the intervened and non-intervened farmers, while in the Nicaraguan case these differences were minimal. We aim at deepening this analysis to provide recommendation for successful interventions.

Second, factors affecting the mental models could be studied. Of particular interest could be to link the different personality factors [74] (for an excellent review) with the resulting mental models of farmers. These factors might affect the way farmers think. This becomes even more relevant when studying the mental models of the future [35]. Additionally, one could relate farmers' livelihood capitals to the way they perceive their capitals.

Third, similarly one could think of analyzing farmers' perceived gains of potential strategies to minimize livelihood risks, such as diversification. That is, one would analyze the "objective" gains of diversification measured by experts and the way experts conceive the system dynamics to get there. An interesting question would be to inquire the way farmers perceive the same strategy and whether the system dynamics farmers perceive are in agreement with the one of experts. If it were not the case, one could envision designing educational programs based on that knowledge in order to engage into a mutual learning process regarding the system and its dynamics.

Finally, the presented methodology has been developed and tested in a Latin American context [29,61]. We consider that further research is needed when adapting the methodology to other cultural contexts for example India or China. In particular the design of farmer interview, e.g., with photographs or pictograms will have to be developed.

6. Concluding Remarks

This paper presented the SMMA as a tool for understanding specific farmers' risks in relation to their livelihood and to distinguish between the risk perception of farmers and experts in developing countries. It provides a system based structured procedure which allow for specifically (i) analyzing the weighting of risks within farmers livelihood and their interrelationship, (ii) identifying the trade-offs farmers face; and (iii) understanding the thinking behind the way farmers balance their risks.

Furthermore, the SMMA presents a basis for identifying potential origins of misunderstandings between experts and farmers (Table 15).

Table 15. Overview of data analysis.

Interview part	Target capital	Aspect analyzed	Analysis and result presentation	Risk aspect considered
Part I	Individual capitals	<ul style="list-style-type: none"> • Definition of capitals • Relative importance of capitals 	<ul style="list-style-type: none"> • Matrix showing elements used for capital definition • Ranking table 	<ul style="list-style-type: none"> • Level of baseline understanding • Trade-offs between livelihood capitals
Part II	Individual capitals	<ul style="list-style-type: none"> • System dynamics 	<ul style="list-style-type: none"> • Separate “state” and “effect” statements • Livelihood and risk perception matrix 	<ul style="list-style-type: none"> • Origins of difference in risk perception
Part III	Social capital	<ul style="list-style-type: none"> • Definition of agents • Agent network 	<ul style="list-style-type: none"> • Agents named by experts • Recognized and complemented agents by farmers • Distance in network • Structure of network 	<ul style="list-style-type: none"> • Active agents working in the region and their perceived relevance • Agents role in interventions

In the first step, the capital definition, differences in the definition of capitals already provide preliminary insights into potential sources of misunderstanding. Having the same definition and understanding of a term is the basis for successful communication. When weighting the capitals, the priorities of farmers and experts are clearly defined. Communication based on a different type of weighting is likely to fail, since the common denominator is missing and messages may easily be misinterpreted. In the second step, the analysis of the capital interaction and system dynamics, the potentially largest differences are to be found. These differences may have their roots in the different definition and weighting of the capitals. They will additionally show the interpretation of past incidences and allow extrapolation to future risk-averse or risk-taking behavior. In the third step, we analyze the farmers’ agent network. Here aspects such as trust and confidence in the agents involved may affect how farmers see their closeness to themselves. From this step, it is possible to deduce which agent is likely to be effective with his/her interventions and which not. Differences between experts and farmers and, moreover, the explanations of such, will show where the misunderstandings are and how agents have to change to potentially overcome them.

First empirical applications of the SMMA have shown that the method is applicable to different issues within rural livelihood research to identify the differences in mental models between experts and farmers. Based on these results, on the one hand, communication and schooling strategies to improve farmers’ livelihood can be set up. On the other hand, the results can be extrapolated applying a representative survey and utilized for developing quantitative behavioral and dynamic simulation models to assess strategies and future perspectives of farmers and experts.

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