Farmer responses to multiple stresses in the face of global change: Assessing five case studies to enhance adaptation

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Abstract: In order for local agricultural systems to produce food sustainably while facing multiple large-scale pressures, a deep understanding of farmer behaviour and decision-making is needed. We synthesize existing literature to identify four spheres of knowledge to be generated to understand farmer decision-making: 1) biophysical and social factors; 2) actors and power relations; 3) cross-scale and cross-level pressures; and 4) temporal dynamics of behaviour. We use these spheres to compare five diverse case studies. We find that these four spheres are important to understanding farmer decision-making, and that they can be used to guide the design and interpretation of future studies. We also identify three methodological barriers, and propose that mixed method research is necessary to successfully address all four spheres simultaneously.

Keywords: farmer decision-making, adaptation to climate change, sustainability, mixed methods

Introduction

Multiple simultaneous and interconnected ecological, economic and social pressures converge in creating stress on agricultural systems (e.g. O'Brien and Leichenko, 2000). On the other hand, agricultural activities are themselves major contributors to a range of environmental issues including greenhouse gas emissions, biodiversity loss, deforestation, water and soil pollution, and soil erosion. It is increasingly recognized that the challenge of producing food while preserving the environment entails a systemic shift in agricultural systems (e.g. Lang and Barling, 2012).

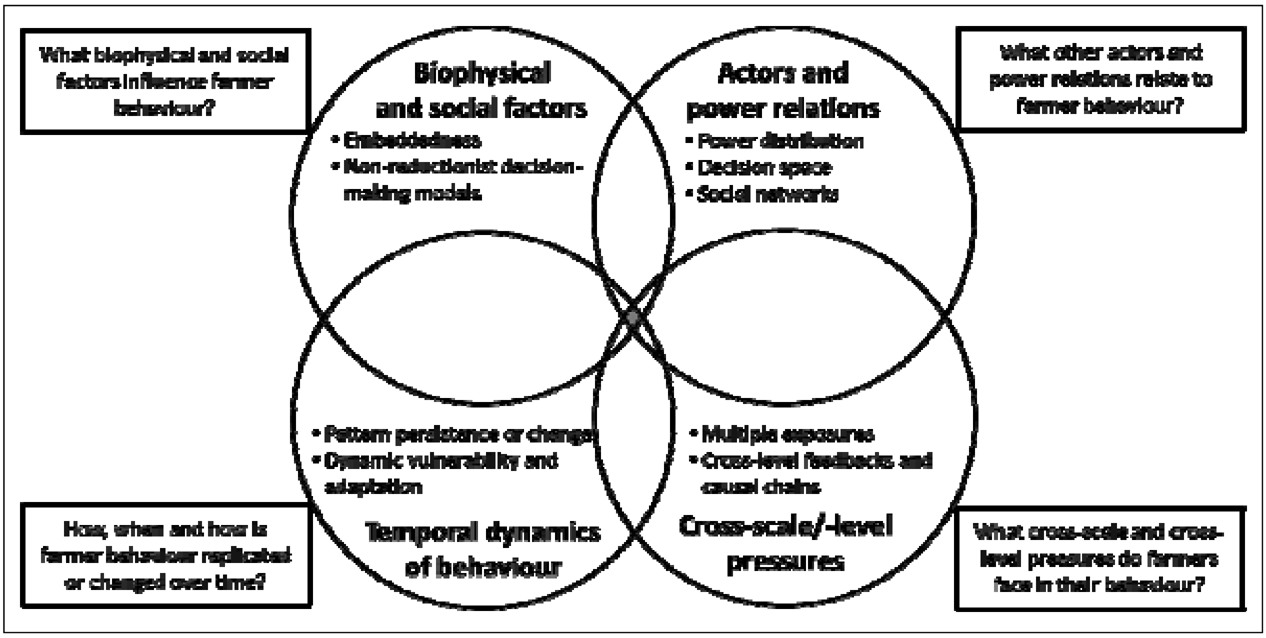
In order for local agricultural systems to produce food sustainably while facing multiple large-scale pressures, a deep understanding of farmer behaviour and decision-making is needed. However, while farmer actions are a key determinant of agricultural systems' ability to adapt, too often research relies on theories and methods that do not capture the complexity of farmer decision-making, and translate into ineffective adaptation or sustainability policies. Understanding the process of actor decision-making is one of the most urgent tasks to improve understanding of coupled social-ecological systems, such as agricultural systems, in the face of global environmental change (Darnhofer et al., 2010; Feola and Binder, 2010; An, 2012; Schlüter et al., 2012). Furthermore, the role of on-the-ground decision-making by individual farmers is often studied in individual cases to determine its environmental, economic, and social effects. There have been few efforts to link across studies in a way that provides opportunities to better understand empirical farmer behaviour, design effective climate change adaptation policies, and be able to aggregate from case studies to a broader level.

This paper deals with the challenge of understanding farmer actions in the face of increasing and simultaneous ecological, economic, and social pressures, and in the dynamic frame of their institutional context, power relations, social networks, and bio-physical environment. First, we discuss four main spheres of knowledge on famer decision-making that we have identified as critical based on previous literature. By comparing five case studies, we then illustrate how these spheres can be investigated in different geographical areas and agricultural systems. The lessons learned from this analysis can assist in understanding farmer decision-making in the context of climate uncertainty and multiple simultaneous pressures.

Analytical framework

In this section we analyse the recent literature and identify four interdependent but analytically distinct spheres of knowledge that need to be addressed to understand the complexity of farmer decision-making, namely: 1) biophysical and social factors; 2) actors and power relations; 3) cross-scale and cross-level pressures; and 4) temporal dynamics of behaviour (Figure 1). While these spheres clearly overlap in practice, they are a construct that can be useful to look at farmer decision-making analytically.

Figure 1: The analytical framework.



Biophysical and social factors

We identify two basic schools of thought in relation to farmer decision-making. The first, commonly used in large-scale modelling studies, tends to focus on biophysical elements like crop yield as measures of system performance. These studies assume general models of ‘rational action’ rather than pursuing an in-depth understanding of the specific decisions made by farmers in their local system. Rational action models are reductive and fail to account for the diverse rationalities that different types of decision-makers employ in real life (Darnhofer et al., 2010; Feola and Binder, 2010). Furthermore, such simplified models tend to result in a ‘technical-fix’ policy approach (Ribeiro and Shand, 2008). This approach defines adaptation to climate change or adopting sustainable agriculture as problems that can be solved by intervening through instrumental measures (informational, technological, economic). In contrast to such a technical-fix approach, a growing body of literature has stressed the importance of looking at the social ‘embeddedness’ of farmer decisions and actions. Crane et al. (2011) for example, showed the importance of understanding "adaptation as a dynamic process that is socially embedded" (p. 179). The agricultural performance is embedded in a social performance in a broader sense and that technical decisions may in fact entail several layers of moral and symbolic meaning (e.g., compliance with traditional systems of values, or socially accepted role models).

Actors and power relations

The technical-fix approach is often associated with a conceptualization of farmers as 'adopters' of practices. However, it is essential to recognize that farmer decisions are enacted in a social landscape bounded by other actors, which include extension agents, rural development agents, local authorities or agri-business. That is, not only other actors might influence farmers directly (e.g., social pressure), but they can do this indirectly, by voluntarily or involuntarily creating physical (e.g., land appropriation and enclosure) or social structures (e.g., norms) that constrain farmers' opportunity space (e.g., Scoones, 2009). More importantly, social, economic and political power is unevenly distributed and therefore the boundaries of farmers' actions may be tighter when there is a large difference between the perceived objective power of farmers and other actors. Power and social relations may underpin situations of intrinsic vulnerability in many rural areas worldwide and in the global South in particular (Scoones, 2009).

Cross-scale and cross-level pressures

Agricultural systems are normally exposed to multiple and simultaneous pressures, such as environmental change and economic liberalization, whose perceived effects are considered by farmers in their farming decisions (O'Brien and Leichenko, 2000). Thus, linking across scales (e.g. temporal, spatial) and levels (e.g. short- or long term, micro and macro), although challenging, is required for a full analysis of rural livelihoods and systems (Scoones, 2009). Multiple pressures often cut across scales and levels. To include cross-level interactions in the analysis has at least two important implications. Firstly, the pressures that farmers respond to might be, or at least might perceived to be, out of the control of farmers' influence. Secondly, causal chains in cross-scale and cross-level interactions are arguably more difficult to be perceived by actors at one level, and therefore considered in the decision-making process.

Temporal dynamics of behaviour

Agricultural activities mostly entail decisions that are cyclically repeated over time, and made at least partly in response to changes and pressures that are the result of previous behaviours and their consequences in the agricultural system. Such cycles can reinforce or change biophysical and social structures (An, 2012; Schlüter et al., 2012). Several studies show that policies aimed at a transition towards sustainable agricultural practices often fail to achieve a structural, durable, self-sustaining change. Moreover, regarding vulnerability and adaptation to climate change, several authors have discussed the notions of 'dynamic vulnerability' and 'dynamic adaptation' (e.g., Westerhoff and Smit, 2009). They point to the changing nature of the pressures farmers are facing and, to the dynamic nature of the adaptation process as based on the observation of continuous feedbacks between actions and consequences in the social and bio-physical system domains. Importantly, to capture the dynamics of how behavioural patterns change or persist, a shift of focus is in order, from the explanation of one-off decisions to the understanding of how some adaptive (or maladaptive) and sustainable (or unsustainable) practices persist or not over time, and how these co-evolve with the system's social and biophysical structures (An, 2012; Feola, 2013).

Case studies

In this section we use five previously conducted case studies that span a range of agricultural systems in distinct geographical contexts across the globe to compare and discuss the four spheres in practice.

The first case study was focused on peri-urban maize production in the Toluca Metropolitan Area west of Mexico City. The study aimed to uncover the processes affecting farmers' decisions to continue or abandon maize production in an expanding urban area and in a country that has experienced significant policy changes and climatic stress since agrarian reform distributed land to formerly landless peasants (Lerner and Appendini, 2011). Despite a production system that is increasingly industrialized to produce grain for the urban consumers of Mexico, small-scale production persists throughout the country. A livelihoods framework was used to examine the factors that could affect farmer decisions, and household surveys and semi-structured interviews (N=146) measured socio-economic, political, environmental, and demographic variables that could cause farmers to abandon or maintain their maize production (Lerner et al., 2013).

The second case study aimed to uncover the behavioural dynamics of unsustainable personal protective equipment (PPE) and pesticide use practices in the Colombian Andes, and to provide policy recommendations for a transition towards more sustainable ones. The study developed and adopted the integrative agent-centred (IAC) framework (Feola and Binder, 2010). A survey (N=197) was carried out and statistical and econometric models of PPE and pesticide use were used to identify influential factors and social dynamics. Finally, a dynamic behavioural model was developed and used to study alternative policies which were identified, simulated and discussed in workshops with local experts and policy-makers (Feola et al., 2012).

The third case study was focused on winegrowing in Northern California. Winegrowing is important both economically, contributing $61.5 billion to the state's economy and producing over 90% of wine in the US, the world's fourth largest wine producer, and culturally, drawing tourism (Nicholas and Durham, 2012).) The Vulnerability Scoping Diagram was used along in-depth semi-structured interviews and ranking exercises with winegrowers to examine farm-scale adaptive responses to environmental stresses, to understand the views and motivations of agricultural managers, and to explore adaptive capacity in practice (Nicholas and Durham, 2012).

The fourth case study examined how cropping decisions in Gujarat, India are impacted by inter-annual rainfall variability, market prices, and access to irrigation. This high inter-annual variability in rainfall can be used as a proxy of climate variability and change that farmers will face in the future. 750 farmers were surveyed across a rainfall and irrigation gradient over three years to understand how a variety of socio-economic and biophysical factors influenced cropping decisions and adaptation strategies. Remote sensing and multivariate analyses were employed, and a comparison of self-reported yield and income data, allowed to assess whether these strategies were adaptive or mal-adaptive (Jain, 2013).

Finally, the fifth case study focused on indigenous smallholder farmers' decisions to participate (or not) in agro-industrial production of 'low carbon' commodity crops in upland Palawan, The Philippines. The objective of the study was to understand non-economic variables that influence indigenous farmers' decisions to continue or abandon swidden cultivation and second growth and residual forests amidst enticements and pressures to engage in oil palm, jatropha, and natural rubber production regimes. The study built on the Institutional Analysis and Development Framework to incorporate the role of social constructions of the environment and environmental discourses in actors' decisions in an institutional setting. It drew from a survey of 529 smallholder households, in-depth interviews with 115 smallholder farmers, and participant observation for over 10 months in the province of Palawan (Montefrio, 2013; Montefrio and Sonnenfeld, 2013).

Discussion and conclusions

The relevance of the analytical framework

The case studies confirm the importance of the four spheres of knowledge that we identified and used as an analytical framework for studying farmer behaviour. In each case study and across different contexts and agricultural systems, we found that by addressing these questions we unveiled key dimensions of farmer behaviour (Table 1). First, we found that social as well as biophysical conditions influenced farmer decision-making, although the specific combination of different factors was highly context dependent. Furthermore, we found that economic drivers or utility maximization motives were only partly able to explain decision-making, and that the socially adaptive behaviour of farmers was of equal, or even more importance. This result confirms the significance of studying adaptation as a social process (e.g. Crane et al., 2011) rather than a technical response to external pressures. For example, integrating social and biophysical factors was essential to understand the factors affecting decisions regarding maize production and pesticide use in Mexico and Colombia, respectively, where farmer decisions were adaptive not only with respect to biophysical (climate, level of pest infestation), but to social and cultural conditions (food culture, social norms).

Table 1: Analysis of the case studies.

Case studies	**Spheres**			
	Biophysical and social factors	Actors and power relations	Cross-scale and cross-level pressures	Temporal dynamics of behaviour
Mexico	Sociocultural factors (symbolic value of maize) more important than biophysical ones.	National liberalization agenda cuts financial support for farmers and constrains smallholders to marginal role or subsistence in a transformed market.		N/A
Colombia	Social structures (i.e. descriptive social norms and social construction of illness) were particularly important. The influence of difference factors was diversified for different pesticide practices.	Some actors (e.g. farmer's wife) exert direct influence, while peers exert indirect social pressure through social norms. Pesticide producers and sellers enjoy high social status and thus influence farmer decision-making.	N/A	Social-ecological and individual-social dynamics (e.g. persistence or change of social norms) were investigated through a simulation model.
California	Biophysical stressors and adaptation strategies, and social factors (demographic, farm tenancy, educational background) were investigated.	Peers who were close in the social network exert some influence on farmers, but the wider network, or other actors, did not.	Broader changes (e.g. in market trends and consumer demands) influence faremr decisions. Stressors at different scales elicited different responses (individual or collective; proactive or reactive)	Adaptation decisions on an ongoing (e.g. irrigation, pruning) and decadal (e.g. row direction) frequency were analysed.
India	Biophysical factors (e.g. soil type) influenced farmer decision-making more than social ones.	N/A	A range of cross-sccale and cross-level stresors influenced farmer decision-making, including market price variability, monsoon patterns, and groundwater depletion resulting in reduced access to irrigation.	Farmers were studied for three years, but some fo the key social-ecological feedbacks observed might unfold over longer timeframes.
The Philippines	Biophysical factors were considered only in their social constructed nature. The symbolic meanings and economic changes associated with low carbon ccommodity crops strongly influenced farmer decision-making.	Indigenous farmers interact with a range of actors (e.g. government officials, agricusiness representatives), which re-produces as discourses and social representation of the environment. Some actors exert a strong power of exclusion of indigenous farmers from access to land.	Broader commodity market changes and climatic change influence land prices, crop profitability and soil conditions, thus constraining farmers' decision space.	The erosion of traditional cultures and changing production regimes and economic landscape (off-farm wage labour) is observed, with contrasting dynamics of abandonment and persistence of swidden agriculture.

We also found that actors other than farmers play a predominant role in constraining farmer decision space. This was often connected to power relations and how they play out in access and use of physical (e.g. land) and symbolic (e.g. authority) resources. Thus, the case studies highlighted the sources of vulnerability and of persistence of unsustainable behaviours. For instance, social networks convey information on adaptive farming practices (California), although social networks might play a role only in reactive adaptation, and may be more difficult to mobilize for anticipatory adaptation (California). Social networks are often associated with power relations, whereby more powerful actors can exert influence on less powerful ones, or exclude them physically and socially from access to resources and farming options (enclosures in the Philippines).

Next, we found that in all case studies farmer decision-making responded to multiple pressures, and that the latter can occur at different levels and be perceived, by farmers or policy makers, as being out of the control of farmers. For example climate change, market price variability and groundwater depletion serve as important drivers of behaviour in India. In the Philippines, biofuel and rubber development and as well as climate change significantly impact behaviour. Additionally, national and international policy in Mexico had profound effects on smallholder maize producers' ability to continue selling maize.

We also found that in order to understand farmer behaviour, a dynamic perspective is essential. For example, an analysis of the feedbacks between decisions and social and ecological structures proved essential to investigate behavioural change and pesticide risk reduction policies (Colombia), patterns of adaptation to climate change (India), and willingness to participate in alternative practices (the Philippines). The persistence of maize producers in urbanizing Mexico could drastically change over time as younger generations opt out of agriculture. In India, farmers alter their decisions from year to year based on variability in early monsoon indicators and market prices, yet few farmers are adapting to longer-term changes like climate change or groundwater depletion. Thus, what seems to be a beneficial strategy (e.g. increasing irrigation during low rainfall years) may actually be a mal-adaptive strategy over longer, decadal time frames.

Finally, and most importantly, the case studies show that these four aspects need to be addressed simultaneously. In fact, while no case study fully considered all four spheres and the respective questions (Figure 1, Table 1), where one sphere was overlooked the need for addressing it emerged during the research. For example, in the study of potato farming in Colombia, in which the role of cross-scale and cross-level pressures was not investigated, it was found that considering the local and national processes of social marginalization of peasants would have contributed to understanding the power relations among farmers and non-farm actors, which is a historical determinant of farmers' disempowerment in the region. In the study of adaptation strategies in India, in which government policies and subsidies were not examined, discussions with farmers suggested that subsidies were likely strong drivers of behaviour given that they heavily factored into profit calculations that farmers made at the start of the growing season, when farmers decided which crops to plant. Finally, in the study of maize farming in central Mexico, in which the temporal dynamics of behaviour were not addressed, it was found that it was impossible to fully understand how the macro-scale processes such as climate and urban growth will affect farmers' decisions to continue in agriculture: while maize production seems to persist in urbanizing Mexico, this could drastically change over time as younger generations opt out of agriculture under climate and policy shifts.

Researching farmer decision-making: lessons learned and open issues

We suggested above that to avoid oversimplification in representing farmer decision-making, and thus inform adaptation and sustainability policy, four spheres of knowledge need to be addressed (Figure 1). However, we recognize that this entails the challenge of merging different paradigms. We therefore propose that to provide the understanding "that go beyond rather simple specifications of human decision making" (Schlüter et al., 2012:220), a methodological reflection on research on farmer decision-making is necessary. Particularly, our comparative analysis suggests three limitations and one possible way forward.

One common limitation that we encountered was that the methods or the theoretical frameworks adopted to address some spheres did not suit other spheres. For instance, some frameworks adopted in the case studies tend to frame decision-making into a static rather than dynamic perspective. This is the case of the Vulnerability Scoping Diagram used in the Californian case study, or the sustainable livelihoods framework, adopted in the Mexican one. On the other hand, the Integrative Agent-Centred framework (Feola and Binder, 2010), which focuses on the dynamics of one specific action or farming practice, may fail to draw the attention of the researcher on how that action or practice interacts with other actions enacted by the same farmer, thus poorly equipping the researcher to uncover multiple cross-level pressures.

Another limitation highlighted is the limited timeframe of typical research project funding. While studying decision-making for multiple years gives some indication of dynamics in the system, to understand farmers' responses and influences on the system, longitudinal studies over longer timeframes would be needed. Nevertheless, the case studies exemplify how this limit can be dealt with. In the study of potato farming in the Andes, a simulation model was used to project possible scenarios and discuss the behavioural and system dynamics triggered by different pesticide risk reduction interventions. In the study of swidden agriculture in the Philippines, qualitative data and ethnographic observations on the present situation were compared with existing ethnographic studies carried out in the past two decades in the same study area. Finally, in the Indian case study, looking at farmers' responses to inter-annual variability in climate and market prices gave an indication to how farmers may respond to shifts over longer time scales.

The methodologies adopted for data collection and analysis also appear to entail relevant trade-offs that affect the possibility to address all four questions in a single study. For example, projects aiming at identifying behavioural patterns and their interactions with the social and biophysical environment at a large level (regional), might face the difficulty to uncover the social networks and power relations at lower levels (e.g. India). Moreover, while modelling coupled social and ecological processes is recognized to be useful to unravel dynamics in agricultural systems (An, 2012; Schlüter et al., 2012), some of the theoretical frameworks and methods adopted in these case studies are more easily integrated with ecological modelling than others on account of their ability conceptualize feedbacks between social and ecological systems (e.g. IAC framework; Feola and Binder, 2010), or to generate quantitative rather than qualitative data.

Finally, we found that one way to overcome the limitations and trade-offs that was adopted in the case studies was to use a triangulation research strategy (Khagram et al., 2010) combining mixed methods. The case studies compared offer several examples of combinations of methods, including survey data and statistical and participatory simulation modelling (Colombia), quantitative household surveys and semi-structured interviews with government officials (Mexico), and social survey data and environmental data such as soil and water quality (India). While the strengths of mixed-methods in environmental change research have been pointed out (e.g. Poteete et al., 2010), our research suggests that designing research to address each of the four research questions and respective spheres of knowledge in our framework will likely require using mixed methods to achieve a holistic understanding of farmer behaviour.

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