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Adaptation to climate change and climate variability: The importance of understanding agriculture as performance

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ABSTRACT

Most climate change studies that address potential impacts and potential adaptation strategies are largely based on modelling technologies. While models are useful for visualizing potential future outcomes and pathways and evaluating options for potential adaptation, they do not adequately represent and integrate adaptive human agency. Richards' concept of 'agriculture as performance' is useful in counterbalancing the modelling approach to adaptation because it highlights how adaptive processes and technologies, whether short term or long term, are more than simple technical responses to biophysical conditions. Instead, adaptive processes are social phenomena whose significance and effects expand well beyond changing climate conditions. This examination of agriculture as performance in the context of climate adaptation draws on two different examples. The first example explores how technical aspects of climate adaptation in Mali are situated within the enactment of ethnic identities and political struggles between farmers and herders. The second example shows how farmers in southeastern United States approach climate variability and climate forecasts as risk management tools. There are substantial differences between approaching adaptation as a dynamic process that is socially – and ecologically – embedded and approaching adaptation as a set of modelled responses to anticipated future conditions. It is unlikely that either is adequate to meet the challenges posed by the uncertainties associated with climate change. However, building a synergistic relationship between the two promises to be as difficult as it is necessary.

1. Introduction

Climate change introduces new dynamics and uncertainties into agricultural production. Not only are climate baselines shifting over the long term, but models also warn for increasing variability in inter-annual and seasonal climate patterns within the long-term shift. Much attention has been given to climate change adaptation as an anticipatory and planned process, managed through new policies, technological innovations and development interventions [1]. Modelling has emerged as the key technology for visualizing and anticipating the processes and impacts of climate change and climate variability on agricultural production systems. Combinations of General Circulation Models, Regional Circulation Models, crop models, soil models, agro-ecological system models, and economic models have been used to illustrate potential impacts of climate change in the coming decades based on various climate scenarios [2–5]. In these contexts, modelling is useful in that it enables visualization of potential future scenarios so that potential adaptation strategies can be evaluated for future planning. However, as important as they are in climate change adaptation research, modelling and planning have their limits. Unfortunately, many of these potential adaptation strategies are based on the 'business as usual approach' or sometimes more harshly referred to as the 'dump farmers' approach'. Farmers' agency as innovators, creative technical actors, and socio-cultural actors – factors that are absent in models – is also extremely important in terms of understanding their adaptation behaviours within the complexities of agrarian socio-ecological systems [6].

This paper explores cases of adaptive processes to climate change and variability from Mali and in the southern United States. Two examples of agriculture as performance will be discussed for each location. The first example from each country will highlight the importance of farmers' agency as technical actors who respond in real time to contingent environmental circumstances. The second example in each case will examine how farmers' positions in social networks and institutions inform and influence adaptation behaviours, illustrating how adaptive agricultural per-

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formance is embedded within social performance more broadly. Taken together, these cases build the argument that research on agrarian adaptation to climate change and climate variability needs a greater emphasis on farmers' creative adaptive capacities and socio-cultural institutions.

Farmers deal with risk on a daily basis due to the uncertainty of future weather conditions. As such, farmers have experience in dealing with climate variability and uncertainty, but increases in ranges of variability have the potential to put farmers' adaptive capacities to the test, creating substantial challenges to the entire range of the world's food producers, from small-scale subsistence farmers in Africa to mega-scale industrial producers in North America and Europe. While the modelled climate change scenarios can be useful for identifying potential stress points and vulnerabilities in biophysical agro-ecological systems, they tend to leave a very large gap in the area of farmers' adaptive capacities and practices, ignoring one crucial factor in understanding the relationship between climate trends and agricultural outcomes: farmers as pro-active agents who respond to climate variability, both in the short term (season) and in the long term (decade). This absence is especially problematic when discussing impacts and adaptation in agricultural systems, where individuals' practices and innovative capacities vary widely and can respond to environmental stimuli relatively quickly. The potential utility and anticipatory power of modelling is not in question here, but the absence of human agency in understanding real system dynamics indicates a major shortcoming of modelling approaches to impacts and adaptation to climate change. Because the real actions and positions of farmers are often not well integrated into large-scale system modelling [7–9], we can logically expect that the development of policies based uniquely on modelling approaches risk running afoul of the actions and positions of real people in implementation.

Understanding agriculture as an emergent result of human agency and social networks in historical and ecological contexts provides a useful counterpoint to the modelling approach to understanding change in agricultural systems under climate change and climate variability. The notion of 'agency' here speaks to farmers' creative improvisation and real-time management of variability and stochastic events in the social, technical or ecological realms. It is this process of reacting to challenges and opportunities as they arise that is captured by the notion of 'agriculture as performance'. Richards' [10,11] works on 'agriculture as performance' have emphasized the importance of analysing farming systems as contingent components of social and ecological contexts, through which farmers draw on their "improvisational capacities called forth by the needs of the moment" [10]. Rather than looking at knowledge as something that is simply deliberated upon and used to reach a decision, Richards' formulation of 'agriculture as performance' instead focuses on agriculture as something that is enacted with some degree of informed spontaneity, referred to as embodied or tacit knowledge, rather than just intellectual expertise.

Highlighting the performative aspects of agriculture is not to deny the important role of planning that goes into farming. While agriculture involves a great deal of planning – organization of labour, tools, seeds, inputs and capital, land preparation, etc. – there is a great deal of room for, and often need for, improvisation and know-how in the execution of those plans, as well as the deviations from them [12]. However, asking where the plan ends and the performance begins misses the point about farmers' agency in adaptation. The very existence of a farm represents the interaction between biophysical resources and phenomena, human social systems and individual actions (both planned and improvised). As an analytical frame, 'agriculture as performance' focuses on farmers' agency and then seeks to understand how that agency interacts with, both as an influence on and as a reaction to, the dynamic social and ecological situations in which it is located. In research on climate adaptation, this has the advantage of starting with existing realities and ongoing processes that represent important spaces for adaptive change as well as understanding variable responses to uncertainty and contingency. Furthermore, looking at agriculture as situated action spans from short-fuse field-level actions in response to weather conditions in the moment (the manifestations of climate) to gradual shifts in production practices situated in dynamic ecologies and cultural histories over the long term.

The performative aspects of agriculture are central components of adaptive capacity, which cannot be captured in agro-ecosystem models. The study of agriculture as situated action provides an analytical lens through which to understand farmers' adaptation processes and how they are embedded in intertwined social, technical and ecological contexts. Adaptation is unavoidably a socio-technical process [13]. As such, analysing agriculture as situated action is useful in making farmers' skills, behaviours, and innovations empirically researchable. Furthermore, it enables an analysis of their technical responses while also analysing how those technical behaviours interact with, both as a driver and as a result of, their positions within diverse and dynamic social networks, including subjective and normative components.

Integrating farmers' agency into adaptation research implicitly acknowledges that agriculture is both a social and a technical process that spans time frames from the momentary to the lifetime. Understanding agriculture as performance is furthermore useful in analysing adaptation practices in agriculture because it acknowledges and integrates the fact that farmers are more than just individuals who execute specific planned technical behaviours on farms. In addition to performing agriculture, they are simultaneously performing their roles as members of social networks and collectivities (families, communities, ethnicities, nations, etc.). Consequently, the social spaces and processes within which technical agricultural practices are embedded affect how they are enacted [14,15]. As will be discussed in the two examples, this has important consequences for how we approach agricultural adaptation to climate change and climate variability. For an agricultural adaptation to be successful it not only needs to be technically effective in reference to climate and ecology, it also needs to be effective in reference to the social needs of the individuals and collectivities who perform them.

2. Long-term transformations in Mali, West Africa

The multi-year droughts of the 1970s and 1980s were devastating for farmers and herders in the Sahel. Immediate impacts included total crop failure, massive die off of cattle, and widespread famine [16]. However, even when the rains 'returned' in the 1990s and 2000s, they were not nearly of the same strength as prior to the 1970s. The droughts were not isolated events in an otherwise steady pattern. Instead, they were extreme events in a decades-long process of changing climatic and thus ecological, baselines. From the point of view of climate history, it is debatable whether this represents 'normal' climate variability in the Sahel (which is known to be extreme) or the beginning of long-term trends resulting from anthropogenic climate change. From the point of view of people who make their livelihoods as farmers and herders in the Sahel, this distinction is largely academic and inconsequential. What matters instead is that the system is extremely dynamic and that the uncertainty about what is coming next is extremely high.

The practices of agriculture and pastoralism in the Sahel are largely centred on uncertainty of biophysical conditions: uncertainty about when the rainy season will start, uncertainty about the quantity of rain, as well as its geographic and temporal distribution during the season, and uncertainty about pest and diseases pressure on crops. The prolonged period of desiccation (from the

1960s to the late 1990s) and the severe droughts of the 1970s and 1980s have stimulated substantial changes in agriculture and pastoralism in the Sahel [16–18]. Technical subsistence practices have transformed, but so have social politics of ethnicity, land use and livelihoods. The following sections explore two examples of how the lens of 'agriculture as performance' can be constructively applied to adaptation processes. The first case explores the management of uncertainty about and variability within one rainy season. The second case takes a much broader view, analysing how long-term technical adaptation strategies undertaken by farmers and herders interact with the performance of ethnicity and interethnic relations. The diversity in these two frames serves to emphasize that the notion of situated action applied at diverse temporal and social scales, from the short term and individual to the long term and community.

2.1. Agency in technical adaptation

The Commune of Madiama in Mali is located in the Cercle of Djenneat, the eastern edge of the Bani River floodplain. This location affords access to diverse agro-ecological zones, from flood-controlled plains with heavy alluvial soils where irrigated rice is grown to sandy upland fields with rain-fed millet. Some of the spaces in between are characterized by soils that mix, in various proportions, sedimentary, clay and sandy soils. Such soils tend to be found in the boundary zones between the floodplains and the upland zones. Although millet is known to produce best on sandy soils that drain quickly, and sorghum performs well on wetter, clayey soils, the main question is what to do with intermediate soils under conditions of uncertain rainfall? The intermediate nature of the mixed soil means that it can take on the characteristics of either of its parent materials depending on the rainfall conditions, especially rainfall amounts and periods of dry spells. The diverse range of possible uses makes mixed soil a highly valued resource for farmers, especially under conditions of high climatic variability and uncertainty.

Local production practices take advantage of intermediate land resources, leading to a simple but effective means of mitigating uncertainty of rainfall. Fields are prepared with ox-drawn ploughs at the beginning of the season. After ploughing, planting is done manually using a short-handled hoe. When planting on mixed soils, each pocket is sown with both millet and sorghum seeds. In the middle of the rainy season, as both millet and sorghum are emerging from these pockets, farmers must make a decision based on their observations of how the rains are affecting the soil and plants. If there has been relatively heavy rainfall and the soil has high moisture content, then sorghum is more likely to be thriving and millet plants are then uprooted. If there has been light rainfall and soil moisture content is low, millet is more likely to be thriving and the sorghum plants are then cut down. Depending on the circumstances, both in terms of rainfall and labour availability, farmers may leave both the millet and the sorghum to produce what they can. Overall, this strategy enables farmers to take advantage of soil heterogeneity by effectively postponing the decision of whether to grow millet or sorghum until later in the growing season, when they have a better sense of the overall rainfall patterns for that season.

Farmers employing this cropping strategy are creating an opportunity for mid-season adjustment based on real-time environmental observations. Richards describes agriculture as performance using a musical analogy, wherein musicians (farmers) must dynamically interact with other musicians (social and environmental processes) in real time during the performance of a piece [10,11]. Following Richards' analogy, the cropping strategy outlined here represents a point wherein the farmer must make a decision to take the song in one direction or another depending on the circumstances, to decide which amongst the possible endings is to be performed during that growing season. As a strategy, the approach represents farmers' creation of opportunities for contingency through recognition of and capitalization upon a flexible resource (mixed soils). This strategy involves a substantial planning component – organizing seeds and labour, identifying well-suited soils – but the plan is basically not to plan too much or too soon. Instead, opportunities are built in for adaptation that can be acted upon in the context of the growing season as it unfolds. Contingency-building strategies of this sort highlight how adaptation to rainfall variability is an action that is fundamentally situated in the particular qualities of both time (growing season) and space (management of specific flexible soil resources). Although the rain and soil aspects are clearly environmental components of the performance, social variables such as labour availability and access to the highly valued mixed soils reveal that social processes are also important in the performance of this adaptive strategy.

2.2. Agency in social context

Looking at adaptation processes more broadly, long-term responses to changing rainfall regimes are situated in the historical positions and trajectories of various social institutions. In central Mali, ethnic groups have historically corresponded closely to the ecological niche that their subsistence strategies filled. For example, historically, only Fulani were cattle herders, and to be a Fulani was virtually synonymous with being a cattle herder.[3] Amongst other ethnic groups, Marka were rice farmers in the Niger River inland delta, Bambara were upland farmers, Bobo were hunters in the highlands, Bozo were fishermen, etc. The construction of ethnic identities has been closely interwoven with technical knowledge of the environment, the social organization of subsistence practices, social boundaries and cultural normative positions. Consequently, technical changes in subsistence practices ripple through social lives and the entire socio-ecological system.

In response to the changes brought on by the droughts of the 1970s and 1980s and the desiccation that occurred in the second half of the 20th century, there has been substantial pressure on all groups to diversify their livelihood strategies, adopting mixed subsistence practices. Although some of this pressure has been political, ecological conditions of increasing land pressure and high climatic variability and uncertainty have created a situation in which diversification of livelihood is an effective means of guarding against climate risks. Virtually every ethnic group now practices mixed agro-pastoralism, and may also opportunistically engage in fishing and hunting when possible. However, the performance of these technical subsistence activities is situated in broader social processes of ethnic identity construction, a fact that has implications for how long-term adaptation unfolds. Although the strength of the association has been somewhat compromised in recent decades, the historic links between ethnicity and subsistence activities are still important social reference points, both in terms of building one's own ethnic identity, and in terms of understanding the place of other ones.

Like the technical practice of agriculture, ethnicity is itself something that is performed, meaning that rather than being a static set of characteristics, it is constantly and iteratively enacted within the contexts of social and ecological processes (especially subsistence practices), which act as stimuli for constructing collective identities. The construction of social identities through engagement in subsistence activities is relevant in terms of adaptation to climate variability and change because it affects the ways in which people perceive and respond to adaptation opportunities.

[3] The major exception to this was being an Islamic religious scholar, which in this region has itself also been largely associated with the Fulani.

The link between what people do and who they are emphasizes that a large part of identity in this region is being defined through specific activities, activities whose technical aspects are situated in social institutions and imbued with meanings, both of which in turn affect technical choices and practices. Even as Marka and Fulani subsistence strategies homogenize towards mixed agro-pastoralism, their constructions of their own identities continue to be rooted in their normative livelihood systems. Furthermore, constructions of the identity of the 'other' are likewise rooted in notions of their appropriate role in the socio-ecological system. Despite the fact that most households are now mixed agro-pastoralists, interviews with Marka in Madiama reveal a strong connection between social identity and agriculture as a subsistence activity.

Many Fulani in Madiama have never fully recovered from the devastation of their herd and rely on agriculture for a substantial part of their livelihood. However, the place of agriculture in their cultural practices is very different. Despite an increasingly substantial reliance on farming, it is a practice that is disliked, denigrated and avoided when possible. Even for those who engage in farming, it is exclusively a subsistence activity, pursued only in as much as is needed to bridge the gaps between household needs and herding income. When asked about engaging in market-oriented farming, a Fulani elder stated "We don't try to make money from our fields. We make money from our cattle." Despite the environmental and political pressures for economic diversification, resistance is sometimes not based on these drivers alone. Responding to the suggestion that wealth could be invested in business enterprises rather than in cattle, another key Fulani informant insistently responded: "We are not traders, we are herders. That is what we do". Conversely, even Marka who come to own large herds of cattle are disinclined to herd the animals themselves, preferring instead to hire Fulani for the task. Not only do Fulani have the technical skills and knowledge for effective cattle herding, but also "We [Marka] aren't used to going out into the bush day after day. With Fulani, that is what they like. Marka are farmers". The implication of these simple statements is powerful. They indicate that in this context, ethnic identity itself is performed; it is not just something that one *is*, it is something that one *does*. The activity itself is seen as a key part of maintaining the identity. While there is a great deal of dynamism and flexibility around the ways in which identities are socially created and negotiated [19], the performance of ethnicity is situated in a social, ecological and historical landscape that shapes the parameters of its content.

Understanding identity as something that is enacted is important because it emphasizes how aspects of identity affect the ways in which technical adaptation options are assessed, valued and responded to. From a purely technical position, diversification into agro-pastoralism does buffer against variability and uncertainty. But the technical actions of agriculture and pastoralism are situated within social institutions and cultural identities that value them in substantially different ways. The differences in these institutions, and their associated normative positions, have strong implications for processes associated with climate change adaptation. For example, because Fulani identity is strongly connected to transhumant cattle herding [20], the performance of that identity creates a context in which individual Fulani actors are likely to try and disengage from agriculture in favour of herding as much as possible, despite the technical benefits of maintaining a diverse livelihood portfolio. Furthermore, even many Fulani with very few cattle tend to support and promote herding-friendly land management policies and positions because they aspire to increase the role of herding in their livelihood strategies. While these values will of course never override or pre-empt the forces of nature, they may influence the political positions and technical approaches in relation to adaptation. As such, normative values associated with identities are important parts of the socio-ecological system, which emerge through analysis of actors' performance of their livelihoods.

3. Seasonal adjustments in Georgia, USA

Despite some of the obvious socio-economic, technical and ecological differences, farming in southeastern USA entails some of the same fundamental challenges as farming in Sahelian West Africa. Uncertainty and variability in environmental conditions (especially rainfall) have led to the development of a variety of risk mitigation strategies including diversification of crops and field locations, use of crop insurance, investment in irrigation systems, and diversification of household livelihood activities. All of these serve to buffer against the ecological and economic shocks endemic to agricultural livelihoods [21].

Inter-annual climate variability, and thus crop performance, is strongly affected by the El Niño Southern Oscillation (ENSO), an annual climate pattern driven by cyclical warming and cooling of sea surface temperatures in the central Pacific Ocean [22]. Given that ENSO has a significant effect on the rainfall patterns in the southeastern USA, the Southeast Climate Consortium (SECC; www.SEClimate.org) was formed as an inter- and trans-disciplinary programme to develop a system of seasonal climate forecasts (SCFs) and related crop management tools, with the intention of developing tools that can help farmers manage risks and opportunities related to inter-annual climate variability [23–26]. ENSO-based seasonal forecasts are a very recent development, since scientific understanding of the ENSO phenomenon, and thus the capacity to provide reasonably reliable forecasts, has really only begun to solidify in the last 15 years.

Starting with global and regional climate circulation models, the SECC iteratively publishes probabilistic 90-day forecasts, as well as a suite of crop models and economic models that draw on the ENSO seasonal climate forecasts as a core input. The agronomic and economic utility of probabilistic 90-day forecasts (and related tools) in risk management is validated through models [27–29] as well as being intuitively apparent. However, interviews with farmers in southern Georgia about the potential for applying ENSO-based seasonal climate forecasts has revealed that the farmers' notions of risk management are socially situated in ways that complicate the question of how seasonal climate forecasts can inform adaptation through influencing management decisions.

The research discussed here was conducted just as the SECC's climate forecasts were starting to reach farmers in southern Georgia, who, consequently, had little prior exposure to and no habit of using ENSO-based seasonal climate forecasts. The purpose of the research was to understand the existing farmers' risk management practices and farm management strategies to assess what role seasonal climate forecasts could play. As seasonal climate forecasts were in the process of being introduced and promoted, we aimed to understand the environment into which they were entering and farmers' ideas about how such information might be integrated into their production practices. Because the idea of ENSO-based seasonal climate forecasts was new to the farmers, these discussions were based around a certain degree of imagination and speculation.

3.1. *Agency in technical adaptation*

Seasonal climate forecasts act as a new information stream entering into farmers' management processes, which already weigh a wide variety of environmental, agronomic, social, political and economic variables [21]. The notion behind developing seasonal climate forecasts as risk management tools is that farmers can use this information to hedge their farming strategies in ways that guard against risks of economic losses or capitalize on opportunities associated with climate variability. However, one farmer described the large, capital-intensive farms, characteristic of American agriculture, as 'battleships' that cannot be turned very sharply or quickly in response to shifting circumstances or dynamic information streams.

Although the room for maneuver in response to climate forecasts is often seen as relatively small, discussions with farmers about their potential applications for seasonal climate forecasts ranged widely, and many management decisions that could potentially be influenced by seasonal climate forecasts were mentioned by farmers. The top six management decisions, in order, were: (1) changing crop selection, (2) changing planting dates, (3) adjusting input management, (4) changing land management practices, (5) changing varietal selection, and (6) adjusting marketing practices (see [21,30] for elaboration of these points). The fact that farmers see these as key management areas in which they have some degree of flexibility is an indication that there is skill involved in them: the listed practices, all of which must be done at certain junctures in their production calendars, can be executed more or less effectively depending on the acumen of the individual farmer, his skill.

For example, one farmer who produced groundnuts and organic fresh vegetables on a variety of land types indicated that seasonal climate forecasts have the potential to influence the ways various plots could be used with certain crops.

> *On my farm, I have about 20 acres in a low area that tends to hold water more and I have about 20 acres on a sand hill where it can rain as much as it wants to and it will never hurt. If I knew it was going to be a really hot, dry summer, I might be more inclined to plant my peanuts – even though I have irrigation there – down in the lower area. But if I know it's going to be a wet year, I won't put peanuts in the wet [low] area because it's going to be a disaster. I would for sure plant them on the sand hill.*

The adjustment of land management practices according to the seasonal climate forecasts – whether shifting certain crops to or from certain soil types or changing cultivation strategies such as planting in mounds vs. furrows – indicates that farmers can see the potential for seasonal climate forecasts to enhance their management skills. Richards [10,11,31] set the notion of performance in contrast to planning, focusing largely on capacity for creative reaction to emerging circumstances. However, the performative aspects of applying anticipatory models, such as seasonal climate forecasts, represent a substantial deviation from Richard's conceptualization. Particularly in industrial-scale agriculture, planning is in itself an important skill performed by farmers. The challenge will be for farmers to develop the skills to use seasonal climate forecasts creatively and effectively, integrating and balancing them with other considerations. Despite the many non-climate drivers and constraints to decision-making in large-scale capital intensive agriculture, seasonal climate forecasts do appear to have the potential to augment agricultural planning skills in adaptive ways. However, this is only true to the point that forecasts are accurate and trusted, a point that will be revisited in the conclusion.

3.2. Agency in social context

One major difference between farming in Mali and farming in the USA is that in the USA very few people are farmers for lack of other livelihood options. Where being a farmer (or herder) is a default activity for much of the population in Mali, in the USA it is something that people actively choose to go into, despite extraordinary stress, uncertainty and instability associated with farming as a livelihood strategy in contemporary USA [32–34]. This is important because it highlights that being a farmer is usually the result of a strong assertion of agency in a social context with many pressures against it. All of the farmers interviewed in this research at some point in their lives, decided that farming, out of all of the other possibilities afforded to them, is what they wanted to do for a living, often against the recommendation of their fathers, who know the hardships of farming life. Interviewees emphasized that beyond technical skills and knowledge, one needs a passion for the lifestyle to be a farmer in the contemporary USA. The passion for the job, the risk and hardships would not be worth the potential gains, which are often modest.

> *My father farmed part-time. My grand daddy tried to talk me out of it because of the changes he had seen, but it is what I had always wanted to do since I was a small child. As far as my kids, I hope they find something else to do.*

While farmers' immediate goals in undertaking adaptive technical management practices are a good crop and good profits, these practices are contextualized in the broader social networks and processes, including subjective motivation. Some of these networks are directly oriented towards realizing profitable farms. However, some social networks are more broadly oriented towards having fulfilling and meaningful lives. Although it is tempting to disconnect the two, claiming they are entirely unrelated, the pursuit of agronomic and economic goals is always contextualized within the pursuit of wider social goals.

Framing agriculture as situated action requires understanding the dynamic relationship between these technical and social practices. Interviews with farmers indicated that social concerns (economic and otherwise) do play a part in how farmers manage risk. Beyond the passion for the lifestyle itself (which puts farmers at risk of hardship and financial ruin by driving the very decision to become farmers in a challenging economic environment), interviewees indicated that the decision to be a farmer is also motivated by desires to maintain family land, to be members of the rural society, and to contribute productively to the wellbeing of their country.

> *I think it's a great place to raise the kids, because we see that they work so they develop a work ethic very young. We still have our independence, I suppose. I think for the most part, at least in this part of the state, farmers are good, moral people and good people to deal with and good people to be around. It's just a good life. As long as it all works, as long as you can make a living at it.*

The economics are clearly important, but the larger driver of agricultural behaviour is often the desire to be a member of a close community and to raise a family in a healthy physical and social environment. This requires maintaining good social relations, creating another important context within which the application of seasonal climate forecasts will take place. Even when weather conditions are unfavourable in the short term, there are substantial pressures to farm as best as possible anyway, in order to maintain access to rented land and equipment, as well as to uphold the obligations to employees who are often members of the community and important social contacts.

> *About 12 or 13 years ago my brother told me, "I see where they are predicting record drought this year, and record temperatures, and if I was you I wouldn't plant anything. They are calling for a record bad year." And I told him, "I got land rented, I got land bought, I got tractors bought and leased, I got people working for me, I can't just say I'm not going to farm this year because they are predicting a bad year."*

In the same discussion, another farmer emphasized that relationships with wholesalers, important actors in the produce marketing chain, must be maintained annually through sustained efforts to deliver regular supplies, regardless of anticipated conditions in any given year. Together these highlight how technical economic considerations are intertwined with social networks and values.

Probabilistic seasonal climate forecasts are increasingly entering into farmers' information streams through programmes like the SECC and others. Exactly what farmers in the American Southeast will be able to do with these tools to increase flexibility and competitive advantage in their management practices remains to be seen. Rather than framing this process as a linear dissemination and application of forecasts, more research is needed to understand how farmers may interpret and creatively use seasonal climate forecasts, both in terms of mitigating risk and capitalizing on opportunities, as an anticipatory technology for adapting to climate variability. Furthermore, examining the changing role of seasonal climate forecasts in farmers' performance of agriculture and skills at planning should include research on how farmers produce in technically effective manners, while simultaneously striving to satisfy personal and social goals, both as farmers and as community members. The processes of adaptation to climate variability represent farmers' efforts to balance the dynamic interactions between these multiple facets of life. As such, it is where farmers' performance as both technical and social actors becomes a crucial point of analysis.

4. Discussion

In the context of adaptation to climate change and climate variability, understanding agriculture as performance requires that researchers take seriously farmers' skills to adapt to erratic and variable circumstances, both in the short term and the long term. Furthermore, these skills must be analysed in the context of their social environments, including the social goals and institutions that shape subjectively lived experience.

In Mali, technical practices, and thus perceptions of adaptation options, are heavily influenced by social history and constructs of ethnic identity, which are closely linked to livelihood niches. Biophysically based models of this system would miss these fundamentally normative positions as influential factors in adaptation [9]. In response to uncertainty and high inter-annual variability, farmers have developed cultivation techniques that take advantage of hybrid soil resources in ways that build flexibility into their agricultural practice and enables them to offset some of the uncertainty and variability they experience. Despite experiencing the same climatic, ecological and political pressures to undertake increasingly similar and diversified subsistence strategies, the Marka and Fulani of Madiama maintain substantially different positions in relation to farming and herding. Although diversification is technically adaptive, it runs up against social boundaries, especially in the context of Fulani farming. In a situation where ethnicity is closely associated with what you do, adaptation is much more than a technical adjustment: it can cut very close to who you are. As such, analysis of people's performance of their technical practices and social lives is an important aspect of understanding adaptation processes.

The Georgia case is rather different in that the development of probabilistic seasonal climate forecasts effectively proposes to farmers that they adjust their existing adaptations to uncertainty and inter-annual variability, not in response to actual circumstances, but in response to anticipated circumstances. From a farmer's point of view, it is not the climate that is being adapted to, but the new information stream that helps anticipate seasonal climate variations. Still, the integration of new information into agricultural management practices is something that itself takes skill. The anticipatory nature of this skill may be reflective of the state of capital intensive industrial agriculture (vs. small-scale subsistence agriculture) in that the skill is really about how to plan more strategically and more effectively. Rather than reacting to environmental circumstances, farmers' use of seasonal climate forecasts (SCFs) represents a reaction to probabilistic information about upcoming conditions.

The probabilistic nature of forecasts, combined with general skepticism regarding the quality of the information, complicates the question of exactly how technical practices can be adjusted. Despite the generally low flexibility of capital intensive agriculture, farmers in southern Georgia have identified *potential* points of adaptation where forecasts might be used skillfully. Existing risk-management strategies cannot be adjusted without some exposure to risk as altering tried and true risk management strategies with the goal of improving them is in itself a risky behaviour. Still, many farmers, extension agents and crop consultants are interested and watching for opportunities to gain competitive advantage using SCFs. Farmers' experimentation with the application of SCFs will likely unfold over years, perhaps decades. Looking for cases of 'use' or 'application' of SCFs is challenging from the research perspective, because their 'use' will always take place in combination with a variety of other factors and drivers. As such, analysis of how SCFs are 'used' will necessarily take account of how they are integrated with and balanced against other considerations, including normative livelihood goals.

Analysing agriculture as performance is centred on the examination of farmers' skills at assessing and creatively managing their biophysical, social and information resources in response to unfolding circumstances at time scales that range from weather events to long-term climate change. Analysis of how farmers learn from these processes, how skills are refined, is an essential component of understanding how adaptive capacities develop. This is not to deny the importance of planning, but simply indicates that the plan is not the same as the enactment of it, much less the divergence from it. Over the long term, climate change adaptation will inevitably stimulate dynamic learning among farmers. The question is can they learn, experiment and adapt fast enough and effectively enough to maintain their livelihoods through increasingly challenging climate circumstances?

5. Summary and conclusions

Projections of the effects of climate change and climate variability on agricultural production are primarily based on approaches that use modelling to anticipate and plan for likely future events, whether in the coming decades or the coming months. Because models are generally oriented towards systemic overviews and interactions, they tend to promote anticipatory and planned adaptation, which implicitly favours approaches originating in science and policy. In some situations, such as designing public infrastructural systems, this makes perfect sense. In agricultural systems, however, the situation is much more complex. Actual farmers – both as creative and engaged technical actors, and as moral actors embedded in social institutional contexts – are often entirely absent from such system analyses. Adaptation efforts based on an understanding of a theoretical agricultural system that does not consider the complex realities farmers face, may have some advantages, but the absence of real farmers and social contexts creates a gap between modelled adaptations and the realities of practice. Furthermore, because modelling is generally an expert technological system, even if useful adaptive technologies may emerge from their use, this does not necessarily translate into increasing farmers' own adaptive capacities. When such models are used to inform policy, they can in fact be disempowering in relation to farmers.

Conversely, approaching adaptation as an on-going and organic process embedded within agrarian communities – a process which is based on farmers' skills of planning and improvisation, of experimenting, learning and adjusting – points to a radically different way of doing adaptation research. By starting from a baseline of existing adaptive capacities, processes and institutions, the development of new or improved adaptation practices will have the advantage of being better situated within both farmers' technical practices as well as their social lives. Such adaptations are more likely to be both technically and socially effective. However, the benefit of farmers' socially embedded and incremental approach to adaptation may also be a weakness [35], in that it rarely leads to radical shifts in practices that may be useful in the context of adaptation to rapid, long-term climate change.

Recent work theorizing 'adaptation science' has called for a radical overhaul of how scientific practice articulates with society more broadly, calling for stronger connections between research and application. This science–society interface is most often cast in reference to 'policymakers', but should also apply directly to farmers [36]. The goal of this paper has been to set modelling approaches in contrast to analytical approaches that put farmers' practices and adaptive capacities at the centre of developing climate change adaptation processes. Each has strengths and weaknesses and neither is sufficient in addressing adaptation to long-terms climate change. The emergent challenge is how to most effectively integrate the strengths of farmer-centred approaches with the power of science-driven modelling approaches so that they synergize in ways that not only produce adaptive technologies, but also contribute to farmers' own adaptive capacities. One potential way of building this synergy comes through doing technographic research [see 37, in this issue] on farmers' and scientists' practices of adaptation. Bringing these often disparate, but related, practices into one frame of analysis would enable the comparison and analysis of overlaps, disjunctures and interfaces between the two approaches. Such analyses would provide empirical insights useful in creating this important synergy.

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