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Agricultural Knowledge Networks in Northern Ghana

IMOGEN BELLWOOD-HOWARD AND ABDUL-FATAHI ALIDU

Abstract. Farmers, researchers and extension officers in Northern Ghana encounter productivity problems, such as striga, acidity, hardpan and bochaa (a Dagbani word denoting low productivity). We undertook a mainly qualitative study using interviews, focus groups and a workshop to investigate, from a science and technology studies perspective, the intersections between their different ways of understanding these problems. Different actors construct definitions of what productivity problems are during the performance of their occupations, for example through peer association and application of available solutions. Actors with different occupations thus disagree over what productivity problems are, with farmers defining them by their symptoms and researchers by the physical, biological and chemical mechanisms through which they act. Extension services have not trained officers to reconcile these identity-linked understandings, which has hitherto prevented hybrid knowledge about such problems from emerging. Yet actors agree on the utility of certain management practices, such as manuring. These have the potential to act as boundary objects, pointing to the possibility of a composite knowledge network within which different actors retain their occupational identities and discrete knowledges, yet share common solutions. Extension agents and researchers would benefit from training on the use of boundary objects as communication tools.

Introduction

The contested theme of indigenous knowledge (IK) is often referred to in contemporary literature on agricultural knowledge production (Lwoga et al., 2010; Halbrendt et al., 2014; Rushemuka et al., 2014). Although the relevance of the term has been debated, it is still used as a route in to describing farmers' use of agricultural management strategies that do not rely on formal scientific knowledge (Reij et al., 2001; Gray and Morant, 2003; Olango et al., 2014). As researchers and practitioners seek practical answers to agricultural management questions, the concept of 'hybrid' knowledge, a convergence between 'indigenous' and 'scientific' or 'expert' knowledge, has emerged in academia and practice (Vissoh et al., 2004; Reed et al., 2007; Caron et al., 2014).

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Contemporary mainstream African agricultural development is influenced by the Comprehensive African Agricultural Development Plan (CAADP) of the African Union's New Partnership for Africa's Development, within which knowledge generation is conceptualized as an expert, technical activity. Simultaneously, publications such as the World Bank's 'IK notes' have described the interaction of scientific knowledge systems with IK, showing that the concepts of indigenous and hybrid knowledge have entered the lexicon of mainstream development discourse as well as academic literature. Nevertheless, these knowledge forms still maintain complex interrelationships with agricultural research and development. For example, indigenous or hybrid knowledge may develop as a response to resource scarcity (Munyua and Stilwell, 2013), while its implementation may be limited by such scarcity (Dalton et al., 2014) or it may be ineffective for other reasons (Briggs and Moyo, 2012). Meanwhile, agricultural problems such as poor soil productivity and the parasitic weed striga (*Striga hermonthica*) persist (Sillitoe, 1998; Caron et al., 2014).

Thus, a fresh look at the limits of, constraints to and possibilities for hybrid and indigenous knowledge is valid, especially when related to such pressing concerns as striga and low productivity. This article undertakes that task. It uses local West African concepts about productivity as a vantage point from which to examine the interacting ontologies of different agricultural epistemic communities.

A focus on hybrid knowledge entails examining the knowledge construction processes of scientists, alongside other actors, and this is a central theme of science and technology studies (STS). The IK literature has intersected with STS, involving such concepts as 'boundary objects' and 'translation' – to be elucidated shortly – to reflect on the role of hybrid knowledge in agricultural extension (Cash et al., 2003). These literatures interact with questions of identity, and not only in describing how local actors construct knowledge in indigenous cultural contexts: identity is equally connected to an actors' occupation and thus the practice of their everyday professional and livelihood activities (Pickering, 1992). Agricultural extension literature has often lauded the application of hybrid knowledge, co-constructed by scientists and farmers, as best practice (Kristjanson et al., 2009; Newsham and Thomas, 2009). This article similarly connects to the idea of hybrid knowledge by using concepts from STS, such as that of boundary objects, to examine how different actors simultaneously construct knowledge about the same phenomena. What is novel is that it uses grounded data to develop the idea of 'composite' knowledge: this emerges when actors fail to co-construct hybrid knowledge, yet still share common ground.

Studies on West African indigenous agricultural practice and knowledge have described farmers' perceptions of how soil and plants interact, the amelioration techniques they implement and the ways that they come about such knowledge (Millar, 2001; Gray and Morant, 2003; Osbahr and Allan, 2003; Maayiem et al., 2012). This article is in the same vein, but takes a new case study, the northern Ghanaian concept of bochaa, as a starting point. The meanings of this word will be elaborated upon in the results, so it suffices to mention here that it encapsulates a range of states of the soil and constraints upon crop productivity. An emic concept from the Dagbani language of northern Ghana, it is an ideal entry point for this study. In the study situation there are many small-scale farmers and few agricultural extension officers, who receive little training. The extension environment is dominated by project-based approaches, further contributing to gaps in provision. Local ideas such as bochaa thus play a prominent role in the activities and everyday experiences of diverse groups of people involved in northern Ghanaian agriculture.

The article will be useful to people working on productivity problems, including striga, and those thinking more generally about soil management in the West African savanna. Its practical contribution is to show how locating boundary objects can help agricultural actors identify appropriate solutions, even while they maintain their extant occupational identities.

The article is structured as follows: it starts by describing the geographical, policy and extension contexts. An overview of relevant literature on agricultural knowledge production follows, focusing on four key concepts of agriculture as performance, translation, hybrid knowledge, and boundary objects. Following the description of methods, the results explain the formation of two knowledge networks in the study site, and the lack of hybridization between them. Finally, we identify boundary objects that hold potential for composite knowledge construction, and explore their implications for agricultural extension policy and practice.

Context

The work took place around Ghana's northern regional capital, Tamale, a city of about 440 000 people, where over half of the population is involved with agriculture (Gyasi et al., 2014). Farmers here are almost all from the Dagomba ethnic group and speak the Dagbani language. Many households are polygamous, and extended families frequently live together, in urban as well as rural settings. The main staple cereal is maize (Al-Hassan and Poulton, 2009). However, pockets of vegetable production have proliferated, including in irrigated areas close to urban markets (Gyasi et al., 2014).

The sandy savanna soils, low in organic matter (Jones et al., 2013), make agriculture challenging. Productivity is fairly low within the sole rainy season. Localized soil complications include iron concretions, hardpan and isolated patches of low pH. Low fertility contributes to striga in some areas. Around Tamale, rapid urban development exacerbates land scarcity (Naab et al., 2013). Fertilizer has been subsidized since 2009, but late supply, poor availability and transport constraints mean that farmers often struggle to access it. When access to mineral inputs is poor, many farmers try to combine inorganic and organic fertilizers within their soil fertility management strategies, although manure and compost can also be scarce. Labour is often familial and may also be accessed through work parties, compensated with cash or reciprocation.

Ghanaian agricultural policy is influenced by international development discourse and donor country initiatives. The Ministry of Food and Agriculture (MOFA) rarely has the funds to implement policy unassisted at the operational scale, and relies heavily on local and international development partners (DPs), such as NGOs, businesses and donor nations, in the extension sector. The two key guiding documents relating to agricultural policy, the Food and Agriculture Sector Development Plan II (FASDEPII) and the Medium Term Agricultural Sector Investment Plan (METASIP), both outline the public–private partnership (PPP) model preferred for extension service provision.[1] In MOFA's hierarchical extension structure, agricultural extension agents (AEAs) are allocated to large spatial areas, within which they use a transfer of technology (TOT) approach: AEAs teach contact farmers, through whom messages are supposed to reach others. Simultaneously, private sector agencies and NGOs implement their own programmes independently, or incentivize MOFA agents to act as staff, training them in the process. The study area has a reputation for being a more agrarian, less developed region, so hosts a plethora of local and international DPs carrying out such activities. Governmental decentralization is another factor perpetuating the pluralist extension system, as local assemblies have not yet streamlined funding arrangements for independent local service provision.

Commercialization is an important theme in contemporary agricultural policy. Maize and export crops are emphasized, further encouraging PPPs related to these crops, such as the Ghana Grains Partnership. Vegetable farmers interact more with purely commercial actors such as seed dealers. Technologies, especially improved seed and fertilizer, are central to this model of agricultural development. The fertilizer subsidy to some extent reflects the integrated soil fertility management (ISFM) approach favoured by prominent DPs such as the Alliance for a Green Revolution in Africa (AGRA). ISFM emphasizes improved germplasm and mineral fertilizer, topped up with organic amendments (Vanlauwe et al., 2010). Towards this end, AGRA encourages targeted subsidies. Improved germplasm is trialled by these and other DPs within productivity enhancement and pest – including striga – management programmes. Ghana's Council for Scientific and Industrial Research (CSIR) also develops and releases such improved germplasm. The Savanna Agricultural Research Institute (SARI) is the northern Ghanaian arm of the CSIR. SARI links to MOFA through the Research Extension Linkage Committee (RELC), the coordinator of which, an agronomist at the time of writing, works within both institutions.

The strategy of involving external organizations in agricultural development policy and implementation means that a top-down approach dominates, and local knowledge plays less of a role at the strategic level. Expert knowledge generation is prioritized and externally developed technologies often become available to individual farmers through isolated projects rather than national programmes.

Within this context, the idea of bochaa acted as our entry point into a case study on different types of agricultural knowledge. We collected qualitative data about farmers', AEAs' and researchers' understandings of bochaa and related productivity problems, with the broader aim of investigating how their understandings about and management of productivity interacted. We offer our results as a resource for extension and development.

Ways of Knowing – Performance, Translation and Boundary Objects

Researchers have long moved beyond conceptualizing a dichotomy between indigenous and scientific knowledge (Agrawal, 1995), but such a distinction remains useful as a heuristic device (Gray and Morant, 2003; Ramisch, 2014). Understanding the forms knowledge takes for different actors helps elucidate how it comes into being. Richards (1989) shows how agricultural knowledge in particular can be seen as 'performance', being shaped as actors carry out everyday livelihood activities such as farming. This resounds with characterizations of IK as tacit and transferred through non-linguistic methods (Krige, 2007; Bloch, 2008). Scholars of local knowledge commonly focus on how environmental understanding, particularly of natural environments, is developed through feeling, seeing and other sensory experiences. This is plausible in situations where livelihoods are inextricably connected to ecological contexts – agriculture being one such example. Lauer and Aswani (2009) demonstrate how this is also the case for another livelihood strategy based on natural resource use, fishing in the Solomon Islands. Yet Ingold (2000) poses that, as a social process, the act of verbal demonstration is also an important mode of vernacular knowledge transfer, even with regard to tangible natural and environmental elements such as soils. As both verbal and experiential construction of local agricultural knowledge are human processes (Munyua and Stilwell, 2012; Curry and Kirwan, 2014), they are embedded in the culture and identity of the actors concerned (Briggs and Moyo, 2012).

In a similar process to the construction of practical agricultural knowledge by farmers, scientific agricultural knowledge is constructed by scientists. The STS authors in Pickering's (1992) collection show that this again happens through the performance of an everyday occupational identity, this time of researchers. Turnbull (2000) thus considers this a process that is 'local' to scientists, making 'scientific knowledge' another vernacular knowledge form. Nevertheless, social scientists and policymakers continue to distinguish between farmer and scientist knowledge generation processes (Halbrendt et al., 2014).

Linked to the exploration of IK, work on hybrid knowledge systems has come to the fore in examinations of agricultural knowledge and extension. These systems combine farmers' and scientists' perceptions to generate solutions to agricultural challenges (Kristjanson et al., 2009; Nguyen et al., 2012). Although knowledge is reproduced in different epistemic communities through activity and performance, both scientists and farmers use words, such as 'bochaa' and 'striga', to describe phenomena, and such common vocabulary allows these different groups to communicate. Comparisons of farmers' and scientists' perceptions are especially common in studies on soil. These move from more abstract, descriptive ethnopedologies (Barrios and Trejo, 2003) to applied works (Gray and Morant, 2003; Osbahr and Allan, 2003; Ramisch, 2014).

The concept of translation, developed in the STS literature, relates to such interactions between knowledge systems. It describes the process through which actors convince each other about their truth claims. Actors 'enrol' other living and non-living 'actants' into their ideas about what is true, aiming to end up with a constellation of such actants that support a particular version of reality. Latour's (1987) development of this idea hinged on a description of how scientists make their particular discoveries real to others, using non-human devices like scientific papers and books to interresse and then enrol other humans in a certain epistemic network. Callon's (1986) classic example involves scientists using data, papers and conferences to convince fishermen and policymakers of a certain model of how scallops cling to rocks. The final step of this translation process involves enrolling enough actors into a network to 'mobilize' it, making it a collective reality. Latour and Callon's examples describe actors being translated from one network of reality to another as they are convinced of new ideas. Palmer (2016) has used the translation concept in a similar way. He describes how a network of Australian indigenous and non-indigenous actors, data, maps and other evidence was mobilized and 'sent' to Paris to convince UNESCO to inaugurate Uluru-Kata Tjuta National Park. As this particular network was itself a hybrid mix of indigenous and scientific actors, the indigenous ideas first had to be made legible to scientific bodies through a process of hybridization, and in order for that to happen they themselves were translated. To describe how this occurred, Palmer involves Latour's idea of centres of calculation (1987), showing how 'indigenous' knowledges were collected and incorporated, in a centre of calculation, into the credible or, to use the STS term, 'durable' actor network that led to the establishment of the national park. Latour introduced this model with reference to the geographical journeys early colonizers made to collect knowledge about new territories. Palmer has also related the concept to the process of neocolonial knowledge appropriation over geographical space (Palmer, 2012).

The boundary concept is a schematic more commonly used in descriptions of knowledge hybridization (and a notion maybe more digestible than the notoriously dense work on translation). This idea connects diverse works on how objects and organizations facilitate connections between knowledge systems. Boundary objects are defined as 'plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites' (Star and Griesemer, 1989). The term has been extended to refer to organizations that perform the same role (Carr and Wilkinson, 2005). The boundary concept has been used in agricultural research: Goldberger (2008) portrays Kenyan organic agriculture NGOs as boundary organizations that forge connections between each other to present organic agriculture as a viable alternative to the technologist Agricultural Green Revolution. Within this literature, boundary objects (e.g. maps, concepts, shapes and projects) are conceptualized as being constructed and developed through boundary work that agricultural actors consciously instigate (Carr and Wilkinson, 2005; Klerkx et al., 2012; Tisenkopfs et al., 2015). The objects then go on to successfully enact translation. Less commonly are they conceptualized as pre-existing entities that are re-appropriated by the actors concerned. A question not tackled in the boundary literature relates to what happens when knowledge systems do coexist and overlap, but actors either do not attempt or fail to construct functional hybrid knowledge systems. It is therefore interesting to identify places where boundary objects already exist even though boundary work has not been performed, or where there is incomplete hybridization or only partial connection between coexisting knowledge systems.

This article situates itself within this literature on knowledge construction, using the idea of knowledge as performance to explain the processes of translation encountered in the data. Its conceptual contribution is to extend the application of the boundary object concept, moving beyond the idea of hybrid knowledge to that of composite knowledge.

Research Questions

The overarching question this work tackles is:

- How can agricultural actors reconcile different knowledges about productivity in search of solutions?

In order to answer this question, we ask three sub-questions:

- How do different agricultural actors in the study context conceptualize productivity problems?
- What are the reasons for any differences between them?
- What do their ideas have in common?

Methods

Our main body of primary data comprises 19 purposively and snowball-sampled qualitative interviews. We also collected soil samples and held a workshop. The study location, around the city of Tamale, was advantageous because it gave access to vegetable as well as staple farmers. We contacted five AEAs through the MOFA Tamale office, purposely seeking those with vegetable farmers in their catchments. This was because we were aware that bochaa was associated with striga but also with other soil problems. Striga is a particular problem for cereal farmers, and we wanted to be able to capture data on the range of its meanings from vegetable farmers too. We asked each MOFA agent to put us in touch with their farmers. The AEAs and seven farmers were interviewed on farm. Some farmers turned their interviews into focus-group discussions, providing opportunities to collect diverse perspectives and data on the social construction of knowledge. There was no such direct link from individual extension agents to researchers, so we contacted researchers at SARI through snowball sampling from the soil science department. Selection criteria for researchers were that they needed to have some understanding of Dagbani and to have encountered the bochaa concept. We met four researchers and one of the MOFA staff attached to the RELC in their work places. We also interviewed two key informant sets, a soap-making group and a Dagbani linguist who was also the retired director of an agricultural NGO. We knew from preliminary investigations that these informants could possibly give us access to relevant data.

It was not intended to make an a priori distinction between the three occupational groups contacted (farmers, AEAs and researchers). Rather, this stratified approach was taken as the most appropriate way to access actors who commonly encounter each other in the everyday context of agricultural practice and extension in northern Ghana. Members of other actor groups who do not necessarily work permanently in the field, such as input suppliers and development workers, are also relevant. The experiences of the actors interviewed were used to elicit the influence of such others on local ways of understanding productivity.

Interview guides focused on:

- understandings of bochaa and associated productivity problems;
- management of bochaa and associated problems;
- how each actor had learnt about these problems and their management.

After the interviews, we revisited six sites in three communities to sample pairs of adjacent soils where farmers indicated bochaa was and was not present. We collected soil to a depth of 20 cm at each sampling point, and sent samples for pH, carbon (C), nitrogen (N) and phosphorous (P) analysis at SARI in Nyankpala, near Tamale. These results acted more as a prompt for discussion between actors than anything else.

Interviews were transcribed in Dagbani and English using the transcription program f4. They were organized into cases, along with photographs and notes on soil samples, in the CAQDAS software QDA Data Miner. Data analysis followed an inductive procedure. All data were coded using thematic codes. Some codes were based on the research questions. Drawing on grounded theory, others were allowed to emerge as the data was coded. These codes were grouped into categories relating to:

- plant productivity and qualities;
- soil productivity and qualities;
- management of productivity problems;
- ways and places of learning;
- non-agricultural uses of the word bochaa;
- actors' self-identity.

Data corresponding to each code were compiled and compared to elicit similarities and differences in representations of productivity problems, their management and the ways different individuals had gained understanding about them.

After this preliminary qualitative analysis and processing of the soil samples, all interviewees were invited to a workshop where the soil and initial qualitative results were disseminated. Two research staff and two farmers who had not been interviewed also attended. After 30 minutes of presentation in Dagbani and English, 75 minutes of heated discussion ensued, which was recorded, transcribed and coded. Earlier data was recoded with new themes emerging from the workshop, before a synthesis was made.

Results and Discussion

In the workshop, the soil results, as seen in Figure 1, were presented first. Productivity is conventionally associated with high soil macronutrient levels and pH values close to neutral, as the AEAs pointed out in the workshop. Yet in Figure 1, N and P levels are not always higher in the plots without bochaa than those with, nor is pH closer to neutral. Workshop participants commented on this, and some AEAs also noted the association of the word bochaa with acidity in the Dagbani language. For example, it can be used to refer to heartburn. This led one AEA to speculate that the bochaa plots should have lower pH, which was not always the case. The consensus conclusion of participants about Figure 1 was that macronutrient and pH levels could not fully explain the productivity problems they were encountering on farmers' fields. Instead, these data acted as an entry point into exploration of actors'

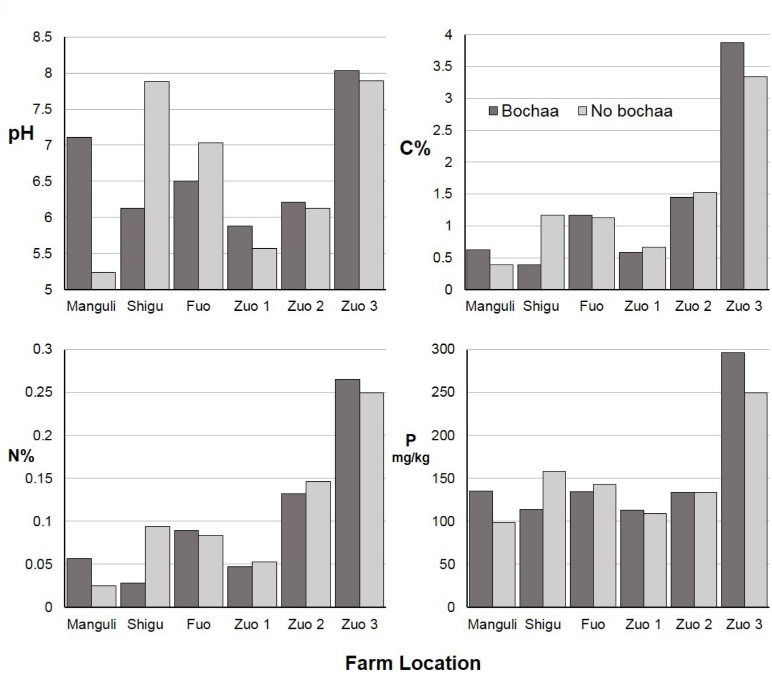

Figure 1. Properties of soils with and without bochaa.

different understandings of the productivity issues they were experiencing.

Networks of Understanding

Among the actors encountered, there were two ways of understanding productivity problems. In this section we explain how they were formed, using the ideas of knowledge as performance and enrolment. Each knowledge network was constructed by a set of actors through the performance of their occupational identity. Actors formed and reinforced those identities through two elements: the way they had learnt about productivity problems and the types of solutions they had seen to function well. Using STS terminology, each of these can be conceptualized as an actant: a non-human network component. These actants became devices, convincing and enrolling the human actors into a particular way of knowing. One knowledge network focused on the symptoms of productivity problems, and the other on the underlying mechanisms for low productivity. We therefore label them the 'symptomatic' and 'mechanistic' networks. We did not set out to align a different network with each occupational actor group, but the data showed that this was largely what happened.

Symptomatic Network

The symptomatic network formed as Dagomba farming elders taught younger practitioners. This happened as part of a more general process of social upbringing called wubsibu. Wubsibu involves teaching people about how to tackle general life issues, of which agricultural problems are one particular type.

> 'When they say bringing up a child it is that they show you things. What we call bringing up a child is not giving you saγim[2] to eat, they tell you "this thing, this is how it works, this particular thing is good, this is not good," that is the bringing up of a child. My grandfather and my father showed me, "this thing, this is how it is," that is the bringing up. If you are in it you will also get to know it. So as you are in it, if someone is doing the same act you can tell him "this is how it is" or "this is how I know it"' (Farmer A).

Wubsibu happened in a tacit fashion as farmers worked together in the farm, but was accompanied by explicit verbal explanation, connecting with the ideas of Bloch (2008) and Ingold (2000) respectively. Farmers described how they had copied their forefathers and also how those ancestors had shown and told them about bochaa, answering their specific questions. For example, farmer D told us how he taught his son how to tackle bochaa as they worked in the farm. As they weeded together, the son asked why certain plants were stunted. D told him this was bochaa and that he should plant the plants further apart to combat it. In an interview, the son corroborated this account, but could not explain why this management practice was effective.

Alongside wubsibu, farmers described how critical observation of their own farms over the course of their farming careers taught them about the causes of certain phenomena. An example given by one group of farmers was the appearance of bochaa around certain trees.

Another way this network was made durable was when farmers used effective low-tech solutions that worked by improving general soil health, specifically manuring and crop rotation. Farmers could not explain the mechanisms through which these technologies worked. Instead, they described the effects the technologies had on the symptoms of bochaa.

> Farmer D: 'You get cow dung and spread it on your field, plough it all, it will mix with the soil, then when you nurse, you see it doing better.'
> Interviewer: 'Why?'
> Farmer D: 'Bochaa makes plants yellow, and cow manure means its yellowness won't be there again and it'll grow.'

Wubsibu and the technologies farmers use to tackle bochaa act as interressement devices. This is the term Callon and Latour use to describe actants that behave as tools to enrol other actants into a particular network. Here, these devices convince Dagomba farmers to use the symptomatic bochaa concept by relating it to their occupational and cultural identities. Briggs and Moyo (2012) describe a similar process, as do Munyua and Stilwell (2013), who say that, in their Kenyan study, 'farmers shared local knowledge… because it was part of their culture, which was preserved through sharing.' Crane et al. (2011) show how the enactment of specific pastoral and agricultural livelihood strategies and knowledges constructs and is in turn shaped by West African ethnic identities. Like Schareika (2014) and Fraser et al. (2015), they emphasize the importance of the social way in which such knowledge is created, and social learning is indeed part of what happens here, stemming from and reinforcing the farmers' self-perception as Dagombas. That self-perception is tied to the imperative to respect the advice of elders and learn from their teaching. The interlinkage between ethnic and occupational identity is thus central to the performance of agricultural knowledge about bochaa. Together, human Dagombas and low-input non-human technologies comprise a symptomatic knowledge network in which the idea of bochaa is durable.

Mechanistic Network

A similar process of performing occupational identity was part of researchers' knowledge construction. The idea that had enrolled them was not of bochaa. They rather had confidence in the existence of soil acidity, hardpan and striga, the phenomena that they held responsible for low productivity. They had been interressed into the reality of these ideas through formal education, training and digital media. Some of the researchers had in fact come from Dagomba farming backgrounds, and formal education had succeeded in enrolling and translating them into the mechanistic network from the symptomatic one, by showing them the mechanisms through which the phenomena named above worked.

> Interviewer: 'You mentioned you've grown up in a farming community.'
> Researcher H: 'Yes. I had that knowledge too… it was concreted then, but… when I went to school… I was able to establish "so this is why we were doing this, this is why we were doing that." Before that I would just *suggest* that we knew what we were doing but I couldn't actually explain *why* we were doing that.'

This quotation shows how researchers learned mechanistic understandings of how productivity worked from formal education and reinforced these by reinterpreting on-farm solutions. To accept manure and crop rotation as technologies, researchers needed to understand the biological, chemical and physical mechanisms through which they functioned, rather than merely describing their effects upon plant symptoms as farmers did. This also happened when they were exposed to more high-tech solutions such as liming and striga-tolerant germplasm: they described how tolerant germplasm discouraged striga by referring to maize genetics and striga physiology. These scientific management practices allowed researchers to apply what they had learnt in formal education, speaking to their identities as educated, professional elites. The technical solutions thus became non-human actants enrolling researchers into the mechanistic network, just as wubsibu, crop rotation, and manure had enrolled farmers into the symptomatic way of understanding.

The self-perception that this engendered was reinforced through peer association. Participants in this mechanistic network described communicating with and learning from colleagues as well as actors from other occupational groups, namely volunteers, development NGOs and commercial and non-profit research corporations, reflecting their participation in the pluralist extension environment. Thus, these parties also acted as components of the mechanistic network.

Actors' experiences of training and education reflected the technical focus of mainstream development policy as well as the involvement of external organizations in shaping professional roles and development agendas. The researchers' educations had all focused on technical competencies such as plant breeding or improved cropping systems; they did not refer to research on, for example, knowledge development or dissemination strategies. Few AEAs had experienced formal workplace-based training; most had been from external projects or chance encounters with researchers and volunteers.

In the mechanistic network, because the researchers' identity involved processing data, Latour's 'centres of calculation' concept, as used by Palmer (2012, 2016), is relevant. The centre of calculation here is the place where data about striga, acidity and hardpan are transformed into scientific knowledge. It has multiple nodes: laboratories, classrooms and conference halls. Journeys, analogous to those made by the Latour's explorers, happen as researchers and data travel between these locations and the farmers' or the experimental field. Researchers described how their enrolment into the mechanistic network had begun in the classroom. Later, they perpetuated the cycle of accumulation of scientific knowledge, collecting more information and formulating solutions through their research activities, specifically legume rotation, use of trap crops and development of striga-resistant varieties. These activities related to striga in particular, reinforcing the importance ascribed in professional development circles to this particular problem and technical solutions to it.

Common Actants

Of the technologies that acted as interressement devices, crop rotation and manure are notable because they played this role in both the symptomatic and the mechanistic knowledge networks. Both farmers and researchers saw manure as strengthening crops against threats to productivity. For researchers, the threat could be striga, in which case manure made nutrients available, allowing crops to grow even when the striga parasite was removing nutrients from them.

> 'If the soil is very poor, a weak maize plant cannot support vigorously growing striga plants, because striga will take the nutrients from the plant, not from the soil. So the manure is for the maize to grow, it is not for the striga to grow well. So if the maize plants are growing well, then the striga

> are not able to kill it' (Researcher M).

In contrast, for farmers, the bochaa that threatened the plant was unexplained, but manure gave the crop the strength to fight it.

> Interviewer: 'You seem to be saying that the place where the soil is strong, the bochaa can't come. Do you know how that works?'
> Farmer S: 'The strength [of the soil] is the reason why the crops are strong. The crops are healthy from the soil and the cow manure. Like that maize there, the bochaa is why it's not strong. If cow manure and compost was in it, you would also see it, so it would get fat and dark and that's what we call strong.'

This is because bochaa is not one biological, chemical or physical process, but a description of the symptoms farmers observe and know how to reverse. Similarly, farmers described how bochaa reduced after several years of rotating legumes with cereals. They did not have an explanatory mechanism for this, whereas researchers explained it by referring to the host-specificity of striga. This resounds with Ingram et al.'s (2010) description of researchers' 'know why' and farmers' 'know how': for the same agricultural problem, farmers have practical experience of which solutions work, and scientists a more theoretical explanation for why they do so.

The AEAs are particularly important in illustrating how these two knowledge networks formed. Some fell between the mechanistic and the symptomatic networks, in the sense that they connected to elements of each and were actively struggling to reconcile them. The interressement devices associated with each network resonated with different elements of their identities. They had practical experience of observing low-technology solutions work in the field, particularly manure. Those who were Dagomba identified to some extent with the farmers and their explanations for bochaa. On the other hand, their professional identities meant that they distinguished themselves as more educated than farmers, and their interaction with peers, researchers, corporations and NGOs had familiarized them with technical terms. Thus, some were confused about the relationship between striga, bochaa and acidity, and could not be enrolled into either network.

> 'The bochaa, as we used to know it, was usually attributed to this witchweed, striga hermotica [*sic*]. But of late I have some difficulty, because once it's like what this particular weed do to crops, you have similar effects when we are talking of maybe some high-level acidity in the soil.' (AEA B)

Figure 2 shows the arrangement of actants in the symptomatic and mechanistic networks. It shows how each network is associated with specific concepts. They are made durable when human actants are enrolled into them by interressement devices. These devices are also actants in their own right, comprising functional solutions and elements related to identity. Some human actants, the AEAs, connect to both sets of interressement devices, so are not successfully enrolled into either network.

Translation between Networks

One aim of the human actors in the mechanistic network was to enrol farmers into their way of understanding productivity problems, and thus change their practice to include exclusive monocrop rotation, hand-weeding of striga, and, where possible,

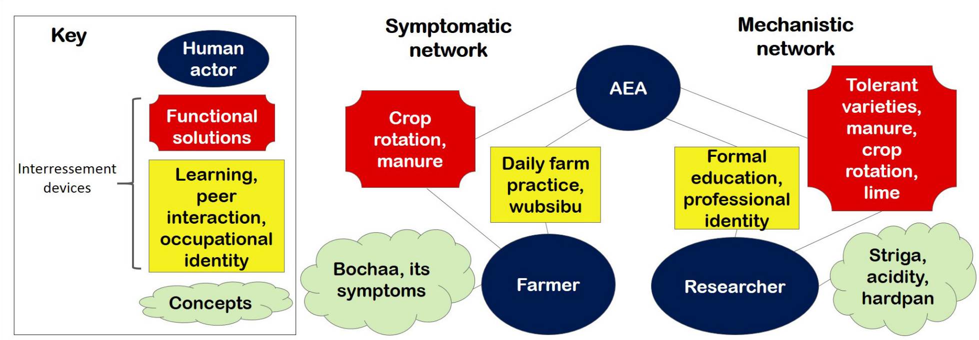

Figure 2. Schematic of the symptomatic and mechanistic networks.

liming and adoption of striga-tolerant germplasm. This resonates with the extension priorities outlines in FASDEPII and METASIP, to improve the low technical knowledge base of farmers and AEAs. However, this section will show why such attempts at translation had failed.

In the workshop, farmers refuted that there was a difference between striga, acidity and hardpan, preferring to group them all under the banner of bochaa. They demonstrated this when a senior scientist stated that 'farmers have the idea that bochaa is the beginning of striga, it is "striga underground", which is wrong' (Researcher E). This scientist asked the farmers as a group if they held to that conceptualization. Farmers collectively stated that they disagreed with distinguishing between bochaa, striga acidity and hardpan. One said 'they all the work the same way' and another added 'they all spoil our crops'.

The actors in the mechanistic network failed to enrol the farmers into this network because the mechanistic interressement devices were not related to the farmers' identity. Those devices worked to reinforce the professional actors' educated status, so were less effective than wubsibu and manure in convincing the farmers. The characteristics of interressement technologies themselves were as important as the identities of the human actors in this. Complex, expensive technologies that had been developed off-farm, such as lime and patented striga-tolerant germplasm, were not available to farmers. Similarly, they had had little contact with AEAs who might explain to them the mechanisms through which those technologies tackled low pH or striga. Low extension capacity is recognized as a problem in METASIP and FASDEPII, but ongoing retrenchment means AEA numbers remain consistently low. Thus, it was impossible for farmers to experience these technologies in the verbal and tacit ways that they had learnt about manure and crop rotation.

This result also helps explain why IK persists as an academic concept and an integral part of farmers' management strategies: Munyua and Stilwell (2013) sum it up well by describing how in their study 'a few farmers used local knowledge when they lacked the funds to implement "scientific" methods.' If the symptomatic network is made durable by farmers' poor access to financial and technological resources, poverty also becomes an actant within it, politicizing the analysis. This is not to suggest that manure and crop rotation are panaceas for poor farmers' productivity constraints. These farmers, as others across West Africa, often had difficulty obtaining manure and mobilizing the labour necessary for its use (Schlecht et al., 2006; Bellwood-Howard, 2013). Nevertheless, in this situation, manure and crop rotation remained more viable technologies than the expensive, unavailable ones constructing the mechanistic network.

The centre of calculation in the mechanistic network had thus created knowledge that had been successfully mobilized for the AEAs from farming backgrounds, but not for the farmers. This network could not exert any type of influence over actors with less formally educated, professional identities, preventing formation of a hybrid knowledge network. In the TOT model underpinning the Ghanaian agricultural extension system, AEAs are supposed to provide a bridge between researchers and farmers. However, despite the approaches that interressement devices from both networks had made to them, this could not, therefore, happen.

Composite Networks As Solutions

The key to the practical significance of this work lies with these AEAs, and will be explored in this section using the boundary concept. As AEAs could not reject the advances of interressement devices from either network, the solutions they had experienced acted as boundary objects. These solutions allowed both networks to exist for the AEAS, without themselves changing in function (Star and Griesemer, 1989).

Boundary objects are usually conceptualized as being constructed by actors through boundary work (Klerkx et al., 2010). This is the case for Cohen (2012), who describes how the idea of a watershed has become a boundary object for groups of land managers. Although watersheds may be seen as natural landforms, Cohen argues that they are actually deliberately socially constructed by neo-liberal, participatory and scientific actors at scales that fit their diverse political projects. Gieryn (1999) gives another relevant example. He describes how the nineteenth-century English botanist Albert Howard developed and named the 'Indore' method of composting, using it as a boundary object to reconcile Eastern indigenous agricultural knowledge with his training in English agricultural science. He performed boundary work as he attempted to use this composting method to enrol agronomists into a network involving organic agricultural practices. In contrast, the manuring and crop rotation encountered in our case study had not been explicitly or intentionally worked on in such a way by local actors. Other technologies had been worked on to a greater extent in the study context, with varying degrees of success. The fertilizer subsidy and the Ghana Grains Partnership are attempts to make fertilizer relevant to farmers, manufacturers, importers, dealers and donors. An NGO, Opportunities Industrialization Centers International, had instigated a composting training scheme in the area, and researchers had done participatory compost trials (Clottey et al., 2006). In contrast, AEAs simply encountered manuring and crop rotation as they already existed within the different networks. Although they recognized these practices as boundary objects, they were working within a paradigm concerned with knowledge verification, where one network had to supersede the other, and had not had training in amalgamating farmer and 'expert' epistemologies. Similarly, researchers and farmers did not perceive these management practices as points of common understanding, but could only see the roles they already played within their respective networks. Without support for the boundary work that could follow recognition of a boundary object, hybrid knowledge could not form.

Nevertheless, one researcher had a different perspective, being willing to understand how boundary objects could be operationalized in an alternative solution.

> 'We can say that there is a common ground as to what bochaa is. It relates to the general well-being of the plant. So the idea of bochaa is a visual example of what happens when things are not going on well in the soil, when the plants are not having enough nutrients. When the soil is sick in terms of acidity. And you can use that example in so many ways if you want to do extension messages… if you want to talk about fertility issues and they talk about bochaa, you can relate the two, if you see their bochaa is not striga but actually nutrient deficiencies in the soil you can relate the two. If you talk about land preparation and they are talking about hardpans, you can relate the two. If you are talking about striga and they are relating it to striga, you can relate them. So to me, I noted about five definitions of bochaa from what was said, they're related and it becomes very powerful, as to what an extension agent can do with all this information, because you can use it to develop strategies about a lot of issues' (Researcher F).

This is not so much a hybrid as a composite solution: it allows the identities that construct both the mechanistic and the symptomatic network to continue existing, with neither attempting to challenge the other's ontology. There is no suggestion that boundary work be performed to arrive at a common understanding. However, even without such work, common practices can be arrived at through the use of boundary objects: these are the manure and crop rotation that the AEAs had experienced. Researcher F also sees the bochaa idea itself as a boundary object, as it may be used as an explanatory device or communication tool.

Recognizing the role of certain solutions as boundary objects permits consideration of the ecological and socio-economic foundations this agricultural system rests upon. The practices of manure application and crop rotation and the idea of bochaa are relevant to both symptomatic and mechanistic conceptualizations because they relate to fundamental characteristics of this West African environment. The generally low organic matter content of sandy savanna soils, combined with poor access to inorganic fertilizer, implies that sustainable field agriculture involves increasing soil organic matter levels. This fits with both researchers' and farmers' ideas about soil health, and resounds with characterizations of farmer knowledge, as a type of indigenous knowledge, being rooted in ecological understanding and experience (Lauer and Aswani, 2009).

Conclusions

We can now draw towards a conclusion, bearing in mind the overarching research question: How can agricultural actors reconcile different conceptualizations about productivity in search of solutions? Component sub-questions ask how different agricultural actors in the study context conceptualize productivity problems, what the reasons are for differences between their ideas, and what their commonalities are.

Our data show how the different occupations of Northern Ghanaian agricultural actors inform their contrasting symptomatic or mechanistic understandings of productivity problems. These different understandings develop because the performance and reinforcement of people's occupational identities involves different learning styles, implementation of different technical solutions, and peer interaction. Yet, despite their differences, the various occupational groups agree about the relevance of manure and crop rotation, low-input solutions that work to ameliorate low productivity and can be seen as boundary objects. Such boundary objects can help reconcile differing conceptualizations about productivity. In situations like the study context, actors' performances of their entrenched occupational identities make it difficult to create hybrid knowledge. Yet the discovery of extant boundary objects such as manuring shows there are areas of common ground between occupational groups. The conceptual tool of composite knowledge allows these to act as common practical solutions, as it permits actors' different extant professional identities to coexist.

If boundary objects are themselves solutions, such as manure or crop rotation, they may relate to more general management principles. For example, the use of manure relates to a need to raise soil organic matter content. If, on the other hand, the boundary objects are concepts, they can be allied to solutions – for example, bochaa is a symbol for poor soil health and a need to apply manure or rotate crops.

Some actors in the study situation had unknowingly used boundary objects to perform agricultural extension, for example by advocating manuring. There is a particular need to pay attention to the boundary concept in the contemporary agricultural development and extension landscape of the study setting, which currently focuses more on importing technical expertise than understanding local knowledge and practice. It could be helpful to broaden the national policy focus, widening the market-oriented model encouraged by the CAADP to encompass more human resource development in specific areas. The METASIP emphasizes the need to enhance farmers' and AEAs' knowledge. Indeed, AEAs need more training in general, but specifically on extension and pedagogical techniques as well as technical procedures. They would benefit from learning how to use boundary objects, concepts and technologies to communicate with farmers and researchers. There is also a rationale for sensitizing CSIR scientists, alongside agents from NGOs and other DPs, on these extension techniques. Such technology developers could usefully engage with farmers' ontologies, both in order to identify appropriate technologies and consider how they will be disseminated.

Simultaneously, MOFA needs to address the function of external organizations in the extension environment. They continue to play an important role, and the newly decentralized authorities will have to consider how to support this whilst facilitating AEA's long-term engagement with farmers outside project contexts. Accordingly, the extension approaches of the various DPs need to be streamlined.

We conclude with a further political contextualization. We suggested that poverty could be an actant in the symptomatic network. Currently, a focus on organic amendment application and crop rotation seems more appropriate to poor farmers' needs than emphasis on expensive, exclusive technologies like patented germplasm. Low resource availability is one reason that boundary objects and IK can be important in finding such solutions when the management practices implied by scientific knowledge network cannot be implemented. However, this useful application of boundary objects should not detract from the importance of boundary work to make technological and knowledge resources available to multiple agricultural actors.

Notes

1. These documents were supposed to guide agricultural policy until 2015, but at the time of writing successors are not yet publically available.
2. The Dagomba's staple maize based food.

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