

COMPOST ADOPTION IN NORTHERN GHANA

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ABSTRACT

Despite describing a decline in soil fertility, Northern Ghanaian smallholders have not universally adopted use of organic, sustainable soil amendments such as compost. Farmers' decisions about whether to use compost depend on their need and ability to do so. The agroecological context of a single rainfall season with low soil organic matter means that farmers' need to compost is a paramount factor determining their decision to do so. Rogers' 'diffusion' model of innovation adoption, that emphasizes the role of communication, is therefore relevant. However, farmers' ability to transport compost is constrained by a lack of financial capital, meaning there is little opportunity for the participatory extension approach that places similar importance upon need and communication.

Keywords: Capital, Compost, Innovation adoption, Livelihoods, Soil fertility management.

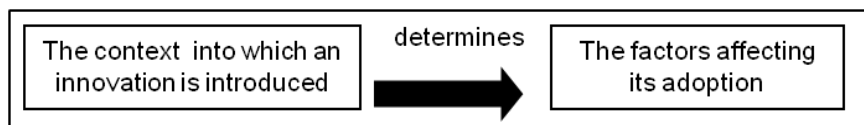
INTRODUCTION

One problem increasingly facing peri-urban smallholders in many parts of West Africa is land shortage (Brinkmann *et al.*, 2012). Cropping intensifies and soil fertility declines as a result (Becx *et al.*, 2012). Mid-20th century solutions to this problem were informed by the 1960s Green Revolution (GR) and promoted the use of inorganic fertiliser. However, later Soil Fertility Management (SFM) approaches recognised the importance of sustainability, and emphasised organic amendments like manures and composts. The 'Low External Input Sustainable Agriculture' (LEISA) that became prominent in tropical SFM in the 1980s was one such approach (Kessler and Moolhuijzen, 1994), and that focus has been maintained in the current Integrated Soil Fertility Management (ISFM) paradigm, acknowledging the importance of combined application of inorganic and organic fertilisers (Bationo, 2009). West African savanna farmers have historically made use of organic amendments, most famously in the densely populated northern Nigerian Kano close settled zone (Mortimore, 1998; Smaling and Dixon 2006). However, although use of organic amendments is increasing in the Northern Ghanaian kingdom of Dagbon, where this study takes place, they have not been universally adopted. This study explains farmers' disinclination to adopt such a seemingly appropriate, sustainable technology.

Composting is both biophysically and socioeconomically appropriate to northern Ghana. The sandy Guinea savanna soils contain little organic matter, leading to low nutrient levels and water retention capacity (Bridges, 1978; West and Beinroth, 2000). The latter in particular increases the risk of farming in the dry, unpredictable monomodal rainfall regime. Anthropogenic factors, including urbanisation and mechanisation (Lobe *et al.*, 2011), exacerbate these unsympathetic conditions in the study area. Farmers' capital endowments also affect their adoption decisions, and the low cost of organic amendments makes them appropriate for the poorest farmers (Kombiok *et al.*, 2012).

Other factors, however, prevent farmers adopting appropriate SFM techniques, and this study draws on two bodies of literature to examine them. Firstly, the livelihoods framework describes how individuals' endowment of financial, physical, human, social and natural capitals affects the livelihood options they can pursue (Scoones, 1998; Ashley and Carney, 1999; Asante *et al.*, 2012). The innovation adoption literature is the second major influence. Throughout the latter half of the 20th century, different development paradigms have informed different adoption models and thus extension methodologies. This study draws upon the participatory, communication and structural models, considering which elements of each explain farmers' non-adoption of composting. The two bodies of literature are synthesised to show that adoption is not just a case of cost-benefit analysis: capital endowments act in different directions to affect uptake, and various actors experience the same factors differently. Understanding the mechanisms through which both biophysical and socioeconomic contexts affect farmers' adoption decisions can explain why they reject inappropriate technologies, helping policymakers facilitate adoption of appropriate techniques. Ideas from the livelihoods and innovation adoption literature combine to inform the conceptual framework illustrated in Figure 1. In this framework, the farmers' context determines which issues or 'factors' affect their decision whether to compost or not. 'Contexts' are specific circumstances such as livestock ownership and cultural setting; 'factors' are more abstract concepts like 'need' that directly affect whether individuals adopt a technology.

Figure-1. Conceptual framework



By identifying and categorising 'contexts' and 'factors', this framework is developed into an adoption model. Traditional innovation studies used regression to determine which of farmers' characteristics were associated with adoption. This work goes further by identifying mechanisms

through which farmers' contexts affect their decisions. Through constructing the model, it addresses three questions:

1. What factors affect Dagomba smallholders' decisions whether to compost?
2. Do the influences of these factors vary between contexts?
3. Where could composting fit within farmers' livelihood strategies?

The literature survey uses three existing innovation adoption models to define the contexts and factors surrounding Dagomba maize farmers. Following description of the site and methods, field data develops the study model. The final version, displayed in Figure 4, is used to answer the research questions. Finally, reflection on how well each model describes compost adoption leads to a consideration of how it could best be facilitated.

LITERATURE SURVEY

Innovation Adoption

The communication, structural and participatory agricultural innovation adoption models have each been associated with different SFM paradigms, informing the extension approaches linked to them.

Rogers' 1962 'diffusion of innovations' communication theory dominated the rural sociology literature in 1960s America. This model emphasised how farmers' personal and psychosocial characteristics, such as wealth, age, political leanings and education (Läpple and Rensburg, 2011; Tveden-Nyborg *et al.*, 2013), determine whether they adopted an innovation. Rogers also emphasised features of the innovation, including, crucially, its compatibility with the farmers' needs (Taylor and Miller, 1978; Ghadim and Pannel, 1999; Yila and Thapa, 2008). Other important factors were social characteristics of the setting, the channel through which the innovation was communicated and the role of the agricultural extension service (Rogers, 1983; Thapa and Rattanasuteerakul, 2011). However, early versions paid relatively scant attention to biophysical factors. This lack of interdisciplinarity may be the reason for the low explanatory power of most early empirical models (typically $R < 0.4$) and contradiction over the direction of many factors hypothesised as explaining adoption (Okoye, 1998). The 1960s Green Revolution promoted the use of high yielding crop varieties, mechanisation and agrochemicals, primarily in Asia. This shifted the focus of adoption research to developing countries and engendered recognition of the structural barriers to innovation adoption. Capital constraints (Tangle, 1987; Mosley, 2002) especially upon land (Baker and Jewitt, 2007), credit (Lawrence, 1988), infrastructure (Lipton, 1989) and labour (Ladejinsky, 1973), alongside insecure tenure (Aribisala, 1983), restricted poor farmers' ability to adopt potentially yield-enhancing practices. Smallholders and poor farmers are risk averse (Delaney *et al.*, 2011), so the introduction of new, risky technologies was perceived as inequitable (Harrison, 1994; Roy and Clark, 1994): wealth is indeed one of the few factors consistently correlating with adoption in the diffusion literature. This

inequity was linked to the potential ecological non-sustainability of many techniques: negative environmental impacts were perceived to disproportionately damage poorer farmers' livelihoods (Shiva, 1991). The macroeconomic climate, including structural adjustment, was a wider factor blamed for African non- and dis-adoption of GR methods (Bates, 1981; Nederlof and Dagbegnon, 2007; Leiman and Behar, 2011). Social and economic critique extended to the diffusion approach associated with the GR as well as the technology itself (Ruttan, 1996), and informed a model emphasising 'structural economic' factors over Rogers' 'communication' limits to adoption (Fliegel, 1993).

The GR's failure in Africa also prompted consideration of the physical factors excluded from the communication model (Rigg, 1985; Gunnel, 1997) such as soil (Nowak, 1987; Byerlee, 1996) and topography (Clay *et al.*, 1998). Research on conservation techniques into the 1980s identified that communication and structural models could simultaneously be relevant to innovation adoption. Taylor and Miller (1978), Jibowo (1981) and Yila and Thapa (2008), for example, recognised that structural *and* personal factors could influence adoption of both conservation and agricultural technologies.

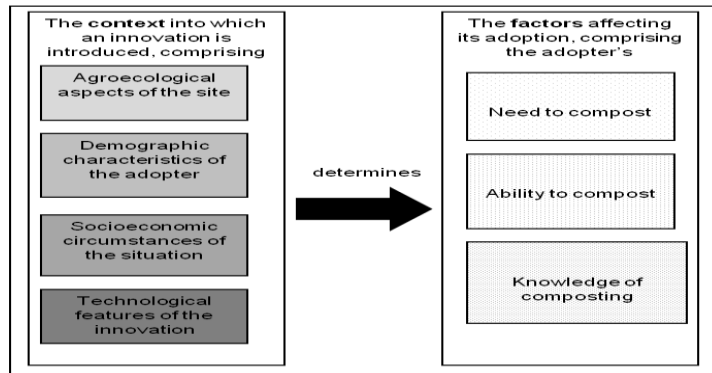
This paved the way for the 1990s shift to 'participation', aiming to empower local people by prompting them to define their own needs and capabilities (Scoones and Thompson, 1994; Neef and Neubert, 2011). This approach was associated with more environmentally sustainable agricultural methods, often drawing upon indigenous and traditional expertise. Participation assumed that the main factor restricting adoption was the top-down imposition of inappropriate, unneeded technologies; a barrier that could be overcome by farmers themselves innovating and experimenting to design appropriate solutions (Chambers, 1994; Douthwaite *et al.*, 2009).

The communication, structural, and participatory models each describe contexts that influence farmers' innovation adoption. Four particularly relevant contexts that can be elucidated from the literature are

- agroecology (linked to natural capital),
- demography (linked to human capital),
- socioeconomy (linked to financial and social capital) and
- technology (linked to physical capital).

These appear in the 'context' box of Figure 2, and will be used to group the specific contexts revealed by the field data. Those contexts will be related to three relevant factors also drawn from the literature: need, ability and knowledge, listed in the right hand box of Figure 2.

Figure-2. Categories of contexts and factors affecting innovation adoption



Before empirical data confirms this model's relevance, the study context and methods are explained.

METHODS

The Dagomba Farm Household System

Dagbon, the tribal area of the Dagomba people, lies in the Guinea savanna of Ghana's Northern Region. Rural Dagombas pursue largely agricultural livelihoods. Cereal, legume, tuber and vegetable farming are increasingly integrated with small ruminant, fowl and occasionally cattle rearing, although under Islam pigs are uncommon.

Patriarchal, often polygynous Dagomba households may contain between three and 50 people. The household head or 'landlord' passes this title to his eldest son. Most of the household's staple maize is grown on the landlord's portion of one to seven acres, usually incorporating compound farms around the house. Junior members of the household reproductive unit assist the landlord, attending to their own cash crop farms in the evenings. Nowadays, tractors or bullocks till cereal and legume fields, although hoes are still used to mound vegetables and tubers. As late as 1973, soil fertility was maintained by bush fallowing (Oppong, 1973). Many farmers later began to claim ownership of bush farms and to rotate cultivation of these fields or practice crop rotation. Population pressure eventually necessitated continual cropping, reducing fertility to the extent that organic or inorganic fertilisers are now essential (Quansah *et al.*, 2001). Composting, in a pit, a heap, or a walled enclosure, was introduced as one such method by the Ministry of Agriculture (MOFA) and various NGOs (Simli, Opportunity Industrialisation Centre (OIC) and CAPSARD in the study villages) in the 1990s. Fieldwork took place between 2008 and 2011, mainly in the villages of Ypilgu, Zaazi and Yong, approximately 20 km north of the regional capital, Tamale, and 7 km from each other. Four other villages, Bunglung, Kukuo, Kpenne and Kpilo were also visited. The motivation for the study stemmed from participant observation and conversations with farmers in these communities about their differential adoption of composting. Most

identified this technique as sustainable and desirable, but uptake was patchy, suggesting that the factors underlying non-adoption warranted investigation. The study used a 'Q-squared' mixture of qualitative and quantitative approaches (Valente, 2011). The research followed an iterative process. Qualitative interview data was first used to inform construction of the quantitative survey tool. At a later stage it was returned to and more was gathered to answer questions that arose in the course of analysis.

Qualitative Data

In-depth interviews took place with 37 farmers, opportunistically sampled from gender, age and household position strata within each village. Interviews focused on soil fertilisation practices and the contexts affecting farmers' decisions to compost. Thirteen further interviews were convened through purposive and snowball sampling with facilitators from the NGOs that had introduced composting to the villages and with research and operational staff from MOFA, University of Development Studies and Savanna Agricultural Research Institute. These sought data on wider institutional, social and economic contexts. Seven groups of eight to 10 respondents used participatory H-diagrams (Simpson, 2009) to identify the advantages and disadvantages of composting, ranking these from 'best advantage' to 'worst disadvantage'. Participants were sampled from different houses within gender and age strata. Seven opportunistically sampled discussions also took place with groups of up to ten farmers.

Quantitative Data

Preliminary content analysis followed the initial qualitative data collection. Thirteen factors (detailed on the x-axis of Figure 3) that participants mentioned as barriers to composting were extracted to construct a questionnaire. The key component of the questionnaire asked 386 farmers across the three villages to choose and rank the three barriers they felt most strongly prevented composting. It also collected data on respondents' socioeconomic characteristics.

Analysis

The questionnaire data was used to test statistical relationships between farmers' socioeconomic characteristics and their opinions and actions; primarily whether they composted or not and what they felt was the main barrier preventing them. The framework in Figure 2 was then completed with farmers' specific contexts gleaned from the qualitative data and the mechanisms whereby these affected their compost adoption decisions. Qualitative and quantitative results are presented concurrently, grouped by the three factors of need, ability and knowledge.

RESULTS AND DISCUSSION

Need To Compost

The participatory and communication models identify that sufficient need for an innovation must exist for it to be adopted. However, in Dagbon, diverse demographic and socioeconomic contexts mean individuals have differential need to compost. The contexts affecting need are underlined in Figure 4.

Guinea savanna agroecology presents an unavoidable need for inputs. Soils are low in organic matter and lie over old, weathered basement complex rocks. Iron and aluminium oxides reduce pH levels and may sorb available nutrients to the surface of concretions. Agricultural extension officers and researchers emphasised that soils therefore have comparatively low carbon and nitrogen levels and release phosphorous and potassium slowly. Physical as well as chemical challenges arise: mid-season dry spells limit yields and increase the risk of crop failure. There is therefore a need for good soil moisture retention, yet compacted soils with low pore space hold little water (Tivey, 1990). Farmers described how compost could tackle this problem by reducing soil bulk density.

'The moisture content, you can still see it..... it's not compact it's very soft so when you step it will sink and your feet will go into it. But as for the fertiliser one, it will be very compact - you step and you wouldn't experience this' (Yakubu 2/2/2010)

Many farmers stated fertilisers 'did not work' and 'burnt' crops in the absence of rain. Crops treated with compost could also 'fail' in drought, but unlike with fertilisers, rain could fall up to a week after compost application and still be absorbed into the improved soil structure. Plants could then continue to take up nutrients, whereas crops fertilised inorganically were more likely to perish after a dry week. A final advantage of compost was that nutrient release continued up to three years after application.

'Compost will give a better yield for three years, but fertiliser next year won't work' (Abdulwahab 17/5/2008)

This is especially important when the availability of inorganic fertiliser is not guaranteed. Despite a 40% government fertiliser subsidy, farmers still cited financial constraints; moreover, once purchased, fertiliser could not always be conveyed to the farm on time. In such an unpredictable situation a long-term source of nutrients reduces risk.

Farmers and professionals alike perceived that anthropogenic factors compounded this agroecological need for compost. Population increase was considered to have reduced soil fertility, as holding subdivision led to continuous cropping. Mechanisation was invoked as accentuating the effects of rainfall unpredictability. Tillage exposes soil organic matter to oxidation, and tractor ploughing turns topsoil 30cm deep and covers it with sand, reducing water retention in

the top layer. In a discussion group in Ypilgu, farmers explained that hoe-ridged and bullock-ploughed fields retain more moisture due to shallower topsoil inversion. These effects were considered to lower soil fertility to the extent that:

'If you don't apply compost or fertiliser you won't get food' (Ibrahim 2/2/2010)

In response to these challenges, many Dagomba farmers have turned to organic inputs: 99.7 % of respondents in Ypilgu and Zaazi claimed to have made compost for themselves or their landlord at some point over the preceding three years; 67.6% had made compost for their own farm in 2009 and 86.6% said their landlord had done so too. In Yong, 28.1% of the sample had made compost and 96.5% had used manure. People who had not used manure, fertiliser, or compost were observed spreading refuse (mainly ash and compound sweepings) on their farm, or said they would weed thoroughly to reduce competition for nutrients.

'If you can't get money you can weed two or three times' (Seidu 8/5/2008)

The savanna environment is thus a regional context defining farmers' need to compost.

Turning to individuals' demographic contexts, household heads are responsible for providing the staple maize, so have particular need for compost. In Ypilgu and Zaazi, chi-squared tests showed that landlords ($p=0.007$) and maize growers ($p=0.000$) were indeed more likely to compost than other people (see appendix). As women and junior men less often grow maize (26.2% of women compared with 81.2% of men), there are also gender and role effects, albeit less significant. A possible exception to this was seen in Zaazi and Kpenne, where women and young men who had diversified into cash vegetables noted that compost-grown produce had longer shelf-life and better quality.

'(Composted) vegetables were nicer than if applied with fertiliser' (Habiba, 17/5/2008)

Some women and youths may therefore need to compost, though this is unlikely to be as pressing a demand as it is for the landlord.

Unsurprisingly, farmers' socioeconomic context, particularly access to financial capital, livestock and labour, affected their need to compost. Reflecting the complexity of smallholder livelihoods (Chambers, 1997), this also influenced their ability to compost and is dealt with in depth in the succeeding section. Nevertheless, a brief explication of the effect of money and livestock upon farmers' need to compost is necessary.

Although richer farmers could buy fertiliser, and the subsidy meant most farmers had access to a least one bag of it, this was insufficient to obviate the need for additional organic amendments.

'Sometimes the problem is money. But that's why they're using both. If you go in for fertiliser, it's money, but if you've got (animal) droppings, it will help' (Abrahaman 2/6/2008)

Those owning many livestock, particularly pigs and cattle, had access to enough manure to negate the need to increase its volume by composting. Many Christians kept pigs, preferring their manure because it was 'strong' as well as plentiful. As pigs are more valuable and therefore more

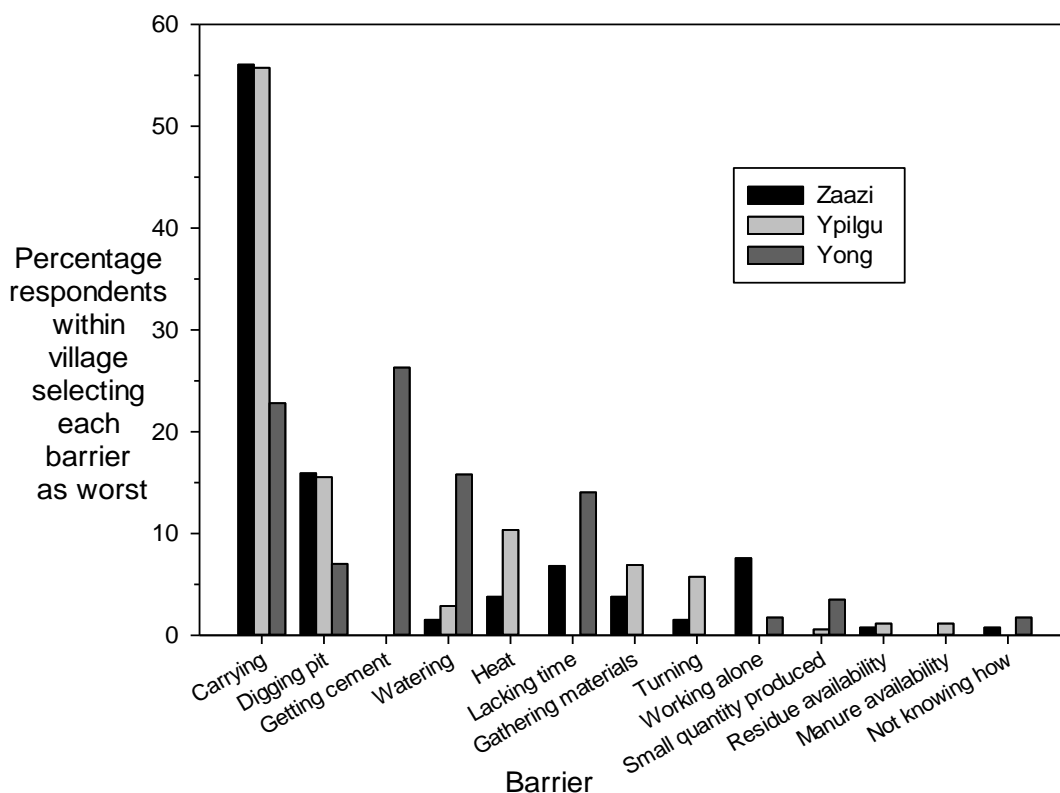
commonly confined than ruminants, collecting their manure is easier. This was probably a major reason for the lower composting rate in Yong, the only Christian village in the sample. This suggests that wealth reduces a farmer’s need to compost. However, its relationship with farmers’ adoption decisions is multidirectional, as it also increases ability to compost.

Ability to Compost

Those who identified a need to compost were differentially able to do so. This ability factor involved the three interconnected socioeconomic contexts of money, labour and livestock.

Richer farmers could buy more fertiliser, seemingly reducing their need for compost. Yet their financial capital endowment also increased their ability to transport compost to the farm. In agreement with previous work in the region (Al-Hassan, 2009), this was demonstrated by the questionnaire results, with carriage most commonly being named the primary constraint to compost use in Ypilgu and Zaazi and second most commonly named in Yong (Figure 3).

Figure-3. Proportion of respondents in each village selecting each barrier as ‘worst’



When asked to suggest solutions to this carriage problem, 47.1% of the whole sample suggested a means of transport (*benzirigu*), such as a hand-pulled truck, a wheelbarrow or an ox or donkey cart. Ownership or hire access to these could only be obtained with financial capital. A lack of

money therefore limited farmers' ability to effectively apply compost as well as fertiliser. The importance of carriage illustrates a principle of agricultural economics, Von Thunen's theory of marginal productivity, 'the isolated state'. This describes how the maximum distance that manure can profitably be carried is the point at which its transport costs exceed its benefits (Grigg, 1995). This explains why compound farms, close to the livestock enclosure, are more fertile and used for vegetables and cereals, sown two per hill. In contrast, legumes dominate the bush farms where any cereals are sown in single stands. Patterns of higher fertility closer to the homestead have indeed been recorded across West Africa (Quansah *et al.*, 2001; Sauerborn *et al.*, 2003).

Farmers' emphasis on physical solutions to the problem of carriage suggests that bicycles could form part of the answer. Yet personal bicycle ownership was not significantly related to whether an individual composted or not or selected carriage as the 'worst' barrier: Abrahaman felt that '*bicycle ... is the same as head carrying*' (14/5/2008), i.e. equally arduous, because its maximum load of around 50kg was insufficient. So, although 75.3% of men, 3.5% of women and 97.7% of households owned a bicycle, this was not enough to overcome the carriage constraint. Respondents considered that a larger, animal drawn or motorized *benzirigu* would be more useful. Such a *benzirigu* was available in 6.9% of households. However, surprisingly, *benzirigu* owners were less likely to compost than those farmers who did not own or have access to one. In explanation, ownership of means of transport, especially motorbikes, may be more meaningful as an indicator of wealth, ability to buy fertiliser and less need to compost. This illustrates the complex links between factors and contexts.

Alongside *benzirra*, livestock is another important form of physical capital. Access to pig manure could reduce Christian farmers' need to compost. In contrast, Muslims in Zaaizi and Ypilgu composted ruminant manure along with other, vegetable, organic residues. In these two villages livestock facilitated composting rather than reducing the need for it: indeed, in Ypilgu many farmers suggested a *lack* of livestock was a barrier to composting. Evidence to support this is that if bullocks were owned within a house, the landlord was more likely to compost ($p=0.02$) (see appendix).

Composting is labour intensive. Social capital helps farmers enlist human capital, suggesting that larger households with influential landlords may be more likely to compost. However, here, households containing more people able to carry compost to the farm were not statistically more likely to compost, because big and small households composted for different reasons. The opportunity cost of labour is lower for larger households, so although many of these were richer and could afford fertilisers, they used compost in addition in order to reduce drought risk. Simultaneously, small, poor households composted because their inability to buy fertiliser necessitated it. An individual's socioeconomic contexts therefore affect their ability as well as

their need to compost and are indicated in bold type in Figure 4. As Goss' structural model recognises, although money and livestock reduce the individual's need to compost, they also facilitate the choice to do so. Farmers were aware of the non-nutrient benefits of compost and used it to reduce drought risk rather than merely substitute for inorganic fertiliser. The importance of capital endowments prompts reflection on the macroeconomic context: subsidy helps farmers to purchase fertiliser, and without it the number using inorganics would undoubtedly have been lower. However, it cannot replace the need to compost, necessitating comparison of the relative importance of ability and need.

'Need' Dominates 'Ability'

Issues of scale become important when attempting to identify the most influential factor. The national fertiliser subsidy differentially affects farmers in diverse socioeconomic and demographic contexts. In contrast, the agroecological reasons defining farmers' need to compost act across the whole savanna zone. Compost could therefore potentially benefit farmers in various situations. This demonstrates the interplay of agroecological and socio-cultural influences (Kolawole, 2013). The primary importance of the agroecological 'need to compost' implies that Rogers' communication diffusion model and the participatory approach are pivotal in describing compost uptake. The former identifies that for an innovation to be successful it must be compatible with a farmer's needs and the latter considers that farmers design solutions to meet their requirements, in this case for an ecologically and financially sustainable soil amendment in conditions of low soil organic matter, rainfall and capital. For those within the 'needy' category, Goss' structural economic model is a secondary tool helping to describe how well they are able to pursue this solution.

Knowledge of Composting

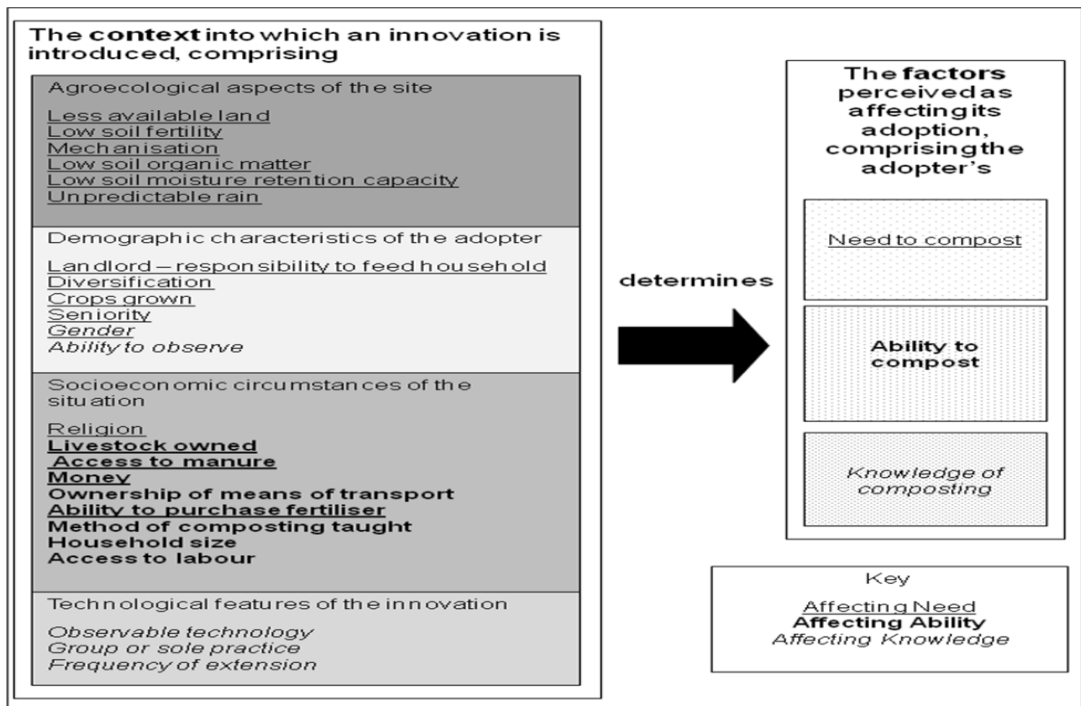
Knowledge was a third, minor factor influencing farmers' composting decisions, reinforcing the importance of the communication and participatory models. Farmers had learnt composting from NGOs, fellow farmers and the Ministry of Agriculture (MOFA). The MOFA extension ideology is based on the 'Training and Visit' (T+V) system, informed by Rogers' diffusion approach. Area extension officers felt that regular visits were critical to successful extension, as did farmers: two farmers in Yong complained that composting facilitators had 'run away' after delivering training. Observable technologies like composting are also easily disseminated through participatory farmer-to-farmer methods (Byerlee *et al.*, 1982). Peer communication was described as effective:

'By knowing each other's farms and seeing the benefits they started to come out and practice' (Yahaya 18/5/2008)

NGOs like OIC, that introduced composting in Ypilgu, used this approach, devolving responsibility for their representation to a 'para-extensionist' resident farmer. Participatory authors have criticised the 'Transfer of Technology' extension methods associated with T+V as

ineffective in facilitating long term adoption (Nederlof and Odonkor, 2006). Yet NGO and MOFA staff identified a mixture of communication and participatory methods as effective, and indeed sometimes collaborated. Figure 4 italicizes the contexts that affect knowledge of composting. This final version of the conceptual model categorizes all contexts identified in the results and indicates the factor they affect.

Figure-4. Contexts affecting Dagomba farmers' adoption of composting



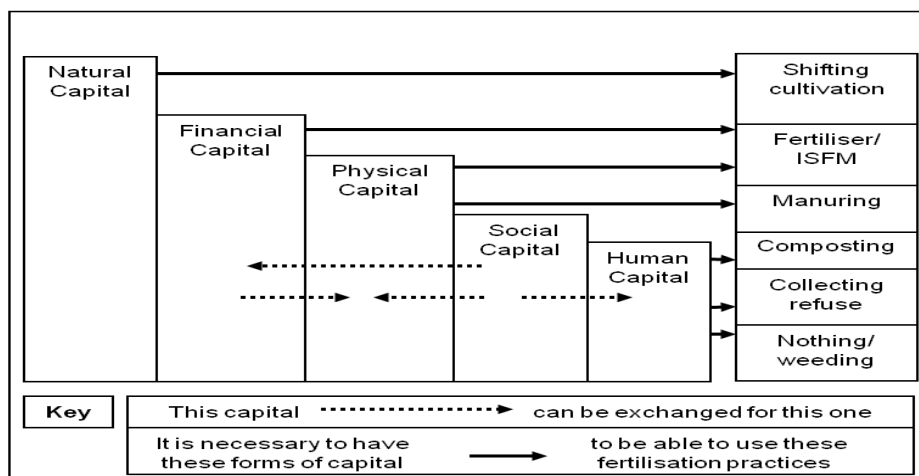
Interacting Capitals

Access to natural, financial, physical, human and social capitals increases farmers' ability to use the organic amendments they need in the savanna. However, more important than their individual effects, the interactions between them ultimately determine whether a farmer adopts compost or not. The chi-squared test showing that larger households were significantly more likely to own bullocks (see appendix) illustrates such capital liquidity: one extension officer confirmed the characterisation of a rich man as '*one with many wives and cattle*'. Similarly, labour can be 'traded' for social capital.

Different SFM strategies also complement and substitute for each other. Farmers cannot meet their need for sustainable SFM with compost alone. The richest are most able to pursue successful, sustainable strategies, reducing risk by integrating inorganic and organic methods. Such flexibility is in fact the primary advantage of having access to a range of assets. It is

therefore most meaningful to conceptualise capitals and techniques as part of a holistic system. Figure 5 illustrates this diagrammatically.

Figure-5. How capital endowments affect individuals' ability to practice SFM techniques.



CONCLUSIONS AND POLICY IMPLICATIONS

The relationships between farmers' contexts and three factors affecting their adoption of compost have been identified using an interdisciplinary methodology. The three research questions laid out at the start can now be answered.

Firstly, a farmer's decision to compost was influenced by two major factors: their need and ability to do so. A third minor factor was the extent of their knowledge. Secondly, the relevance of these factors varied between farmers' agroecological, demographic, socioeconomic and technological contexts. These contexts acted on the crucial factors of need and ability in different directions. Richer and poorer farmers were equally likely to compost, although due to different mechanisms. Those with access to vehicles and labour were most able to transport compost to the farm. Yet although structural constraints prevent some poorer farmers from composting, the regional effects of unpredictable agroecology mean most need to do so - especially landlords in peri-urban areas responsible for providing their household's staple maize. As need for a sustainable technology remains a dominant factor over ability, the communication and the participatory models remain most relevant to compost adoption.

These results illustrate how SFM links to other issues within smallholder livelihoods. Answering the third question, compost is one of many intensification techniques necessitated by rising population and urbanization in the savanna. As climate changes, mechanisation advances and

livelihood strategies change from cereal to market vegetable farming, its relevance increases as a tool for diversification as well as intensification. In agreement with the SFM literature, the farmers of the study area confirm that composting can comprise part of an integrated sustainable intensification strategy. Agricultural policy should therefore promote it. Rogers' model suggests that adoption could be encouraged by external extension. What is more likely is that, as described in the participation model, it will become more popular as land pressure rises and more farmers require sustainable solutions. A useful policy focus would be on removing the remaining barriers to composting, beginning with transportation. Subsidizing vehicles or researching and testing communal ownership (Nowak, 1987; Millar, 1999) or hire systems could prove fruitful. Simultaneously, promoting off-farm diversification and production on compound farms could reduce the need to carry compost for long distances.

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APPENDIX

Selected Chi-square tests

Test variable		Grouping variable		X ²	df	p
0	1	0	1			
Composted	Did not compost	Landlord	Not landlord	7.37	1	0.007
Composted	Did not compost	Maize grower	Not maize grower	26.536	1	0.000
Composted	Did not compost	Bullocks owned by a household member	No bullocks owned by any household member	5.402	1	0.02
Household over 20 people	20 people or under	Bullocks owned by a household member	No bullocks owned by any household member	11.719	1	0.000

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