Local-level appraisal of benefits and barriers affecting adoption of climate-smart agricultural practices: Ghana

Technical report for the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

March, 2014

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SUMMARY

Although Climate-Smart Agricultural (CSA) practices are expected to boost adaptive capacity, food security and climate change mitigation in resource poor, smallholder farming systems, the barriers that can restrict their uptake are diverse. This study investigated the principal barriers hindering the adoption of CSA practices in the Upper West region of Ghana with the aim of inventorying existing uptake of CSA and providing recommendations to CCAFS as to practices with potential for further research or implementation on the farm level. A questionnaire survey of 60 households in 2 villages in Lawra District, in addition to focus group discussions and semi-structured interviews, revealed that non-adoption was most often a result of insufficient financial capital, difficult access to or low availability of the necessary agricultural inputs (tools, seeds and fertilizers), water scarcity, and in some cases insufficient labor to carry out the practice. Women farmers were often less aware of CSA practices than men and were more likely to perceive increased labor load as a disadvantage to adopting them. The author noted rainwater harvesting, improved crop varieties, efficient fertilizer use, and improved forages, as well as continued use of pit composting, as practices with high potential for further CCAFS investigation and/or on-farm participatory trials.

INTRODUCTION and OBJECTIVES

The combination of projected world population growth and changing human diets will have far-reaching effects on food production systems. The challenge of increasing production by 70% to feed the world's population in 2050 is made all the more difficult by climate change and its negative impacts on agricultural production (Lobell et al. 2008) and food security (Schmidhuber and Tubiello 2007) in hunger-prone areas of the global tropics.

The widespread uptake of practices and technologies that are conscious of these impacts is of primary importance to increase the adaptive capacity of farming systems and mitigate agriculture's considerable contribution to global greenhouse gas emissions. Climate-smart agriculture (CSA) is a concept intended to address the need for climate consciousness in agriculture while not placing undue burdens on the resource poor small farmers who are often the most vulnerable to climate impacts.

As defined by the Food and Agriculture Organization of the United Nations, CSA is agriculture that "sustainably increases productivity and resilience (adaptation), reduces or removes GHGs (mitigation), and enhances achievement of national food security and development goals" (FAO 2010). At the local level, CSA can be conceived as a suite of practices – ideally ones that have been assessed for local suitability – that can improve a farmer's capacity to adapt to changes in climate and/or increase the mitigation potential of production through carbon sequestration or reduced emissions, while still meeting or exceeding food security goals. At the national or regional level, CSA is more often considered a conceptual framework that examines the tradeoffs between the three "pillars" of adaptation, mitigation, and food security.

Determinants and barriers for CSA adoption

For CSA to have the desired impact on the adaptation of global agricultural systems it must be applied across a multitude of geographical, social, economic and political contexts. However, for farming communities within each of these contexts the obstacles that impede or complicate CSA adoption are different. Therefore, local-level assessments are necessary to first verify the suitability of target practices and subsequently to determine how their widespread adoption might best be facilitated.

Case studies from both the developed and developing world point to common variables that affect the likelihood that an individual farmer will adopt sustainable practices, including practices that fall under the CSA framework. For example, the scale of the farming operation, the farmer's age, gender, wealth, membership in agricultural organizations, land tenure status, and education level all have an influence on practice adoption (Smithers and Smit 1989; Deressa et al. 2008). Adoption rates also hinge on subjective variables such as farmers' awareness of new practices, personal willingness to adopt them, and overall concern for the problem the practice aims to address (Below et al. 2010). These variables are themselves contingent on pre-existing worldviews on relevant actions, institutions, and information sources, among others (Koltko-Rivera 2004).

Even when conditions favor the adoption of the target practices, farm level or technology-specific barriers such as inappropriate soil types or difficult-to-acquire material inputs can cause additional hindrances. Commonly reported barriers to the adoption of climate-smart practices are financial constraints and shortages of labor, land or water (Deressa et al. 2008), as well as lack of necessary transportation assets or low farmer organization membership (Ibrahim et al. 2012). Farmers may be generally willing to adopt new practices, but perceive a specific practice to be inadequate, unnecessary, or difficult to incorporate into existing management systems (Smithers and Smit 1989).

Widespread CSA adoption also depends on factors of social differentiation – most notably age, gender and diversity. Women and men farmers, for example, may not access, use, or benefit from practices in the same way (see Archer, 2003). The same may be true of farmers with different income and education levels, family size, land tenure status, religious beliefs, place of birth or relationship to institutions and individuals in power. These factors must be considered when analyzing appropriateness of CSA practices as well as barriers to their adoption.

Likewise, the degree of institutional support in an area will affect whether CSA practices – especially those requiring more substantial startup investments or technical knowledge – can be adopted easily. Institutional investment in agricultural communities (infrastructure, extension services, health care) will affect farmers' ability to absorb risk and, in turn, adopt new practices (Below et al. 2010). Legal and political frameworks also influence adoption rates. For example, policy on informal seed fairs and genetic resources can affect farmers' ability to save seed of locally tolerant varieties or access improved varieties through exchange with other farmers (Progressio 2009). Thus, technological, social, economic, and institutional factors all play a role in whether target CSA practices can or will be adopted, both within farming communities and on the national and regional scales.

Objectives

West Africa, East Africa and Latin America are focal research regions for the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). These regions are characterized by severe projected climate impacts and a large proportion of their populations relying on agriculture for their livelihoods. This research made an appraisal of the benefits and barriers to adoption of CSA practices in three countries: Ghana, Colombia and Tanzania. Despite the distinctiveness of each location, the anticipation was that complementary lessons or ideas may be observed that could be translated between contexts to facilitate the widespread adoption of appropriate CSA practices.

The aim was to identify the current extent of CSA adoption at sites in these regions, with an emphasis on the barriers that may be preventing its widespread uptake. Questions to be addressed were:

- What practices are currently being utilized in the area of interest, and how do farmers perceive their benefits and disadvantages?
- Why are practices that are seen as desirable or beneficial not currently being utilized?
- What gender differentiation factors exist relating to the perception of benefits, disadvantages, and overall desirability of each practice?

Foundational CCAFS research has already been carried out at the selected research sites in Ghana, Colombia and Tanzania. This work includes the CCAFS Baseline Household Surveys, which provided corroboration for some findings, pre-existing household lists for selection of participants at each site, and data for additional comparative analyses (see Kristjanson et al. 2012; Naab et al. 2011). Additional participatory and survey-based CCAFS research is ongoing in Ghana (see Naab and Koranteng 2012) and Tanzania (see Shikuku et al. n.d.). CCAFS' Latin America program is still incipient, although the Baseline Surveys were carried out in sites in Colombia by researchers from Bioversity International in 2012 and the data was available for the above purposes.

The overall objectives of this study were as follows:

1. Inventory local CSA practices currently in use in each site;
2. Summarize barriers and constraints to CSA adoption from the farmers' perspective (both in qualitative and quantitative forms), including how gender differentiation could impact adoption/non-adoption;
3. Make recommendations to CCAFS and partners as to promising avenues for further research, especially with regard to CSA practices that show potential for beneficial impact and widespread farm-level adoption.

METHODS

West Africa – and Ghana in particular – has been identified as a core region of interest for CCAFS. The region was selected due to its large rural populations that depend on rain-fed, cereal based subsistence farming or pastoralism for their livelihoods, and are thus highly vulnerable to climate variability (see description of region selection for CGIAR Challenge Programs in Förch et al. 2013).

Climate change in Ghana is expected to take the form of more frequent and intense drought, increasing rainfall variability, and higher temperatures – from between 2°C to 4°C by 2100, or about 1.5 times higher than the global average (Nii et al. 2011). These changes are expected to affect crop yields and resource availability in a region already characterized by scarcity.

Study Area

The Lawra area of Northwestern Ghana is located in the Guinea Savannah agro-ecological zone. Agriculture in the area mainly takes the form of mixed crop-livestock smallholder systems with maize, sorghum, and groundnuts constituting the three most important crops (Förch et al. 2013). Climatic conditions are variable, making agriculture difficult, and poverty levels are high. The principle constraints on agricultural production are soil fertility and water availability.

Dazuuri and Bompari villages were chosen as hosts for this study from among villages in the CCAFS household baseline survey sample block identified in 2010-2011 (sampling described in Kristjanson et al. 2012). They were selected based on suggestions from key informants in Lawra District as well as considerations of distance from Lawra town, size, research fatigue of community members, and complementarity with previous or ongoing research by CCAFS and its partners in the area. The two villages are adjacent to one another and could thus be assumed to experience relatively similar climatic conditions, although they differ slightly in topography and distance to a permanent water source. Members of both Dazuuri and Bompari villages participated in a CCAFS Farms of the Future training and exchange in 2012.

Literature Review and Verification

A brief literature review of existing reports on CSA work in Ghana was undertaken to gain an *ex ante* perspective of the status of CSA work in Ghana and the appropriateness of certain practices for environmental conditions in the Upper West region. Literature included reports on specific practices, i.e. trials of farming practices or technologies, gleaned from the CCAFS climate-smart agriculture database (Rosenstock, Bruno, & Gosset, unpublished) as well as reports and publications on participatory work or programs being undertaken by organizations, NGOs, and government ministries in the area. Searches were also refined to the specific agro-ecological zone and crops of interest by using keywords such as “Upper West,” “Guinea savannah,” “savannah,” “Ghana, maize,” “Ghana, rice,” “groundnut,” and “Ghana, groundnut.” These searches formed the basis for a rough list of CSA practices hypothetically appropriate for the Upper West region and Lawra District in particular.

This rough list was later verified and refined through consultation with on-site informants who were able to speak to the context of the information gleaned from the literature review. These informants could identify practices that were clearly unsuitable for the Lawra area or largely unknown, in addition to indicating potentially appropriate CSA practices that were not yet widely in use. Informants were selected based on their ability to give insights on CSA adoption in Ghana from the institutional perspective, their familiarity with the district and villages in question, and their knowledge of relevant climate change and agriculture related projects and research. They included the leaders of organizations working in the area, regional learning platform contact points, ministry officials and extension officers, and researchers.

Household questionnaires and semi-structured interviews

CSA practices identified as locally appropriate, well-known or actively promoted in Lawra district were incorporated into a questionnaire survey, semi-structured interviews, and focus group activities conducted in Dazuuri and Bompari villages from 7 April to 14 May, 2013.

Community entry and sampling

The communities were introduced to the research team, the purpose of the project, and the activities to be undertaken first through an individual meeting with the chief of each village, and later an open attendance, community-wide meeting. The individual meeting with the chief was arranged through cooperation with Ministry of Food and Agriculture (MoFA) extension agents already well known by the chief and villagers, and served to solicit the chief’s permission to work in the village.

At the community-wide meeting, villagers were reminded that MoFA had previously constructed a complete list of households and performed a baseline survey, and that the current research team represented a follow-up to this original effort. The purpose of the study was explained, emphasizing the random and anonymous nature of data collection, the importance of equal gender representation, and the need for objectivity on the part of participants.

Using the household list generated for the 2011 Baseline Household Survey, 39 households in Dazuuri and 21 households in Bompari were randomly selected in a lottery-style activity during the community meetings. Sample size was calculated for a stratified random sample with proportional allocation (N=200; confidence=90%; error=10%; number of strati=2). One individual from each household participated in the paper questionnaire, and care was taken so that an equal number of both men and women farmers were questioned.

Questionnaire design and administration

Questionnaires were administered in the local Dagaare dialect by a translator accompanied by a supervisor. Picture cards representing CSA practices served both to help define each practice and to aid respondent recall. The questionnaire was formatted to incorporate both formal quantitative questions and open-ended questions that allowed space for conversation and story-telling.

Questions were designed to take into account that CSA is a new term applied primarily at the institutional level; it is virtually unused in the rural populations being studied here. Although farmers may be aware of a particular agricultural practice, they may not necessarily associate it with CSA or even understand the concept's definition in the same way as the research team. Thus, the questionnaire made no explicit mention of CSA but rather focused on individual practices: Whether the farmer had heard of the practice, whether they use it on their land, what they see as its benefits and/or drawbacks, and the social, economic, environmental, or other barriers that may be preventing them from adopting a practice that they consider beneficial.

Additionally, respondents were allowed to identify individuals in the village who were known to have adopted CSA practices or be particularly innovative. These individuals were sought out for additional interviews to generate more in-depth, qualitative information on perspectives of change in farming systems and climate and the challenges affecting productivity and sustainable innovations in Lawra District.

See Appendix 1 for a copy of the complete questionnaire and appendix 2 for sample semi-structured interview guiding questions.

Participatory focus groups

Focus group sessions served as a qualitative complement to the questionnaire, giving community members a chance to self-analyze, present opinions, venture questions to fellow group members and share stories of successes and failures related to selected CSA practices. Two small male- or female-only focus groups of 10-15 participants were held in each village. Group participation was strictly voluntary, meaning sampling was non-representative for the purposes of rapid assessment. Because village contact farmers were responsible for inviting participants, group composition was likely biased. This weakness should be taken into account when interpreting the results, especially considering that some marginalized groups may have been left out of the conversation.

An institutional mapping activity asked participants to reflect on the organization of their village and the institutional arrangements within and without. Group members were directed to first list of all institutions, organizations, and formal and informal groups active in the community. They gave a brief explanation of the purpose of each institution and indicated whether membership was male-only, female-only, or mixed gender, and whether the institution was internal (composed mostly of community members) or external (composed mostly of outsiders) to the community. Participants then assigned each institution a circle size depending on their relative importance (i.e. activeness in community, degree of positive impact, frequency of meetings or visits). Through the direction of the other participants, a group-elected representative drew these institutions on the ground with a stick or piece of charcoal, positioning them to represent their relationship with a larger, empty circle representing the entire community as well as their relationship with the other institutions on the list.

Afterwards, an informal story circle was conducted giving participants the opportunity to discuss freely the CSA practices with which they were familiar, how they learned about them, and what they liked or didn't like about them, among others. Picture cards were used to guide farmers as to possible practices for discussion, although they were given the option to discuss "good agricultural practices" that were not represented in the cards. This activity linked to the institutional mapping activity by prompting participants to think about the media through which new agricultural information arrives to the community and subsequently spreads among its members.

See appendix 3 for example focus group guiding questions.

Analysis

Results from the household questionnaires were summarized by descriptive statistics. A two-tailed Student's t-test or two-tailed z-test for proportions were used where appropriate to determine gender differences in response frequency, type or diversity. Correlation analysis described the relationship between awareness of CSA practices and their overall adoption, and a Kruskal-Wallis "analysis of variance by ranks" non-parametric test indicated differences between adoption rates for users with different education levels or amounts of land available for agriculture. Qualitative analyses of focus group and interview results were used to complement results from the questionnaire and, in some cases to explain those results.

RESULTS

CSA practices for Lawra, Ghana

The literature review and subsequent verification by informant interviews identified a total of 20 relevant CSA practices for the Lawra District (this list is not considered exhaustive). Table 1 lists these practices and their basic definitions; qualifications or modifications are noted where the definition may depend on site-specific considerations. Justification for each practice's inclusion in the list is provided, i.e. its contribution to any or all of the three CSA "pillars": climate change adaptation, GHG emissions mitigation, and food security. These justifications are based primarily on empirical evidence available from the scientific literature (key examples are listed in the "source" column) as well as interviews with farmers and informants in Lawra (noted as "personal communications" in the "source" column).

In some cases, debate exists in the literature as to whether a practice can be considered climate-smart. Chemical fertilizers, for example, are GHG emissions producers and may be an unsustainable long-term adaptation measure due to negative impacts on soil quality. However, they were included in the list of CSA practices for Lawra because farmers repeatedly indicated that they viewed them as an adaptation measure against declining soil fertility and shorter growing seasons, as well as an imperative for household food security. Practices such as chemical fertilizer use exemplify the nature of CSA trade-offs, and they are included with the aim of incorporating farmer opinion into analyses and better understanding the extent and pattern of their use.

Table 1. Agricultural practices included in "Barriers to CSA adoption" questionnaire and definitions as per the local context in Lawra District, Upper West Region, Ghana.

Practice	Definition	Justification for inclusion	Source
Agroforestry	Deliberate planting or protection from removal of more than one tree in the past 12 months either on agricultural land, its borders, or land set aside specifically for tree planting purposes. Includes a number of practices such as border planting, living fences, strip cropping, fruit trees and windbreaks, among others.	**Adaptation**: soil fertility maintenance; creation of favorable microclimates; reduced moisture stress **Mitigation**: soil carbon sequestration; erosion prevention **Food security**: tree products and environmental services; improved productivity	(Verchot et al. 2007) (Garrity et al. 2010)
Chemical fertilizers	A substance of synthetic origin that is applied to the soil to supply one or more key nutrients for plant growth and crop yield.	**Adaptation**: compensation for declining soil fertility and nitrogen deficiency; speedier crop development to account for shortened growing season **Mitigation:** trade-off between intensification and land-sparing may result in net emissions reduction in some contexts **Food security**: increased productivity; farmers emphasize crop failure when fertilizer use omitted	(Palm et al. 2010) Personal communications
Composting	Collection and heaping of organic waste materials such as food scraps, crop residues or livestock manure in a pit, pile or other structure to allow for decomposition and later application to cropland soil.	**Adaptation**: compensation for declining soil fertility **Mitigation**: emissions reduction from avoidance of raw animal manure application; improved soil carbon sequestration **Food security**: increased productivity; lower input requirements	(Edwards et al. 2010) (Niggli et al. 2009)
Contour and ridge planting	Construction of continuous lines of mounded dirt upon which crops are planted. Ridges are constructed along the contours of cropland to prevent run-off of rainwater. In Lawra, used instead of the traditional planting mounds.	**Adaptation**: increased water retention to compensate for drought & reduced rainfall; increased nutrient absorption **Food Security**: increased productivity on sloping marginal lands or compacted soils	Personal communications (Walton, 1962 as cited in Lal, 1995)

Crop rotation	Systematic movement of crop plots year after year to avoid the exhaustion of soil nutrients through continuous use by the same type of crop. Includes either unconscious use—the farmer switches crops when s/he notices yields declining on a particular plot—or conscious use—the farmer purposefully chooses to alternate crops that will replenish the nutrients depleted by the other, for example planting groundnuts after maize. Omits fallow rotations.	**Adaptation:** compensation for declining soil fertility; increased pest and disease resistance **Mitigation**: improved soil structure; soil carbon sequestration; erosion prevention **Food security**: productivity maintenance through avoidance of soil exhaustion	(Adiku et al. 2009) (Stringer et al. 2009)
Dry season gardening	Cultivation of vegetables and other food products in a dedicated plot during the non-productive season, either near the household or to a water source such as dam or river.	**Adaptation**: diversification of food sources in case of low productivity or crop loss **Food security**: provision of food/nutrition during usually unproductive, food scarce season	(Laube et al. 2012) (Barbier et al. 2009)
Erosion control	Use of one or more of a suite of practices that reduce runoff by slowing the flow of water over the soil's surface or improving infiltration speed, including ridge-building, bunding, and tree-planting.	**Mitigation**: improved soil structure; soil carbon sequestration **Food Security**: improved/sustained yields through prevention of soil degradation	(Smith et al. 2010) (Branca et al. 2011)
Improved forages	Deliberate sowing of easily digested or high-protein forages on rangelands, including select undomesticated grass and legume species and genetically improved varieties.	**Adaptation**: restoration of degraded lands **Mitigation**: nitrogen fixation with leguminous fodders; reduction of emissions from enteric fermentation of livestock through easier digestion **Food security**: healthier livestock; improved income from market price; meat for household consumption	(Peters et al. 2013)
Improved livestock breeding	Genetic improvement of a herd or flock through targeted cross-breeding for specific traits, including pest/disease resistance, heat tolerance and overall productivity.	**Adaptation**: resistance to climate related stresses, pests, and diseases **Mitigation**: herd reduction through improved quality of fewer number of stock **Food security**: increased milk/meat productivity for own consumption; better market price	(Gill et al. 2010) (FAO 2007)

Improved crop varieties	Use of genetically improved germplasm specifically bred for traits such as increased yield, stress tolerance and/or disease resistance.	**Adaptation**: stress tolerance and disease resistance; early maturing to avoid crop loss from shorter growing seasons or unreliable rains **Food security**: higher productivity; decreased risk of crop failure	(Below et al. 2010) (Branca et al. 2011)
Intercropping	Planting of two different, though complementary, crops on the same plot of land, either in a mixed, row, or strip intercropping system.	**Adaptation**: reduced risk of total crop failure **Food security**: diversification of production	(Laube et al. 2012) (Stringer et al. 2009)
Irrigation technologies	Systems to transport and supplying water to crops making use of labor saving or increased-efficiency technology, either on a large scale such as a canal/pump system, or as a smaller micro-irrigation scheme.	**Adaptation**: compensation for drought or reduced rainfall **Food security**: increased productivity; diversification of production by making off-season vegetable production possible	(Laube et al. 2012)
Manure management	Supplementation of soil fertility using manure from cattle, goats, pigs, sheep, poultry or other livestock that has been collected and often composted together with household refuse, to later be applied to the fields.	**Adaptation**: compensation for declining soil fertility **Mitigation**: emissions reduction from composted rather than raw manure; soil structure and soil carbon sequestration **Food security**: improved productivity; fewer input requirements	(Chadwick et al. 2011) (Fening and Safo 2010)
Minimal tillage	Tillage refers to all methods used to prepare soil for planting, especially the loosening and breaking up of top soil by the use of a hoe, plow or similar tilling implement. In the Ghanaian context, minimal tillage usually refers to land preparation through slashing of existing vegetation, allowing for some regrowth and then application of a glyphosphate-based herbicide, followed by hand seeding or seeding using a planting stick. Residues from vegetation removal are left on the soil surface as mulch.	**Mitigation**: emissions reduction compared to deep tillage and plowing; improved soil structure; erosion prevention **Food Security**: improved productivity in some cases through moisture retention and prevention of soil compaction and degradation	(Ekboir et al. 2002) (Lal and Bruce 1999)
Mulching	Covering the soil surface with a layer of organic residues (leaves, straw, stems, cut grasses) and allowing for eventual decomposition with the aim of stifling weed growth and evaporation of soil water content. In Lawra, usually refers to application on small scale in gardens or tree seedlings.	**Adaptation**: reduction in soil temperatures to compensate for higher air temps; improved moisture retention to compensate for drought and reduced rainfall **Mitigation**: reduced emissions from exposed soil surface **Food security**: improved productivity; reduced risk of crop loss	(Acharya et al. 1998)

Organic pest management	Application of organic (ash, manure sprays) substances to prevent or eliminate the occurrence of pests on crop leaves, roots and fruits both pre- and post-harvest. No mention made of Integrated Pest Management methods as these were largely unknown in the area.	**Mitigation**: reduced emissions associated with production/use of synthetic insecticides **Food Security**: prevention of crop loss by providing pest control method for farmers without means to purchase chemicals	(Scialabba and Müller-Lindenlauf 2010) (Ziesemer 2007)
Residue management	Non-burning of organic material left behind after harvest (usually cereal crops), and instead either leaving residues on soil surface to act as a mulch or collecting them for composting and later application to fields. Often a combination of both depending on speed of decomposition and residue volume.	**Adaptation**: improved water retention to compensate for drought or reduced rainfall; reduced soil temperature to compensate for higher air temps **Mitigation**: reduced emissions from burning residues **Food security**: productivity maintenance through avoidance of soil degradation	(Andreae and Merlet 2001) (Acharya et al. 1998)
Stone bunds	Piling or mounding stones either across contours to create terraces in sloped areas, or in a continuous line along contours to slow the flow of rainwater and allow the accumulation of plant debris and fine soil particles. Earthen bunds not included as these were often confused with ridges.	**Adaptation**: improved water absorption and retention for drought or low rainfall conditions **Mitigation**: reduced emissions from soil erosion; soil carbon sequestration **Food security**: productivity maintenance through avoidance of soil erosion and degradation	(Dutilly-diane et al. 2003)
Sunken beds	The digging-out of a bed area in preparation for gardening and construction of earthen walls along bed borders to create a low-lying area for planting that maximizes water retention.	**Adaptation**: maximized water retention during drought or low rainfall conditions **Food Security**: diversified food sources through off-season vegetable production	(Vohland and Barry 2009) Personal communications
Water harvesting and storage	The collection and storage of large quantities (more than the traditional 10-gallon iron pots) of rainwater using a rooftop harvesting system and plastic or concrete tanks or pools.	**Adaptation**: additional water source during drought or low rainfall conditions **Food security**: increased productivity or reduced crop/livestock loss when used as irrigation or watering hole	(Sturm et al. 2009)

CSA Practice Adoption

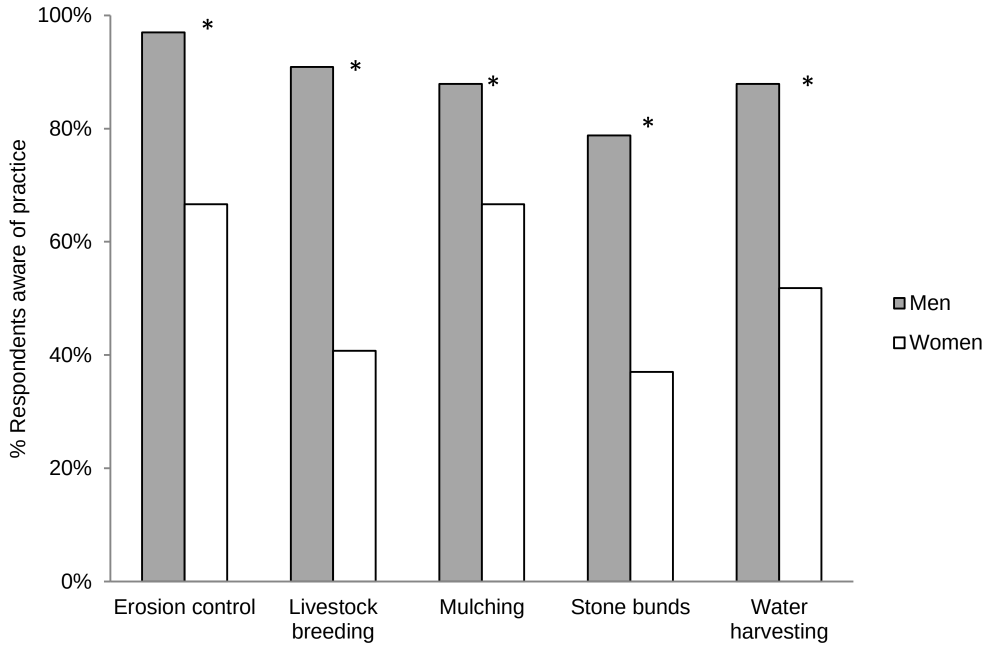
Results from the questionnaire survey in Dazuuri and Bompari villages (n=60, 45% women and 55% men) indicate that more than half of surveyed respondents were aware of selected CSA practices, with the exception of improved forages (30% aware) and minimal tillage (50% aware) (Table 2). Overall adoption rates were highest for crop rotation (92%), composting (88%), manure management (88%), planting on ridges (88%) and residue management (85%). Least adopted practices were improved livestock breeding (0%), improved forages (2%), and stone bunds (8%).

Table 2. Proportion of 60 surveyed households in Dazuuri and Bompari villages, Upper West, Ghana, aware of, currently using, or, if not currently using, willing to introduce CSA practice on their farms.

Practice	**Aware of practice (%HHs)**	**Using practice (%HHs)**	**Willing to introduce practice (%HHs)**
Crop rotation	93	92	100
Manure management	100	88	100
Planting on contours and ridges	98	88	83
Composting	97	88	80
Residue management	98	85	88
Intercropping	80	67	88
Chemical fertilizers	98	63	100
Erosion control	83	57	81
Organic pest management	80	57	100
Agroforestry/tree planting	98	55	81
Mulching	78	45	85
Minimal tillage	50	32	82
Dry season gardening	98	18	67
Irrigation	92	17	76
Improved crop varieties	87	15	98
Sunken beds	55	15	75
Water storage/harvesting	72	13	89
Stone bunds	60	8	58
Improved forages	30	2	71
Improved livestock breeding	68	0	88

n=**60**

Men and women respondents were equally aware of most CSA practices, although men were more aware than women of erosion control methods (z=3.13, p<0.01), improved livestock breeding (z=1.83, p<0.01), mulching (z=1.98, p=0.047), stone bunds (z=3.28, p<0.01) and water harvesting (z=3.08, p<0.01) (Figure 1).



*p<0.05

Figure 1. Gender differences in awareness of select CSA practices in Dazuuri and Bompari villages, Lawra, Ghana. Men (n)=33; Women (n)=27.

Although awareness of a particular CSA practice is a prerequisite to its adoption, high awareness of a practice did not necessarily lead to high adoption rates. For dry season gardening, improved irrigation technologies, improved crop varieties and improved livestock breeding less than half of respondents who said they were aware of the practice also reported that they were currently using it on their farms (Figure 2). In fact, for dry season gardening, only 20% of respondents who were aware of the practice reported that they were also using it on their farms. On the other hand, 90% or more of households that were aware of contour/ridge planting, composting and crop rotation techniques were also using those practices on their farms.

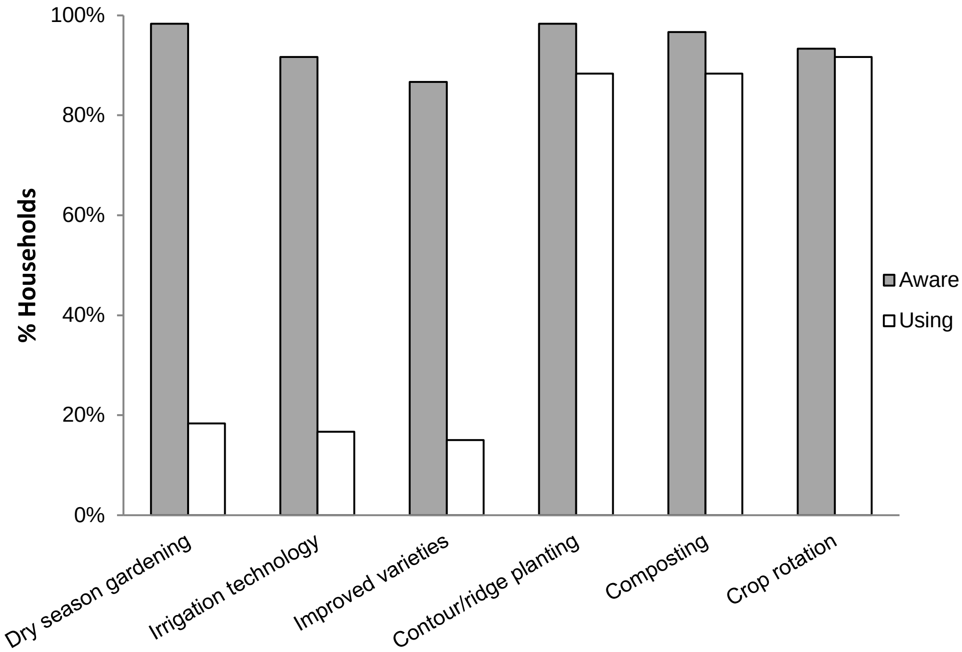


Figure 2. CSA practices with the largest and smallest discrepancies between proportion of 60 households aware of practice and proportion actually using practice on the farm in Dazuuri and Bompari villages, Lawra, Ghana.

Level of education had no relationship to overall rates of CSA adoption in a household (H=7.16, p=0.07), although the number of CSA practices in use was weakly correlated to the amount of land a household had available for agriculture (R=0.37).

The practices most often cited by respondents as the most important for getting a good harvest were: 1) manure management (53% of households), 2) chemical fertilizers (42%), 3) residue management (40%), and 4) composting (32%) (Table 3). Eighty percent of all responses were distributed across the first four "most important" practices. Of these practices, the use of chemical fertilizers was the only practice that was not also one of the most widely adopted.

Table 3. CSA practices most often mentioned as a top 3 practice, i.e. those that the respondent considered most important for good production among 60 households in Dazuuri and Bompari villages, Lawra, Ghana.

Practice	**Chosen as most important** (%HHs)	**Mentioned in focus group** (% mentions)	**CSA Category**
Manure management	53	13	Soil; Waste
Chemical fertilizers	42	16	Soil
Residue management	40	5	Soil; Water
Composting	32	4	Soil

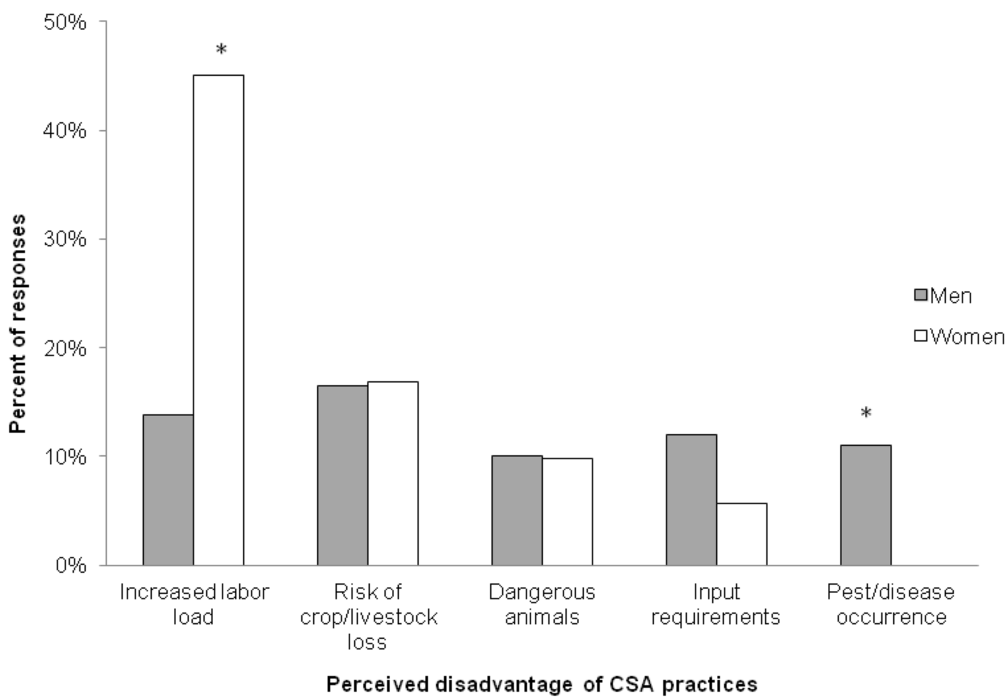
Planting on contours and ridges	32	7	Soil; Water
Crop rotation	25	4	Soil; Agronomy

n=60
Includes only those practices mentioned by more than 20% of households.
Each respondent could mention up to 3 practices.

Advantages and Disadvantages of CSA Practices

Improved crop productivity, soil fertility and household food security were the most commonly perceived advantages in relation to adoption of CSA practices. Commonly perceived disadvantages included increased labor load, increased risk of crop loss (due to incorrectly performing the practice, e.g. applying too much fertilizer) and increased presence of dangerous animals (e.g. risk of injury from scorpions after leaving crop residues on the field).

Women and men perceived the same principle advantages from CSA practices. However, women were more likely than men to see increased labor load as a disadvantage to a CSA practice (z=4.18, p<0.01) (Figure 3). Women were also less likely to see the benefits of a practice (z=2.11, p=0.03), and gave a lesser quantity (t=2.71, p=0.01) and lower diversity (t=3.09, p<0.01) of responses with regard to potential benefits.



*p<0.05

Figure 3. Gender differences in perceived disadvantages of CSA practices from households in Dazuuri and Bompari villages, Lawra, Ghana. Men (n)=33; Women (n)=27.

The most commonly abandoned practice (i.e., used in the past but not currently using) was the use of chemical fertilizers. Lack of financial capital, unavailability or inaccessibility of material inputs such as seeds, land, fertilizers and water, or lack of sufficient labor were given as the principle reasons that households tended to abandon a practice, reasons that were essentially the same for men as for women. In addition to inputs and financial capital, households also reported that they would need more information – especially about practices such as organic pest control and improved livestock breeding – before these could be introduced (Figure 4).

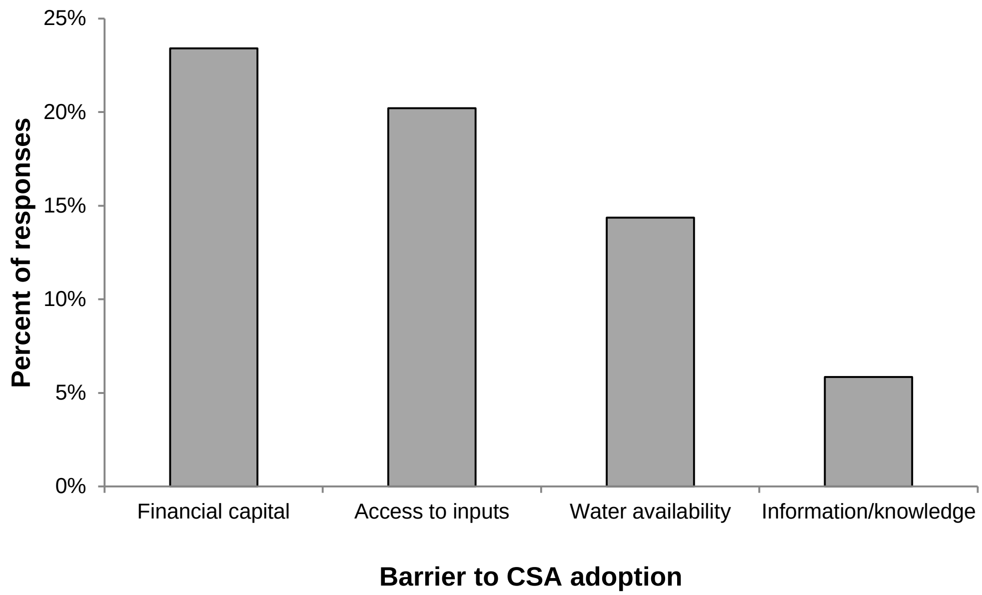


Figure 4: Most commonly mentioned barriers to be overcome to adopt CSA practices for 60 households in Bompari and Dazuuri villages, Lawra, Ghana. Participants could mention multiple barriers.

Households that were unwilling to adopt select CSA practices cite low input availability as well as lack of labor to implement practices as factors contributing to their disinterest. Dry season gardening and stone bunding were most frequently mentioned by households as practices they would be unwilling to adopt, either because of lack of water, distance from the farm to the river, or the inappropriateness of the landscape (not sloping enough, no stones available).

Knowledge and Institutional Support

According to survey responses from both genders, men are primarily responsible for the decision making related to CSA practices. Responsibility for carrying out the practice also lies with men in most cases except manure management and dry season gardening (sunken beds), which are the responsibility of women only, and composting, intercropping and irrigation, which are the responsibility of both men and women. While observational evidence would confirm the result that male household member are the primary agricultural decision makers, it would also indicate that labor concerning CSA practices is most often shared between both men and women, in contrast to questionnaire results.

The most commonly cited information sources related to CSA practices were the respondents' own experiences and traditional knowledge. Evidence from focus group discussions, on the other hand, suggests that the Ministry of Food and Agriculture (MoFA) extension agents and community meetings are instrumental in knowledge dissemination. Institutional diagrams produced in the focus group discussions (both men's and women's groups) all gave MoFA high importance, and it was the only institution mentioned by all four groups aside from the District Assembly's sanitation program (Sama Sama) (Figure 5). Many external organizations related to agriculture were in some way connected to MoFA, although not necessarily connected to each other. The emphasis on experiential knowledge given in questionnaire responses may be the result of respondent interpretation of "information source" as "how do you know whether a practice is good or bad?", even though institutional mapping pinpointed MOFA as a key disseminator of technical knowledge.

In both Bompari and Dazuuri villages, only the women's groups mentioned development organizations such as RAAP, CARE and CRS in their institutional diagram. Women's diagrams were generally richer in detail than men's diagrams, suggesting that group membership or networking may be stronger among women than men.

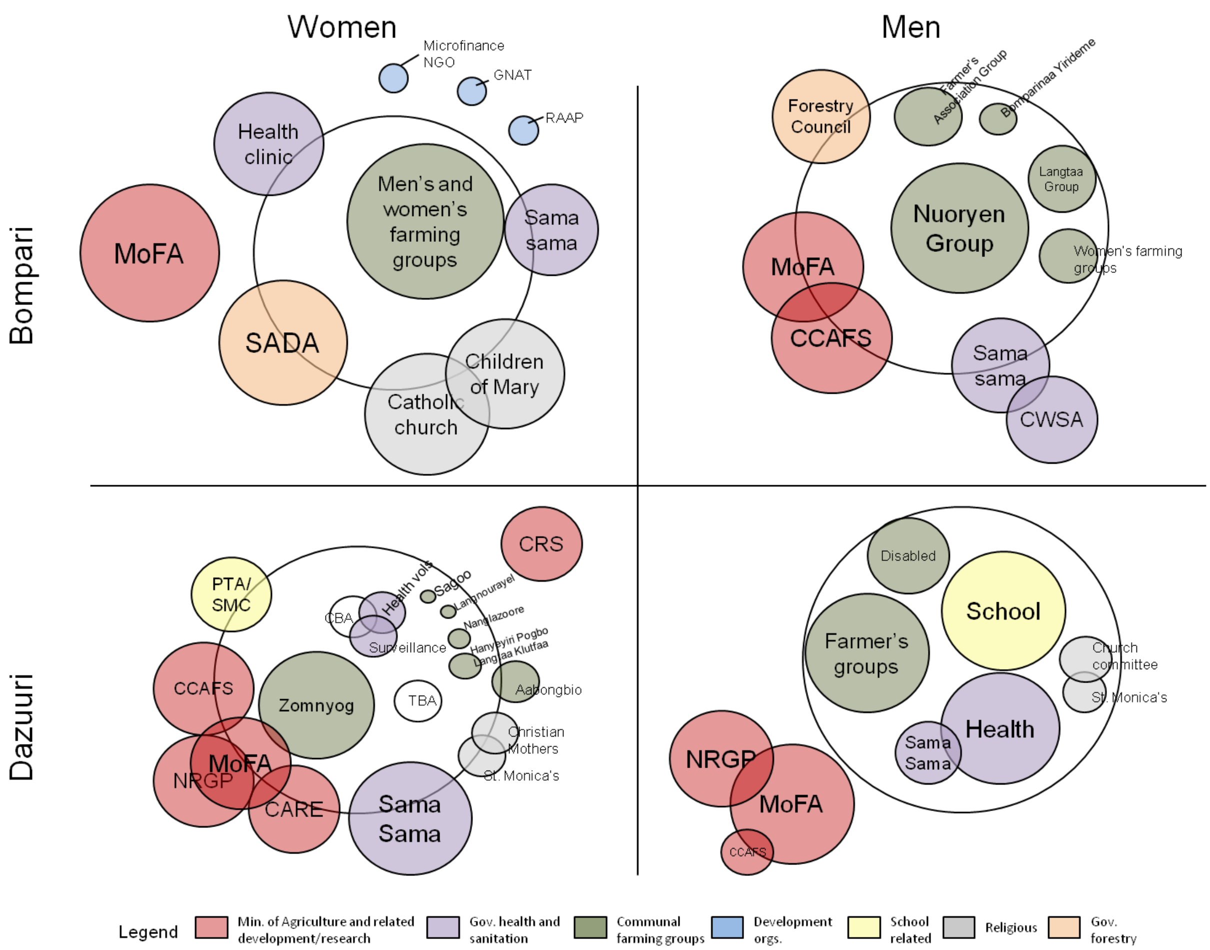


Figure 5. Institutional Venn diagrams created by men and women focus group participants in Dazuuri and Bompari villages, Lawra, Ghana. The large, unnamed central circle represents the village in question, and the colored circles represent the relationship of institutions to the village (internal, external, or both) and to each other.

DISCUSSION

We can assume based on the high overall awareness rates of selected CSA practices among questionnaire respondents that, with some exceptions, non-adoption was most often a result of factors other than lack of familiarity with the practices. We must especially note those practices where high levels of awareness were juxtaposed with low levels of adoption – small scale irrigation, dry season gardening, and improved crop varieties in particular – and investigate why that might be the case.

Consistent with previous findings in Sub-Saharan Africa, men and women farmers in Bompari and Dazuuri villages that were both aware of CSA practices and willing to adopt new ones indicated that the main barriers to CSA practices adoption were lack of sufficient financial capital, difficult access to or low availability of the necessary agricultural inputs (tools, seeds and fertilizers), and in some cases insufficient labor to carry out the practice. Water scarcity was also a major hurdle for practices such as micro-irrigation, dry season gardening and agroforestry (farmers reported that tree seedlings often died due to lack of water).

Although farmers were well aware of the benefits of improved, early-maturing varieties of groundnuts and were eager to implement them on their own farms, many did not know where to acquire the seeds, thought they might be too expensive to purchase, or thought that they would have to travel far to the south to find them. Although improved seed varieties can often be obtained for free from the local agricultural extension office, many farmers were simply unaware of this fact. Thus, even though MoFA is likely the institution in Lawra with the greatest ability to transmit technical agricultural knowledge, its reach may not be long enough to inform farmers that are not already very active in community events or extension activities.

Practices addressing soil and nutrient management such as manuring, composting, fertilization with synthetic compounds and non-burning of harvest residues were considered the most important among both men and women farmers, indicative of the severe constraint on agricultural productivity posed by nitrogen deficiencies in the area's soils (Henao and Baanante 1999; Waddington et al. 2010). Manuring, composting and non-burning also represent some of the practices that are the easiest/most commonly adopted (Below et al. 2012), likely because they do not require major investments or changes to the management system.

Composting, although it requires extra labor from both men and women, was readily taken up by area farmers after it was introduced by a MoFA program, demonstrating eagerness for an alternative to expensive chemical fertilizers. The application of manure to agricultural fields is in fact a traditional practice in this area, although the addition of composting to the process has likely improved nitrogen absorption from manure application and, incidentally, reduced emission factors (Fening and Safo 2010; Chadwick et al. 2011). Synthetic fertilizers, although highly prized for what farmers perceive as their ability to speed up crop development and improve yield, are difficult to acquire, expensive, and often simply not available due to shortcomings in government subsidy systems (Banful 2009). Furthermore, farmers in the area are often not fully aware of proper application, safety, and storage procedures to make effective use of fertilizers when they are able to acquire them.

Rainwater harvesting techniques that collect water from corrugated tin roofs could save households a considerable amount of time and work and ensure water supply for numerous household and small-scale agricultural tasks like kitchen gardens. It could also serve as one solution to the water scarcity that was mentioned above as being a principle barrier to the adoption of certain CSA practices, facilitating adaptation to increasingly variable rainfall patterns and enabling supplementary, small-scale irrigation. Nevertheless, it is currently practiced by a very low percentage of households compared to its desirability and potential usefulness (Below et al. 2012).

Special note should be made of gender when considering adoption barriers. Although women farmers perceived similar benefits and barriers to CSA practice adoption as men when they were aware of said practices, they were often less aware than men of certain practices, specifically erosion control methods, improved livestock breeding, mulching, stone bunding, and water harvesting. Women's unawareness of the latter practice is noteworthy, as it is normally women who must perform the arduous work of retrieving water from boreholes and carrying it to the house to store in large iron pots.

Gender roles in relation to agricultural activities are strictly defined in these communities. Women perform the majority of on-farm labor; in addition to retrieving water, they are also exclusively in charge of gathering manure and spreading it on crops after it has been composted, caring for household or dry season gardens and cultivating non-cereal food crops such as yams (Naab and Koranteng 2012). Consumption and selling responsibilities are also borne by women (Naab et al. 2011). That women farmers are more likely than men to perceive increased labor load as a disadvantage to implementing CSA practices implies that practices must be carefully evaluated for differential gender impact before they are promoted or implemented in the area.

Paths of information dissemination should be examined to further understand adoption tendencies for CSA practices, again with special reference to gender. Previous Participatory Rural Appraisal work in the Lawra and Jirapa districts confirms that women's knowledge base is often "second-hand," that is, men are the first to learn about and apply new practices in the field, and women learn about the practice through farming with their husbands (Naab and Koranteng 2012).

Although in this study both men and women indicated that their primary sources of information on new agricultural techniques are their own experience, traditional knowledge and communication with neighbors, evidence from focus group discussions and personal interviews suggests that men also learn about new practices or programs from MoFA extension officers, and sometimes from community meetings or MoFA-hosted farmer field schools, including CCAFS-led programs such as the Farms of the Future learning exchange that took place in early 2012. However, women are less likely to attend community meetings – either because of time constraints or because they are not invited in the first place – and husbands do not always share the proceedings with their wives.

The apparently conflicting results as to whether CSA information primarily comes from outside institutions or farmers' own experience may be explained by some questionnaire respondents interpreting "information source" as how they come to find out whether a practice is useful or not, rather than where or who originally introduced them to the idea. Information retention may also be affected by low literacy levels and low effectiveness of the oral transmission techniques commonly employed by MoFA technicians (Hanna et al. 2012). Although extension agents occasionally employ "farmer field school" methods of technical advising – where farmers can learn by doing, rather than hearing – these activities need to be emphasized further to improve information dissemination in Lawra.

Group membership Lawra and nearby districts tends to be low (Naab et al. 2011) and external institutional involvement in Bompari and Dazuuri villages seems limited to MoFA and related entities, with a few exceptions. Women, however, differed from men in their institutional diagram analysis by mentioning involvement with development and health related institutions as well as high levels of membership in internal, communal farming groups. These groups could be pathways for dissemination of CSA knowledge that reach and benefit women directly (Naab and Koranteng 2012).

CSA has been criticized for being too broad in the sense that virtually any practice that contributes to improved food security or more efficient resource use could be considered CSA, regardless of its implications for climate change mitigation (see Neufeldt et al., 2013). For the purposes of this study, practices considered CSA were restricted to those that enhance food security – normally in the form of improved productivity – while also including a considerable element of either adaptation or mitigation according to empirical evidence. That is, practices had to demonstrate a clear double-win for producers as well as the potential for additional benefits for either adaptation or mitigation. Exceptions to empirical justifications were noted when key informants at the site (or the farmers themselves) specified that a certain practice represented a strong adaptation or food security benefit to local farmers.

A technology or practice driven approach (rather than a systems level, political, or institutional approach, for example) was taken for this research with the reasoning that if desirable or easily adopted practices and surmountable barriers could be identified in each site, these could serve as points of departure for further CSA related development and research. The *ex ante* development of the practice list may have restricted the freedom of participants to suggest adaptive practices that had not been already taken into consideration, although this approach was meant to conserve relative consistency in the definition of practices to be considered CSA in accordance with the above concern.

This study was intended to serve as an entry point for further CCAFS work on CSA in the Lawra area. Farmers' preference for practices that address crop yields and soil fertility, and their concern for water scarcity, agricultural input accessibility, and financial and labor related insufficiencies, must be factored into future planning and adaptation exercises. The potential of CSA practices such as rainwater harvesting, improved forages, improved crop varieties, dry season gardening and micro-irrigation techniques to provide benefits to farmers should be noted, in conjunction with attempts to facilitate more extensive adoption of these techniques.

Next steps will include further participatory research at multiple governance levels to first prioritize CSA actions to be taken and later pilot initiatives with the involvement and evaluation of local stakeholders. Impact and vulnerability analyses and environmental modeling should also be a part of this process to further ensure the appropriateness of selected CSA practices for each site. The aim is for this sequence of diagnosis, prioritization and action to be repeated and improved upon in other CCAFS sites and regions for eventual widespread uptake and implementation of climate-smart farming techniques.

RECOMMENDATIONS

The benefits and barriers to CSA adoption outlined above point to several possible directions for future CSA related research and development in the Lawra District to identify and facilitate the uptake of locally appropriate practices:

1) Take steps to improve access to critical agricultural inputs.

Improved crop variety seeds, for example, are in high demand among farmers in Lawra, though many are unaware of how they can be acquired through local extension officers. The solution in this case could simply be improved education and promotion of seed programs in collaboration with MoFA and support of informal seed saving and exchange networks where possible.

In the case of synthetic fertilizers, another high-demand input, improved access is more complicated and depends on enabling policies at the national level for effective subsidy programs as well as improved infrastructure to ensure that supplies are available even for remote districts like Lawra. Fertilizer access should also be accompanied by appropriate education and extension to ensure its efficient and safe use, as over-application or untimely application tips the balance from a climate-smart practice to a climate-liable one.

2) Enable financial support mechanisms for practices with high start-up costs.

CSA practices involving water availability, though critical in this water-scarce region of Ghana, often involve large investments to be made in equipment and structures. Rainwater harvesting and storage is one practice that could provide multiple and far-reaching benefits and that, with sufficient start-up capital, would not be difficult to implement. Many houses in Lawra District are already equipped with corrugated tin roofs, for example, and even thatched roofs can serve the purpose if collected water is later sanitized; the main costs would lie in piping and storage materials. Micro-financing programs and Savings and Credit Cooperative Organizations have had success with rainwater harvesting projects in the past (UNEP, n.d.), and support of similar initiatives in this area could facilitate their adoption.

3) Promote agricultural education programs and farmer field schools with evidenced-based learning techniques for lesser-known or technically demanding practices.

The use of improved forages for improved grazing land and livestock nutrition was the least well known of all practices considered, although Lawra extension officers indicated that successful forage projects had been carried out in neighboring districts. Farmer field schools or on-farm trials would raise awareness of the practice and allow farmers to evaluate the utility of the practice firsthand. Farmer field schools in particular had been noted by community members to be an effective and impactful way of communicating agricultural knowledge to lead farmers. Nevertheless, dissemination of that knowledge among community members not involved in the school must be improved, as expecting information to "trickle down" to the rest of the village can possibly exacerbate existing disparities in knowledge access.

4) Funnel CSA initiatives through local government institutions and increase the capacity of these institutions to deliver information widely.

Local government institutions (Ministry of Forestry, Health and Agriculture in particular) tend to have ongoing contact with villages and are the most trusted by community members, whereas permanent or long-term non-governmental institutions and projects are almost nonexistent in this area. Almost all current agriculture related projects in Bompari and Dazuuri were connected with MoFA to some extent, and information that does not use MoFA's networks will be unlikely to reach the desired audience. However, Ministries often do not have the resources to send a sufficient number of agents to the field and are continually understaffed. Additional approaches taking advantage of women's involvement with development organizations and communal farming groups may also be called for.

5) Take gender factors into account when designing research and on-farm trials of CSA practices.

Women farmers must be given special consideration in future educational programs to ensure that they are both recipients and generators of primary knowledge. Women's unique perceptions of advantages and disadvantages must be taken into account when prioritizing practices for on-site trials, especially considering that they may end up bearing the majority of the labor load. Special emphasis should be placed on proactive inclusion of women in community meetings or outreach to women that are unable to attend, as well as investment of time and research resources in practices designed specifically to minimize women's labor load or targeted to agricultural activities that are principally the domain of women farmers.

ACKNOWLEDGEMENTS

This research was funded by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) Theme 1, "Long-Term Adaptation to Climate Change." The author whishes to acknowledge A. Jarvis and O. Bonilla-Findji for the opportunity to conduct the research and for funding, travel and intellectual support, M. F. Oviedo for administrative support, and A. Helfgott, J. Twyman and C. Corner-Dolloff for collaboration on development of the initial concept and survey materials. Members of the University of Oxford SIA research team provided in-country support and M. Bailey and J. Thorn in particular provided invaluable guidance, advice and companionship at the Lawra field site. J. Naab and N. Karbo of CSIR-SARI and CSIR-ARI generously aided with pre-visit logistics and project concept development. P. Shelio, D. Anwune Baafa and M. Dang-Ire provided much needed translation services and motorcycle driving lessons. Finally, the in-field guidance and collaboration generously offered by the staff of MOFA-Lawra District, in particular J. Vuuro and D. Tampouri, was highly appreciated and made this study possible.

The author especially thanks M. Bailey and C. Corner-Dolloff for their thoughtful comments and edits on the original manuscript.

REFERENCES

Acharya C. L, Kapur O. C, Dixit S. P. 1998. Moisture conservation for rainfed wheat production with alternative mulches and conservation tillage in the hills of north-west India. *Soil and Tillage Research* 46(3-4): 153–163. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0167198798000300.

Adiku SGK, Jones JW, Kumaga FK, Tonyigah A. 2009. Effects of crop rotation and fallow residue management on maize growth, yield and soil carbon in a savannah-forest transition zone of Ghana. *The Journal of Agricultural Science* 147(03): 313–322. Available at: http://www.journals.cambridge.org/abstract_S002185960900851X [Accessed: 13 November 2012].

Andreae MO, Merlet P. 2001. Emission of trace gases and aerosols from biomass burning. *Global Biogeochemical Cycles* 15(4): 955–966.

Archer ERM. 2003. Identifying Underserved End-User Groups in the Provision of Climate Information. *Bulletin of the American Meteorological Society* 84(11): 1525–1532. Available at: http://journals.ametsoc.org/doi/abs/10.1175/BAMS-84-11-1525 [Accessed: 12 February 2014].

Banful AB. 2009. *Operational Details of the 2008 Fertilizer Subsidy in Ghana — Preliminary Report*. Washington, D.C.: International Food Policy Research Institute (IFPRI).

Barbier B, Yacouba H, Karambiri H, Zoromé M, Somé B. 2009. Human vulnerability to climate variability in the Sahel: farmers' adaptation strategies in northern Burkina Faso. *Environmental management* 43(5): 790–803. Available at: http://www.ncbi.nlm.nih.gov/pubmed/19037691 [Accessed: 23 January 2014].

Below T, Artner A, Siebert R, Sieber S. 2010. *Micro-level Practices to Adapt to Climate Change for African Small-scale Farmers*. Washington, D.C.: International Food Policy Research Institute (IFPRI).

Below TB, Mutabazi KD, Kirschke D, Franke C, Sieber S, Siebert R, Tscherning K. 2012. Can farmers' adaptation to climate change be explained by socio-economic household-level variables? *Global Environmental Change* 22(1): 223–235. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0959378011001993 [Accessed: 25 January 2014].

Branca G, McCarthy N, Lipper L, Jolejole MC. 2011. *Climate-Smart Agriculture : A Synthesis of Empirical Evidence of Food Security and Mitigation Benefits from Improved Cropland Management*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Chadwick D, Sommer S, Thorman R, Fangueiro D, Cardenas L, Amon B, Misselbrook T. 2011. Manure management: Implications for greenhouse gas emissions. *Animal Feed Science and Technology* 166-167: 514–531. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0377840111001556 [Accessed: 31 May 2013].

Deressa T, Hassan RM, Alemu T, Yesuf M, Ringler C. 2008. *Analyzing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia*. Washington, D.C.: International Food Policy Research Institute (IFPRI).

Dutilly-diane C, Sadoulet E, de Janvry A. 2003. *Household Behavior Under Market Failures: How Natural Resource Management in Agriculture Promotes Livestock Production in the Sahel*. Berkeley, CA: CUDARE Working Papers.

Edwards S, Berhan T, Egziabher G, Araya H. 2010. *Successes and challenges in ecological agriculture: Exeriences from Tigray, Ethiopia*. Rome: FAO.

Ekboir J, Boa K, Dankyi AA. 2002. *Impact of No-Till Technologies in Ghana*. Mexico, D.F.: Internatinoal Maize and Wheat Improvement Center (CIMMYT).

FAO. 2010. *"Climate-Smart" Agriculture: Policies, practices and financing for food security, adaptation and mitigation*. Rome: Food and Agriculture Organization of the United Nations (FAO).

FAO. 2007. *The State of the World's Animal Genetic Resources for Food and Agriculture*. Rischkowsky B, Pilling D, eds. Rome: Food and Agriculture Organization of the United Nations (FAO).

Fening JO, Safo EY. 2010. Manure management, quality and mineralization for sustaining smallholder livelihoods in the Upper East region of Ghana. *Journal of Science and Technology* 30(2): 1–10.

Förch W, Sijmons K, Mutie I, Kiplimo J, Cramer L, Kristjanson P, Thornton P, Radeny M, Moussa A, Bhatta G. 2013. *Core Sites in the CCAFS Regions: East Africa , West Africa and South Asia Version 3*. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Garrity DP, Akinnifesi FK, Ajayi OC, Weldesemayat SG, Mowo JG, Kalinganire A, Larwanou M, Bayala J. 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. *Food Security* 2: 197–214. Available at: http://link.springer.com/10.1007/s12571-010-0070-7 [Accessed: 21 January 2014].

Gill M, Smith P, Wilkinson JM. 2010. Mitigating climate change: the role of domestic livestock. *Animal* 4(3): 323–333. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22443938 [Accessed: 30 January 2014].

Hanna R, Mullainathan S, Schwartzstein J. 2012. *Learning Through Noticing: Theory and Experimental Evidence in Farming*. Cambridge, MA: Harvard Kennedy School Faculty Research Working Paper Series.

Henao J, Baanante C. 1999. *Estimating Rates of Nutrient Depletion in Soils of Agricultural Lands of Africa*. Muscle Shoals, Alabama: International Fertilizer Development Center (IFDC).

Ibrahim M, Florkowski WJ, Kolavalli S. 2012. The Determinants of Farmer Adoption of Improved Peanut Varieties and Their Impact on Farm Income: Evidence from Northern Ghana. In: *Selected Paper prepared for presentation at the Agricultural and Applied Economics Association Annual Meeting, Seattle, WA, August 12-14, 2012*. Seattle, WA, p 1–16.

Koltko-Rivera ME. 2004. The Psychology of Worldviews. *Review of General Psychology* 8(1): 3–58. Available at: http://doi.apa.org/getdoi.cfm?doi=10.1037/1089-2680.8.1.3 [Accessed: 26 March 2014].

Kristjanson P, Neufeldt H, Gassner A, Mango J, Kyazze FB, Desta S, Sayula G, Thiede B, Förch W, Thornton PK, Coe R. 2012. Are food insecure smallholder households making changes in their farming practices? Evidence from East Africa. *Food Security* 4(3): 381–397. Available at: http://www.springerlink.com/index/10.1007/s12571-012-0194-z [Accessed: 4 February 2013].

Lal R, Bruce JP. 1999. The potential of world cropland soils to sequester C and mitigate the greenhouse effect. *Environmental Science & Policy* 2: 177–185.

Laube W, Schraven B, Awo M. 2012. Smallholder adaptation to climate change: Dynamics and limits in Northern Ghana. *Climatic Change* 111(3-4): 753–774. Available at: http://link.springer.com/10.1007/s10584-011-0199-1 [Accessed: 7 February 2014].

Lobell DB, Burke MB, Tebaldi C, Mastrandrea MD, Falcon WP, Naylor RL. 2008. Prioritizing climate change adaptation needs for food security in 2030. *Science (New York, N.Y.)* 319(5863): 607–10. Available at: http://www.ncbi.nlm.nih.gov/pubmed/18239122 [Accessed: 21 January 2014].

Naab JB, Koranteng H. 2012. *Using a gender lens to explore farmers' adaptation options in the face of climate change: Results of a pilot study in Ghana*. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture andFfood Security (CCAFS).

Naab JB, Sissoko K, Zougmoré R, Traoré B, Amadou M, Moussa AS, Forch W, Garlick C, Ochieng S, Kristjanson P, Thornton PK. 2011. *Summary of Baseline Household Survey results : Lawra-Jirapa, Ghana*. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Neufeldt H, Jahn M, Campbell BM, Beddington JR, DeClerck F, De Pinto A, Gulledge J, Hellin J, Herrero M, Jarvis A, LeZaks D, Meinke H, Rosenstock T, Scholes M, Scholes R, Vermeulen S, Wollenberg E, Zougmoré R. 2013. Beyond climate-smart agriculture: toward safe operating spaces for global food systems. *Agriculture & Food Security* 2(1): 12. Available at: http://www.agricultureandfoodsecurity.com/content/2/1/12 [Accessed: 21 January 2014].

Niggli U, Fließbach A, Hepperly P, Scialabba N. 2009. *Low greenhouse gas agriculture: Mitigation and adaptation potential of sustainable farming systems*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Nii S, Codjoe A, Atidoh LK, Codjoe SNA, Burkett V. 2011. Gender and occupational perspectives on adaptation to climate extremes in the Afram Plains of Ghana. *Climatic Change* 110(1-2): 431–454. Available at: http://www.springerlink.com/index/10.1007/s10584-011-0237-z [Accessed: 25 October 2012].

Palm CA, Smukler SM, Sullivan CC, Mutuo PK, Nyadzi GI, Walsh MG. 2010. Identifying potential synergies and trade-offs for meeting food security and climate change objectives in sub-Saharan Africa. *Proceedings of the National Academy of Sciences of the United States of America* 107(46): 19661–6. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2993394&tool=pmcentrez&rendertype=abstract [Accessed: 30 May 2013].

Peters M, Rao I, Fisher M, Subbarao G, Martens S, Herrero M, Hoek R Van Der, Schultze-kraft R, Miles J, Castro A, Graefe S, Tiemann T, Ayarza M, Hyman G. 2013. Tropical Forage-based Systems to Mitigate Greenhouse Gas Emissions. In: Hershey CH, Neate P, eds. *Eco-Efficiency: From Vision to Reality (Issues in Tropical Agriculture Series)*. Cali, Colombia, Colombia: Centro Internacional de Agricultura Tropical (CIAT), p 252.

Progressio. 2009. *Seed saving and climate change in Zimbabwe*. London: Progressio.

Rosenstock T, Bruno J, Gosset L. Unpublished work. *Best Bets for Climate-Smart Agriculture: The Scientific Basis*. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Schmidhuber J, Tubiello FN. 2007. Global food security under climate change. *Proceedings of the National Academy of Sciences of the United States of America* 104(50): 19703–8. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2148361&tool=pmcentrez&rendertype=abstract.

Scialabba NE-H, Müller-Lindenlauf M. 2010. Organic agriculture and climate change. *Renewable Agriculture and Food Systems* 25(02): 158–169. Available at: http://www.journals.cambridge.org/abstract_S1742170510000116 [Accessed: 14 February 2014].

Shikuku KM, Laderach P, Twyman J, Eitzinger A, Winowiecki L. Smallholder farmers' attitudes and determinants of adaptation to climate change: Evidence from East Africa. *Unpublished work*: 1–44.

Smith P, Olesen JE, Change C, Paper A. 2010. Synergies between the mitigation of, and adaptation to, climate change in agriculture. *The Journal of Agricultural Science* 148(05): 543–552. Available at: http://www.journals.cambridge.org/abstract_S0021859610000341 [Accessed: 31 May 2013].

Smithers J, Smit B. 1989. *Conservation practices in southwestern Ontario agriculture: Barriers to adoption*. Ontario: University of Guelph.

Stringer LC, Dyer JC, Reed MS, Dougill AJ, Twyman C, Mkwambisi D. 2009. Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. *Environmental Science & Policy* 12(7): 748–765. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1462901109000604 [Accessed: 30 January 2014].

Sturm M, Zimmermann M, Schütz K, Urban W, Hartung H. 2009. Rainwater harvesting as an alternative water resource in rural sites in central northern Namibia. *Physics and Chemistry of the Earth* 34: 776–785. Available at: http://linkinghub.elsevier.com/retrieve/pii/S147470650900062X [Accessed: 3 February 2014].

UNEP. Selected Case Studies. p 1–25. Available at: http://www.unep.org/pdf/RWH/casestudies.pdf.

Verchot L V., Noordwijk M, Kandji S, Tomich T, Ong C, Albrecht A, Mackensen J, Bantilan C, Anupama K V., Palm C. 2007. Climate change: linking adaptation and mitigation through agroforestry. *Mitigation and Adaptation Strategies for Global Change* 12: 901–918. Available at: http://link.springer.com/10.1007/s11027-007-9105-6 [Accessed: 23 January 2014].

Vohland K, Barry B. 2009. A review of in situ rainwater harvesting (RWH) practices modifying landscape functions in African drylands. *Agriculture, Ecosystems & Environment* 131: 119–127. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0167880909000243 [Accessed: 25 January 2014].

Waddington SR, Li X, Dixon J, Hyman G, Vicente MC. 2010. Getting the focus right: production constraints for six major food crops in Asian and African farming systems. *Food Security* 2(1): 27–48. Available at: http://link.springer.com/10.1007/s12571-010-0053-8 [Accessed: 19 February 2014].

Ziesemer J. 2007. *Energy use in organic food systems*. Rome: Food and Agriculture Organization of the United Nations (FAO).

APPENDIX 1: Barriers to Climate Smart Agriculture Adoption Questionnaire

Date (dd/mm/yyyy) __ __/__ __/__ __ __ __   Time __ __:__ __

Interviewer name _______________   Signature _____________________

Supervisor name ________________   Signature _____________________

Introduction and consent

Before the beginning of the interview read out the following paragraph and ensure that the respondent understands before asking for consent.

"Good morning/afternoon. We are coming to ask you some questions with permission from the chief. We are conducting a survey and interviews to understand what different agricultural practices you use and why, and how new agricultural practices are introduced. We would like to ask you some questions that should take no more than an hour to an hour and a half of your time. We would like to share some of this information widely in order that more people understand how food is grown and land managed in this region and the issues that you face regarding access to and use of agricultural information and practices. Your name will not appear in any data that is made publicly available. The information you provide will be used purely for research purposes; your answers will not affect any benefits or subsidies you may receive now or in the future. You may withdraw from the study at any time and if there are questions that you would prefer not to answer then we respect your right not to answer them. Do you consent to be part of this study?

Has consent been given? *(1=Yes, 0=No)* [__]

Section 1: Household data

1.1 Respondent ID [__]
Respondent name ____________________________________

1.2 Respondent sex *(1=Male, 2=Female)* [__]

1.3 Relationship of respondent to household head [__]
0=Head *3=Child*
1=Spouse *4=Grandchild*
2=Parent *5=Other (Specify)* ______________

1.4 Are you Dagao? [__]
1=Yes
0=No (Specify ethnicity _____________)

1.5 Household type [__]

1=Male headed with single wife
2=Male headed with multiple wives
3=Male headed, divorced, single or widowed
4=Female headed, divorced, single or widowed
5=Female headed, husband away for more than 3 months
6=Other (Specify) ____________

1.6a How many people, including yourself, are in your household? A household is defined as a group that shares the same food, i.e. eats from the same pot. [__ __]

1.6b How many people in your household are under the age of 5 years? [__ __]

1.6c How many people in your household are over the age of 60 years? [__ __]

1.7 What is the highest level of education completed by any adult household member? [__]

0=No formal education
1=Primary
2=Secondary
3=Post-secondary

1.8 How much land does your household have access to for cropping or grazing?

	Quantity (acres)
Owned	[_ _ _._ _]
Rented	[_ _ _._ _]
Sharecropped	[_ _ _._ _]
Borrowed	[_ _ _._ _]

Do you use communal land? *1=Yes, 0=No* [__]

1.9 Who is responsible for making decisions about the land? [__]

1=Only man/husband
2=Only woman/wife
3=Man responsible for some parts and woman responsible for others
4=Man and woman jointly responsible
5=Other

1.10 Are you part of a communal farming system in which neighbors regularly labor on each other's farms without financial compensation? *(1=Yes, 0=No)* [__]

1.11 What are your main crops and livestock?

Crops	*6=Millet*	*12=Yam*	*2=Chickens*
1=Cotton	*7=Rice*	*13=Bean*	*3=Goats*
2=Cowpea	*8=Shea nuts*	*14=Other (specify)*	*4=Pigs*
3=Groundnut	*9=Sorghum*		*5=Sheep*
4=Guinea Corn	*10=Soya*	**Livestock**	*6=Other (specify)*
5=Maize	*11=Tobacco*	*1=Cattle*	

crops[__ __]
[__ __][__ __]

livestock[__][__][__]

Section 2: Climate smart practices

Fill entire column before continuing to the next column.

2.0	2.1	2.2a	2.2b	2.3	2.4
Practice	Are you aware of [practice]?	Are you using [practice] currently on your farm or have you used it in the past 12 months?	Which practices are the most important? ***Mark (*) up to three practices from those marked YES in 2.2a***	Did you previously use [practice] on your farm even though you are not using it now?	Would you start using or reintroduce [practice] if you could?
	1=Yes>>2.2a 0=No>>Next practice	***1=Yes>>Next practice 0=No>>Next practice, then 2.3, 2.4***		**1=Yes>>2.12 0=No>2.4**	**1=Yes>>2.13 0=No>>2.14**
Agroforestry or tree planting					
Chemical fertilizers					
Composting					
Crop rotation					
Dry season gardening					
Erosion control					
Improved forages					
Improved livestock breeding					
Improved or stress tolerant crop varieties					
Integrated pest management					
Intercropping					
Irrigation					
Manure management					
Minimal tillage					
Mulching					
Planting on contours and ridges					
Residue management					
Stone bunds					
Sunken beds					
Water storage or harvesting					

2.5 **(Fill for practices marked YES in 2.1)** What do you perceive as the benefits, if any, of using [practice/s]?

Practices	Benefits

2.5	14 - Tree products (fuel, timber, fruit, etc)
1 - Improved crop productivity	15 - Environmental services (shade, rain, micro-climate, biodiversity)
2 - Improved soil fertility and/or structure	16 - Prevents diseases/pests (both animal and livestock)
3 - Reduced risk of drought-related losses (crop or livestock)	17 -Improved livestock productivity
4 - Reduced risk of flooding-related losses (crop or livestock)	18 - Improved animal nutrition
5 - Improved household food security	19 - No benefit observed
6 - Increased household (or individual) income	20 – Reduced input costs
7- Reduced household labor requirements	21 – Easier or more reliable access to inputs
8 -Reduced soil erosion	22 – Insurance in case of crop failure
9 - Improved water retention	23 – Diversification of production
10 - Diversified income sources	24 – Reduced risk of crop/livestock loss
11 - Improved access to water/easier access to water	25 – Improved human nutrition/wellbeing
12 - More access to material for mulching	26 – Greater quality of produce
13 - Improved availability of livestock feed in dry periods	Other, specify

2.6 **(Fill for practices marked YES in 2.1)** What do you perceive as the disadvantages, if any, of using [practice]?

Practices	Disadvantages

2.6	9 – Increased risk of crop/livestock loss
1- Lower harvest/productivity	10 – No disadvantage observed
2 - Hard to find or obtain materials/competition for materials	11 – Decreased soil fertility
3 - Increased labor load	12 – Increased weed growth
4 - Increased input requirements (water, fertilizer, cost)	13 – Reduction in available cropping area
5 - Increases pests and diseases/not as disease resistant	14 – Harbors dangerous animals
6 - Quality of produce is poor	15 – Increased risk of financial loss
7 - High start-up costs	Other, specify
8 - No market for produce/crops	

Fill questions 2.7 through 2.11 for all the practices marked in 2.2b

	2.7	**2.8**	**2.9**	**2.10**
Practice (write in from 2.2b)	Why did you decide to start using [practice]?	What is your main source of information for [practice]?	Who made the decision to start using [practice]?	Who is primarily responsible for performing [practice]?

2.7	**2.8**	**2.9, 2.10**
1 - Improved crop productivity 2 - Improved soil fertility and/or structure 3 - Reduced risk of drought-related losses 4 - Reduced risk of flooding-related losses 5 - Improved household food security 6 - Increased income 7- Reduced household labor requirements 8 -Reduced soil erosion 9 - Improved water retention 10 - Diversified income sources 11 – Improved/easier access to water 12 - More access to material for mulching 13 - Improved availability of livestock feed in dry periods 14 - Tree products (fuel, timber, fruit, etc) 15 - Environmental services 16 - Prevents diseases/pests 17 -Improved livestock productivity 18 - Improved animal nutrition 19 – No benefit observed 20 – Reduced input costs 21 – Easier or more reliable access to inputs 22 – Insurance in event of crop failure 23 – Diversification of production 24 – Reduced risk of crop/livestock loss 25 – Improved human nutrition/wellbeing 26 – Improved quality of produce Other, specify	1 - Government extension workers 2 - NGOs 3 - Community meetings 4 - Farmer organizations 5 - Research stations/Researchers 6 - Religious groups 7 - Agri-service providers, seed companies 8 - Family members 9 - Neighbors 10 - Radio 11 -TV 12 - Newspaper/Bulletin 13 - Schools/Teachers 14 - Cell phone/Internet 15 - Traditional knowledge 16- Agricultural Shows 17- Farmer Field Days 18 - Own experience Other, specify	1 – Man 2 – Woman 3 – Both man and woman 4 – Male child 5 – Female child 6 – various members of hh

2.12 **(Fill for practices marked YES in 2.3)** Why did you stop using [practice/s]?

2.13 **(Fill for practices marked YES in 2.4)** What would have to happen or change before you could introduce/re-introduce [practice/s] if you desired?

2.14 **(Fill for practices marked NO in 2.4)** Why are you not using or not interested in using [practice/s]?

APPENDIX 2: Sample semi-structured interview checklist

- How long have you been farming on this particular piece of land?
- How did the farm look *x* years ago compared to how it looks now?
- How did your village look *x* years ago compared to how it looks now?
- What do you think are the reasons for some of these changes?
- What was the climate like *x* years ago compared to what it is like now?
- Do you use any practices or techniques that you did not use when you first started farming?
- How did you first learn about these techniques?
- What has been your most important resource for learning about good agricultural practices?
- Which of the new practices you have introduced has been the most important for your farm's productivity?
- Have a lot of people in your village adopted these practices, or are they uncommon?
- If they are not widely adopted practices, why do you think that is the case?
- Which part of your farm are you most proud of and why?
- What part of farming nowadays do you find most difficult? Is farming now easier or harder than it was *x* years ago?

APPENDIX 3: Sample guiding questions for focus group discussions

- How many of you have heard of some of these practices?
- Which have you heard of?
- Which are already done in this community?
- Let's start with [practice]. What are some of the benefits and/or disadvantages of using this practice?
- What type of producer usually uses it?
- Is this something you could see using on your farm? Why or why not?
- What are some potential problems you see that might prevent you from adopting it?
- Do you think that adopting this practice would change farm/household dynamics? For example, division of labor, time spent in the field, decision making, kind or quantity of inputs?
- What would need to change for you to be able to adopt [practice], or could you adopt it without anything changing?