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Understanding Agricultural Households' Adaptation to Climate Change and Implications for Mitigation: Land Management and Investment Options

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1. Introduction

1.1. Climate Change Adaptation/Mitigation and Agricultural Households

Climate change and food security are two of the most pressing challenges facing the global community today. Improving smallholder agricultural systems is a key response to both. Strengthening agricultural production systems is a fundamental means of improving incomes and food security for the largest group of food insecure in the world (World Bank, 2007; Ravallion & Chen, 2007). Given that agriculture is the key economic sector of most low income developing countries, improving the resilience of agricultural systems is essential for climate change adaptation (Conant, 2009; World Bank, 2009; Parry et al., 2007; Adger et al., 2003). Improvements in agricultural production systems also offer the potential to provide a significant source of climate change mitigation by increasing carbon stocks in terrestrial systems, as well as by reducing emissions through increased efficiency (FAO, 2009; Paustian et al., 2009; Smith et al., 2008; Lal et al., 2007).

As of 2009, nearly 1 billion people live in chronic hunger (Bruinsma, 2009). Most of these are directly or indirectly dependent on agriculture. Growth in population is expected to result in even greater pressure on the smallholder agricultural sector, with the largest increases expected in areas of high food insecurity and dependence on agriculture, particularly in South Asia and Sub-Saharan Africa (Schmidhuber & Tubiello, 2007). At the same time, nearly all researchers conclude that although average global crop production may not change dramatically by 2050, certain regions may still see average production drop, and many more are likely to face increased climate variability and extreme weather shocks, even in the near term (c.f. IPCC 2001 & 2007; Rosenzweig and Tubiello 2006). With respect to those areas that currently suffer from a high degree of food insecurity, Lobell et al. (2008) studied the potential crop impacts in 12 food insecure regions of the world and found that climate change could significantly impact agricultural production and food security by 2030, particularly for Sub-Saharan Africa and South Asia, due to changes in mean temperatures and rainfall as well as increased variability associated with both. Changes in pest and disease patterns could also significantly impact agricultural production (Lobell 2008). In particular, parts of South Asia and Sub-Saharan Africa are expected to be hardest hit, with decreases in agricultural productivity between 15-35 percent (Stern Review 2006; Cline 2007; Fischer et al. 2002; IPCC 2007). These are precisely the same regions that already exhibit high vulnerability to weather shocks, meaning that increasing the adaptive capacity of agricultural systems of these regions is necessary, not only to meet the Millennium Development Goals in the near term, but also to ensure that such gains are not lost when negative climate change impacts increase in the future.

1.2. Climate Change Mitigation and Adaptation Policy Issues for the Agricultural Sector

Over the last two years, there has been a considerable increase in attention given to the role that the agriculture sector in developing countries must play in order to meet food security needs and achieve the Millennium Development Goals, culminating in commitments of $20 billion over three years for agriculture sector development. At the same time, the Copenhagen Accord resulted in commitments for fast track funding approaching $30 billion for the period 2010 – 2012 and the goal of mobilizing an additional $100 billion annually by 2020 to help developing countries respond to climate change, including both adaptation and mitigation. These actual and potential increases in financial resources create a critical opportunity to move agricultural systems in developing countries to more productive and sustainable levels, while simultaneously addressing climate change.

However, there are considerable challenges in achieving an effective use of these funds. Key gaps in knowledge (primarily driven by the absence of appropriate data) on i) the tradeoffs and synergies between food security, adaptation and mitigation that are generated by various transformation pathways for smallholder agriculture and ii) the potential impacts of policies on achieving these three objectives need to be addressed. In addition, the knowledge needed to identify key policy and institutional arrangements that support such smallholder transformations is very limited, as are practical assessments of the potential for linking mitigation finance to smallholder agriculture.

Presently, many developing country governments are still in the process of drafting climate change strategy policy documents, building national and sub-national institutional structures for implementing climate change policies, harmonizing climate change issues across sectors, and integrating climate change considerations into other key policy documents such as national development strategies. One avenue to increase financing to climate change activities in the agriculture sector is to draw up "Nationally Appropriate Mitigation Action" plans (NAMAs) and "National Adaptation Programmes of Action" (NAPAs) or "National Adaptation Plans" (NAPs), which include actions to be undertaken in the agricultural sector.

Broadly speaking, however, many of the policies that countries currently need to put in place for a resilient and productive agricultural sector are similar to policies that will be needed to adapt to climate change – and to access climate change mitigation financing where appropriate. As others have noted, many countries, particularly in Sub-Saharan Africa, already face an "adaptation deficit" in the sense that the agricultural sector is already highly vulnerable to weather and other shocks. Lack of access to credit and insurance, poor public infrastructure, degraded forests and agricultural lands, limited access to information on different varieties and cultivation practices that reduce exposure to climate shocks, and limited irrigation are all reasons why farmers are currently vulnerable to weather events. Broader scale issues, such as the management of national and transboundary watersheds, trade-related impacts, and property rights and contract enforcement may also affect the ability of a country to address current and future vulnerabilities to climate change.[1] The need for adaptation to climate change creates an even greater impetus to address these vulnerabilities, and puts relatively more emphasis on managing risk and

[1] For a very thorough treatment of the policy issues related to natural resource management investments in the agricultural sector, c.f. the World Bank's sourcebook on agricultural investments (World Bank, 2006).

uncertainty than a world not facing the likelihood of significant changes in temperature and precipitation patterns.

1.3. Living Standards Measurement Study

The Living Standards Measurement Study (LSMS) surveys, which have collected information on many dimensions of household well-being for over 36 countries since 1980, are one of the most important data sources for informing policy making on development. LSMS surveys are designed and implemented by the LSMS team in the Development Research Group (DECRG) of the World Bank, in collaboration with national statistics offices, and have been used to assess household welfare, to understand household behavior, and to evaluate the welfare impact of various government policies.[2] These surveys are generally multi-topic and nationally representative, providing a cross-sectional snapshot of a country.

The multi-topic nature of LSMS surveys enables researchers to understand income diversification and the allocation of productive resources to both farm and non-farm activities, which is particularly relevant to modeling climate change mitigation and adaptation. For example, the incentives to adapt to climate variability in the short term and changing conditions in the longer term will be affected by household capacity to make changes both on- and off-farm. In addition, LSMS surveys typically solicit rich information on household welfare, including but not limited to comprehensive data that allows for the computation of a consumption-based welfare measure, permitting the investigation of overall impacts of external shocks and trend changes (Grosh & Glewwe (eds), 2000). For instance, under certain conditions, household welfare may be higher if the household reallocates resources off-farm, even though yields and/or total agricultural production may decline. Surveys focused solely on agriculture cannot uncover such relationships.

Aside from being multi-topic, LSMS surveys are a public good – the surveys are knowledgeably implemented, well-documented, and the vast majority are freely accessible online via either the LSMS website or the respective national statistics office. Although panel surveys are typically better than their cross-sectional counterparts for impact evaluation purposes, cross-sectional LSMS surveys can be used to study a considerable number of public and private sector initiatives with respect to climate change, and are well-positioned to capture heterogeneous impacts in view of their nationally-representative sample designs.

1.4. Understanding Agricultural Household Choices

Taking into account the various benefits of panel household survey data, and the pressing need in much of the developing world for high-quality smallholder agricultural data solicited within a multi-topic framework, the LSMS team established the Living Standards Measurement Study – Integrated Surveys on

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[2] LSMS survey questionnaires and data are available online at: http://iresearch.worldbank.org/lsms/lsmssurveyFinder.htm.

Agriculture (LSMS-ISA) project in 2009 with a grant from the Bill and Melinda Gates Foundation. The primary purpose of the LSMS-ISA initiative is to improve the quality, relevance and sustainability of smallholder agricultural data in Sub-Saharan Africa. The project is currently supporting seven countries in the region, namely Ethiopia, Malawi, Mali, Niger, Nigeria, Tanzania, and Uganda, to establish systems of multi-topic, panel household surveys with a strong focus on agriculture. The surveys collect essential information to improve our understanding of economic development in Africa, particularly with regards to agriculture and linkages between farm and non-farm activities. While each survey is specifically adapted to suit the local context in every country, essential indicators are rendered comparable across the LSMS-ISA partner countries.[3]

The surveys conducted under the LSMS-ISA project are particularly well-suited to capturing the dynamics underlying household choices to adopt farming practices and undertake investments in land quality in the face of climate change. The integration of household, community and agriculture questionnaires under a single LSMS-ISA survey effort creates an ideal opportunity for the creation of knowledge on climate change as it relates to household-level adaptation choices and mitigation strategies. Additionally, as detailed in Hsiao (2006), the advantages of the panel component of LSMS-ISA surveys include greater ability to uncover dynamic relationships, greater ability to understand the role of heterogeneity in explaining adoption and investment behaviors over time, and greater ability to control for omitted variables, particularly with regards to program selection bias. Byerlee & Murgai (2001) also stress the need for panel datasets in order to determine trends in total factor productivity in agricultural systems, including measures of agro-ecosystem health, because of potential biases of relying on cross-sectional measures where agricultural production exhibits high spatial and temporal variability, as is often the case. All of these advantages of multi-topic panel datasets are particularly useful for understanding household choices in the face of climate change, as detailed below.

First, in terms of understanding dynamic processes, we note that many household-level *investments* that reduce exposure to climate variability entail relatively large outlays up-front. However, full benefits to these investments may not accrue for some years, e.g. improvements in soil quality and water management due to investments in stone bunds, terraces or agro-forestry. In terms of farming *practices*, many of these need to be undertaken continuously, or for a sufficiently long period, in order for the farmer to realize full benefits in terms of improved adaptive capacity. For instance, switching away from burning crop residues, engaging in "conservation agriculture" tillage practices, and employing rotational grazing in pastures all must be practiced continually for a number of years for improvements in soil quality and enhanced adaptive capacity. Continuity in such practices is also important in terms of carbon sequestration; for instance, carbon can be lost if no-tillage plots are subsequently put under the plough. Even though such practices are generally modeled as "short-term" production decisions for the farmer, such decisions also have long-term consequences in terms of adaptive capacity and carbon sequestration. Using cross-sectional data, it is often difficult to tease out the dynamics of investments,

[3] Learn more about the LSMS-ISA project at: http://www.worldbank.org/lsms-isa.

and more difficult still to document factors affecting adoption in the current period only. Panel data can provide information not only on the timing of such decisions, but also on the "persistence" of adoption over time.

Second, cross-sectional surveys often provide limited data from which to uncover distributional impacts over the range of households, particularly where these households are heterogeneous along key dimensions, such as in their holdings of natural, human, and physical capital, or in their ability to access markets, infrastructure and services. The inability to sufficiently account for heterogeneity in returns to various agricultural technologies has masked the real reasons why failure to adopt such technologies has been so widespread, even where "average" net returns are quite high (c.f. Suri, 2009; Zeitlin et al., 2010; Duflo et al., 2008). These authors subsequently relied on panel datasets to evaluate more fully the factors affecting net returns and persistent adoption over time, although the scope of the surveys was limited to certain types of farmers in specific regions of a country.

Third, there are a number of planned public-sector investments and private sector initiatives targeted towards improving adaptive capacity or increasing land-based environmental services, including carbon sequestration. While a quasi-experimental design would be best for impact evaluation, in most cases and in most countries, such designs are unlikely to be implemented. Panel data, where initial surveys can provide a baseline, are more likely to generate useful impact evaluation data, particularly where such programs are rolled out over time (assuming one can control for geographic availability).

At the same time, it is important to note that panel datasets are not without their own issues. For instance, even panel datasets will be insufficient to capture the timing and persistence of climate change mitigation investments and practices if the length of time covered by the panel survey is inadequately short. This may well be the case for modeling household adaptation behavior, as it is possible that the necessary length of time required to capture such behavior will be beyond the capacity of a given panel survey. In other words, conducting a panel survey does not automatically translate into certain models being easily estimable, given the likely heterogeneity in the timeline for the materialization of outcomes. The ability of a panel survey to observe the persistence of adaptive/mitigative behavior and the impacts of adoption of a given agricultural practice on household-level agricultural production, welfare and/or food security-related outcomes will depend more on the frequency of a panel survey and the time period that a panel survey program covers, than on the availability of empirical tools. Furthermore, panel data can suffer from non-random attrition, which can interfere with the potential analytical capacity of a dataset, particularly if no inferences can be made with regards to the nature of the bias.

In short, climate change is predicted to have effects both in the short and long-term, with changes in both climate trends and climate shocks (variability). Household investments and practices as well as public and private sector initiatives will affect the adaptive capacity of farming systems and the ability of such systems to sequester carbon over time. However, the uncertainty of climate change impacts both spatially and temporally adds additional complexity to decisions made at all levels. Understanding the dynamics of household behavior is thus critical to understanding successful responses to, and mitigation of, climate change.

The remainder of the report is organized as follows. In the following section, we discuss the practices and investments broadly associated with sustainable land management, review the literature on factors affecting adoption, and detail the types of information necessary to capture dynamic household behavior and factors affecting that behavior. For organizational purposes, we consider three broadly overlapping categories: Agro-Forestry, Soil and Water Conservation, and Grazing Land Management. Many factors will affect the decision to adopt these practices, such as programs, policies and investments based on external adaption and mitigation, including government and/or private-sector initiatives. Variables required to capture these impacts are discussed in Section 3.1. Finally, certain variables that affect the adoption of adaptation and mitigation practices and investments are likely to be difficult to measure, requiring prioritization, and other variables are likely to be endogenous. In the third section, we discuss possible ways for addressing more difficult variables to measure, how to prioritize data collection where time and resource constraints make it impossible to add all relevant questions, and how endogeneity might best be addressed.

There are also issues related to climate change adaptation and mitigation that will not be handled in this document. As part of the LSMS-ISA project, another sourcebook – "Improving Household Survey Instruments for Understanding Agricultural Household Adaptation to Climate Change: Water Stress and Variability" – has been written which focuses extensively on water resource issues (Bandyopadhyay et al., 2011). Here, we only discuss household-level investments in structures that manage water but also reduce erosion, e.g. bunds and terraces. Additionally, there are other related issues that are already handled well on most existing LSMS surveys, and which we will not go into much detail here. These include questions on shocks faced during the cultivation period and risk perceptions. Many of the newer surveys also ask more detailed information on seed varieties and collect price information, generally at the community level. In terms of adaptation, the availability of locally-adapted seed varieties that give high yields but are also resilient to drought, floods, high temperatures, or shorter growing seasons will be important. Existing questions on household demand, prices faced and transaction costs will be important to understanding demand for different seed varieties; however, a separate, non-LSMS, instrument would be needed to fully understand supply.

2. Household-Level Agricultural Practices & Investments: Adaptation and Mitigation

There are a number of household agricultural practices and investments that can contribute to both adapting to climate change and mitigating greenhouse gases (GHGs). For instance, a striking feature of many sustainable land management (SLM) practices and investments is that many such activities also increase the amount of carbon sequestered in the soil; these include agro-forestry investments, reduced or zero tillage, use of cover crops, and various soil and water conservation structures. Thus, there are often long-term benefits to households from adopting such activities in terms of increasing yields and reducing the variability of yields, making the system more resilient to changes in climate. Such activities generate both positive "local" (household-level, and often community-level) net benefits as well as the global public good of reduced atmospheric carbon. However, adoption of many SLM practices has been very slow, particularly in food-insecure and vulnerable regions in Sub-Saharan Africa and Southeast Asia.

There are a number of potential explanations for failure to adopt such activities (and indeed, for continuing practices that lead to further degradation), including the following:

i. although SLM activities increase productivity in the medium- to long-run through improved soil characteristics and water retention, in the short-run, cultivation intensities and yields can decline (Giller et al., 2009), and yield variability can increase while farmers "learn by doing" (Graff-Zivin & Lipper, 2008), which reduces adoption incentives (particularly where information is scarce, and where credit and insurance markets are thin or absent (Antle & Diagana, 2003));

ii. many activities generate local public goods (e.g. windbreaks, terracing and other water management structures), meaning that local collective action failures will lead to under-provision of such activities; and

iii. tenure insecurity may reduce incentives to make long-term investments on the land (Otsuka & Place, 2001).

The above explanations indicate that financing and risk management instruments, technical information to "smooth" the adoption process, collective action at the local level, and tenure security should all be key variables that explain adoption. The differences in the distribution of time-invariant unobservable characteristics relevant for agricultural production across adopters and non-adopters can also serve as an explanation for the limited adoption of SLM practices; however, this can be controlled for with panel data. In the following sections, we discuss in more detail the benefits and costs of various SLM activities and investments, and summarize factors associated with successful adoption found in the literature.[4]

2.1. Agro-forestry

Agro-forestry generates adaptation benefits through its impact on reducing soil and water erosion, improving water management and reducing crop output variability (Ajayi et al., 2007, 2009; Mercer, 2004; Franzel & Scherr, 2002). Trees and bushes may also yield products that can either be used for food consumption (fruits), fodder, home production (building materials, firewood), or can be sold for cash, leading to greater average household income and contributing to household risk management via reduced income variability (Ajayi et al., 2009; Franzel et al., 2004). Planting trees and bushes also increases carbon sequestered both above and below ground, thereby contributing to GHG mitigation (Verchot et al., 2007).

One of the key constraints to widespread adoption identified in the literature is the availability of a range of suitable tree and bush seedlings and seeds (Ajayi et al., 2003, 2007; Franzel et al., 2004; Phiri et al., 2004; Place et al., 2004; Place & Dewees, 1999). Another key constraint concerns information and

[4] Much of the detailed empirical literature review can be found in McCarthy et al. (2010), which received funding from the Mitigation of Climate Change in Agriculture (MICCA) program, Natural Resource Management and Environment Department, Food and Agricultural Organization.

knowledge flows. Information on the types of agro-forestry options, particularly those well-suited to local conditions, is often scarce; this lack of information increases the risk of planting expensive perennials that may not survive or may otherwise do poorly (Ajayi et al., 2007; Franzel et al., 2004; Franzel & Scherr, 2002). Thus, information available to farmers on the types of trees/bushes that are well-adapted to the locality is likely to be an important determinant of adoption. Information may come from a number of sources, including government extension programs and NGO/donor programs promoting the adoption of agro-forestry. Note that since households are rarely "randomly" selected as participants in such programs – and programs may actively select certain households – researchers need to be able to account for both selections. Another constraint concerns up-front financing costs and opportunity costs of land taken out of production when establishing trees and bushes, particularly where benefits are delayed (Ajayi et al., 2007; Kiptot et al., 2007; Mercer, 2004; Franzel, 1999). Just how binding a cash constraint might be is obscured by the fact that many projects promoting trees/bush planting in fact provide the seeds/seedlings for free, particularly in East and Southern Africa (Franzel et al., 2004); thus, it will be particularly important to account for the conditions under which farmers access seeds/seedlings. Nonetheless, a number of empirical studies find that wealthier households with greater landholdings are more likely to adopt agro-forestry, indicating that cash constraints and opportunity costs of land are likely to affect adoption decisions (c.f. Phiri et al., 2004; Kuntashula et al., 2002; Place et al., 2004; Franzel, 1999).

Additional factors constraining adoption include the labor and/or additional investments required to ensure that seedlings receive sufficient water until their roots are firmly established and to ensure that they survive (Blanco & Lal, 2008; Franzel et al., 2004). In particular, local rules and norms regarding livestock grazing and bush-fires can substantially affect the costs of ensuring seedling survival. For instance, where customary practices allow for free-grazing livestock post-harvest and the use of bush-fires to clear land, the costs of protecting seedlings will be much higher than in communities that have functioning rules concerning grazing practices and limitations on bush-fires (Ajayi et al., 2007; Franzel et al., 2004; Phiri et al., 2004). The latter means that information will need to be collected on land and natural resource governance at the community level. Land tenure may also affect agro-forestry investments; however, the relationship in this case may run in both directions. That is, greater tenure security may promote investments in agro-forestry, but at the same time, investments in trees and bushes may lead to increased tenure security (Otsuka & Place, 2001 and references cited therein).

Also, because many agro-forestry investments yield benefits to both the investing farmer as well as farmers with surrounding fields, such investments will be underprovided where collective action is weak and/or very costly (Dutilly-Diane et al., 2003; McCarthy et al, 1999). In addition, providing agro-forestry on communal grazing lands presents a "double" collective action problem (McCarthy et al., 1999). Communal grazing lands represent an important land use in many Sub-Saharan African countries, and although there remains some disagreement among rangeland ecologists as to drivers of degradation (Vetter, 2009; Ellis & Galvin, 1994), the fact remains that measures to restore degraded lands often include planting trees and bushes (Dutilly-Diane et al, 2007; Woomer et al., 2004). Thus, measures of capacity to effectively undertake collective action will be required.

Finally, as with other SLM structures/investments discussed below, it will be necessary to account for investments in trees/bushes made before the "current" survey period. Initial stocks will influence current investments, but may also be correlated with omitted relevant variables in the current period estimations; this is also problematic when using many other household capital variables. While "new" households and/or households with relatively small holdings may remember the standing stock when they took possession of the plot(s), older farmers with larger landholdings may not know. In any case, it is worth capturing information on stocks at least one period prior to the survey period.

We can summarize the above information needed into the following: 1) investments in trees and bushes over the past 12 months, 2) the benefits generated, 3) factors affecting the marginal productivity of the investments (e.g. land quality, initial stocks of trees and bushes), and 4) the costs involved. The types of agro-forestry investments are straightforward, as are direct benefits, such as the value of tree/bush outputs either used in home consumption and production, or sold. There will also be indirect benefits, at least in the medium to long term, in terms of improved soil quality and water management on-farm, which should lead to both higher and more stable yields. Therefore the standard information on crop production will also be needed (this is not repeated here, as it is already captured in existing LSMS Agriculture survey modules). Factors affecting productivity of investments are mainly the underlying agro-ecological characteristics and current soil and water management characteristics, as well as land tenure and security. Additional household-level human and physical capital endowments will also affect the productivity of agro-forestry investments. Costs will be a function of labor availability (or wages, where labor markets function well), cost of accessing credit, cost of accessing seeds, cost of accessing information on suitable species and measures to reduce risks in adoption, and costs associated with remaining risks.

At the community level, local rules and norms that affect tenure security, the costs of protecting trees/bush investments, and incentives to generate local public goods provision will affect household incentives to adopt agro-forestry practices and investments. For instance, community-level information on customary land allocation and land use practices and restrictions can provide additional information on land pressures, as well as the quality of "tenure security" for household-level investment in trees and bushes. Customary practices such as free-grazing livestock post-harvest or lighting bush fires increase costs of ensuring survival of trees and bushes. Rules and norms restricting such practices will only be effective in reducing costs if they are enforced. In terms of local public goods, indicators of cooperative capacity at the community-level will affect costs and benefits realized by individual households both when such investments are undertaken on private land but nonetheless provide public benefits, and when households are requested to contribute to these investments on communal lands. Measures of community-level infrastructure and organizations capture the transaction costs associated with accessing information as well as transportation costs, and potentially serve as proxies for access to credit and the ability to pool and share risks. Market-based prices and measures of goods/services availability will provide data on potential benefits from sales as well as direct and transaction costs of obtaining various inputs.

2.2. Soil and water conservation practices

2.2.1. Conservation Agriculture

Conservation agriculture (CA) incorporates a wide range of practices aimed at minimizing soil disturbance, and minimizing bare, uncovered soils (Blanco & Lal, 2008, Chapter 8). Reduced or zero tillage in addition to incorporation of residues or other mulches reduces wind and soil erosion, increases water retention, and improves soil structure and aeration (Blanco & Lal, 2008). Reduced erosion, improved soil structure, and greater water retention reduce yield variability due to weather events in general. Thus, conservation tillage practices can increase farm system resilience and improve the capacity of farmers to adapt to climate change. At the same time, such practices reduce carbon losses that occur with ploughing, and also further sequester carbon via residue incorporation and reduced erosion (Lal, 1987). However, in many circumstances, farmers who adopt such practices still periodically plough the land (Blanco & Lal, 2008; Maguzu et al., 2007). Whereas periodic ploughing may improve yields without compromising the gains in terms of resilience and adaptability, such ploughing will release stored carbon. However, there is yet little evidence on how much carbon would be released (as a fraction of the additional carbon stored during the period of zero tillage) (Conant et al., 2007). Since the issue of "permanence" is of central importance to reducing atmospheric carbon dioxide, collecting data on continuity in adoption is critical.

Following Blanco & Lal (2008), there are a wide range of practices that reduce soil disturbance in seedbed preparation vis-à-vis conventional tillage. "Conventional tillage" is usually defined as animal or mechanical moldboard ploughing. In addition to hand-hoeing and conventional moldboard ploughing, tillage practices include zero tillage, strip or zonal tillage, and ridge tillage. Zero tillage is as the name suggests: no mechanical preparation of the seedbed, except for narrow holes for seed placement (FAO 2008). A "zero-tillage system" presupposes that some residue will be incorporated into the plot. In strip or zonal tillage systems, the seedbed is divided between seeding zones that are prepared mechanically or by hand-hoe only where seeds will be planted, and zones that are not ploughed. The practice should also include mulching of the undisturbed portion, although whether or not that is done should be seen as a separate question. Finally, the use of "planting pits", where small holes are dug and seeds deposited, are often used in semi-arid areas prone to crusting, in order to retain moisture and build soil fertility (Imbraimo and Munguambe, 2007; Roose et al., 1993). This practice also disturbs the soil less than conventional ploughing (Imbraimo and Munguambe, 2007). In summary, as noted in FAO (2008), "minimum tillage" may take on different meanings in different contexts, so that pre-testing will be critical in defining practices in the area of interest.

Incentives for individual farmers to undertake these practices will, of course, be a function of the marginal benefits of doing so. One of the key benefits affecting adoption of zero-tillage in many developed countries is the fact that fuel costs for tractors are significantly reduced. However, in the African context, very few farmers rely on fuel-based tractors or machinery to prepare the fields; Giller et al. (2009) point out that this may be a key reason behind limited adoption of such practices in Sub-Saharan Africa vis-a-vis Latin America. Furthermore, conservation tillage projects promote the use of specialized planting tools and other implements which are often not easily available in the area or are prohibitively expensive; this has been found to be a barrier to adoption in many African countries (Giller, et al., 2009; Mkomwa et al., 2007; Ringo et al., 2007; Shetto & Owenya, 2007; Boahen et al., 2007; Baudron et al., 2007; Bishop-Sambrook et al., 2004). Where herbicides are not accessible, increased labor required for weeding can also reduce the net benefits of zero tillage (Giller et al. 2009; Mkomwa et al., 2007; Ringo et al., 2007; Shetto & Owenya, 2007; Boahen et al., 2007); however, as discussed below, cover crops and crop rotations can also be used to reduce weeds. Agro-ecological characteristics can be important, though there is limited evidence in the empirical literature on which factors have consistent impacts on adoption. One key characteristic appears to be the drainage capacity of the soils; poorly drained soils may yield more limited benefits than well-drained soils, at least in the short-to-medium term (up to five years), due to increased soil compaction in these early years before the benefits to soil structure from zero tillage is realized (Blanco & Lal, 2008). There is also some evidence that in the semi-arid regions where termites are abundant, surface mulch is eaten by termites, thereby limiting benefits to conservation agriculture (Sanginga & Woomer, 2009, Chapter 10). Generally, benefits to conservation agriculture should also be greater on lands with more highly erodible soils and steeper slopes (Blanco & Lal, 2008; Uri, 1997).

Additionally, crop residues are used for a variety of purposes: as feed for livestock, as fuel for cooking, and as thatching/craft material. The greater these competing uses and the more costly are substitutes, the less likely will crop residues be left on the field. In many cases, it is long-standing customary practice to allow animals to graze fields post-harvest (Giller et al., 2009; Bishop-Sambrook et al., 2004; McCarthy, 2004). While animals do not remove all of the residue, such grazing may leave too little residue in the field, and grazing can be sufficiently heavy to compact the soil, making planting with zero-tillage more difficult (Bot & Benites, 2005).

Finally, in many cases, the full benefits in terms of higher and more stable yields will not be realized for four years or more, whereas costs will be incurred up front (Blanco & Lal, 2008; Hobbs et al., 2008; Bot & Benites, 2001; Sorrenson, 1997). Households with limited resources facing credit constraints will thus find it much more difficult to adopt conservation agriculture techniques, especially where initial investments are relatively high. Risks may also be greater initially where farmers need to learn new practices and techniques and adapt them to on-farm conditions (Graff-Zivin & Lipper, 2008). As with many agro-forestry techniques, many proposed conservation agriculture systems require greater management skills than traditional systems, so farmers not only need to learn a new system but generally also a more sophisticated system (Sanginga & Woomer, 2009; Bot & Benites, 2001). Farmers' perceived risks of adopting conservation practices has been identified as a key constraint to adoption in the African context, and study results suggest the key role that can be played by extension (or other information sources) in reducing these risks (Bot & Benites, 2001; Dreschel et al. 2008; Wondwossen Tsegaye et al., 2008). Furthermore, given the long-term nature of benefits accruing to these practices, security of tenure may also influence the adoption of such practices, to the extent that greater security increases incentives to invest for long-run increases in yields and greater yield stability (Bot & Benites, 2001; Steiner, 1998); however, there is limited consistent empirical evidence on the tenure impacts *per se* (Mercer, 2004).

To summarize, there are a number of key factors that will affect incentives to adopt conservation agriculture practices, including: 1) availability of implements/machinery adapted to local conditions, 2) availability of herbicides, 3) access to information to reduce risks associated with adopting new practices, 4) ability to keep fields permanently covered (no grazing), 5) availability of credit and insurance mechanisms, 6) underlying agro-ecological conditions and history of land use, 7) availability of substitutes for crop residues in animal production, fuel consumption, and thatching/craft materials, and 8) secure tenure. To avoid repeating information needs already detailed in the Agro-Forestry section above, below we only include explanatory variables that are additional to those found in that section, primarily those associated with the first three key factors listed above.

2.2.2. *Cropping Patterns: Cover Crops, Intercrops, Improved Fallows & Alley Crops*

In addition to seedbed preparation, various cropping patterns can also serve to improve soil and water conservation characteristics; cover crops and rotation patterns can alleviate potential weed problems where herbicides are not available or are inaccessible to poor smallholders. Alley cropping between cover crops provides similar benefits to those described above for alley cropping with agro-forestry systems; continuous cover between main crops can reduce erosion, build soil organic matter, and improve the water balance, leading to higher and more stable yields on the alleys sown to main crops (Blanco & Lal, 2008). Cover crops or improved fallows ensure that the soil is not left bare after harvest. Leaving residues on the field is one method of covering the soil, discussed above. Cover crops, on the other hand, are either additional crops planted on the field post-harvest or can also be crops inter-cropped with the main crop (usually the case where there is a single, relatively short rainy season, e.g. in the semi-arid regions of the Sahel) (Blanco & Lal, 2008; Bot & Bonites, 2001). Improved fallows also include fast-growing plant species that produce easily decomposable biomass (Matata et al., 2010). The purpose is both to keep cropland covered during the entire year, and in the case of improved fallows, to increase soil fertility. With intercropping, the type of species and the timing of intercropping need to be carefully assessed in order to ensure minimum competition with the main crop (Bishop-Sambrook et al., 2004). An additional benefit from continuous crop cover is reduction in weeding and pest control, at least after some period; in fact, many authors note that where adoption has been substantial, weed suppression has been perceived by farmers to be the main benefit (Tarawali, 1999; Erenstein, 1999). In terms of soil sequestration, cover crops and improved fallows can increase soil carbon, particularly when combined with zero or minimum tillage (Govaerts et al., 2009; Bot & Bonites, 2001; FAO, 2001). In terms of adaptation, such practices can reduce erosion and enhance water retention, both of which should enhance resilience to drought (Conant, 2009; Peterson & Westfall, 2004). Additionally, land under cover crops can reduce soil surface temperature significantly, which may be particularly beneficial in drought years under high temperatures (Lal, 1987).

A number of cover crops and improved fallow crops have had at least partial success in many African contexts. These include leguminous cover crops such as cowpea, pigeon pea, lablab, and mucuna, as well as improved fallows seeded with fast-growing tree species such as *sesbania sesbans* and *gliricidia sepium*. There are a number of factors associated with the successful adoption of cover crops and improved fallows, and many of these overlap with conservation agriculture tillage and residue practices noted above, particularly the ability to keep community animals from foraging on the land (Matata et al. 2010; Bishop-Sambrook et al., 2004; Ajayi et al., 2003). The availability of cover crop seeds has also been singled out as an important barrier to widespread and continued adoption (Morse & McNamara, 2003; Tarawali et al., 1999; Steiner, 1998).

Climate may also affect adoption both directly and indirectly. Woodfine (2009) discusses the likely greater benefits (at least in the near term) of bare fallow versus improved fallow with a cover crop due to relatively greater increases in soil moisture storage in arid regions where biomass production of the cover crop is relatively low, whereas Peterson & Westfall (2004) document increases in income and food security in semi-arid regions. Therefore, marginal benefits should be low in both very dry regions (due to increased soil moisture storage from bare fallow) and in humid regions, where marginal benefits to increased soil moisture will be lower, all else equal. Indirectly, improved fallows that generate sufficient biomass to cover the ground and also feed livestock are more likely to occur in higher rainfall areas (Steiner, 1998) leading to higher incentives to adopt in these areas. The longer the length of the growing season, the more likely it is that cover crops can be seeded to minimize competition with crops, and to spread labor requirements (Vissoh et al., 1998).

Population pressure and the need for continuous cultivation (abandoning slash and burn fallow practices) have also been found to increase adoption of cover crops (Vissoh et al., 1998; Ehui et al., 1989). Additionally, where weed and pest problems are greater (e.g. invasive species such as *imperata cylindrica* and *striga h*. in West Africa), the marginal benefits to cover crops should be higher (at least in later years), particularly where zero or minimum tillage is also practiced (Erenstein, 1999; and case studies contained in Buckles et al. (eds.), 1998). As with conservation agriculture more generally, use of cover crops often requires access to specialized planting implements, since seeds will be planted directly into fields under the cover crop. Improved fallows that require land to be fallowed for two or more years in order to provide soil fertility benefits are less likely to be successful where opportunity costs of land are high and farmer discount rates are high, as is often the case with poorer households with limited landholdings (c.f. Matata et al., 2010).

To summarize, agro-ecological conditions are likely to be very important in determining whether or not cover crops are grown or improved fallows seeded; these include rainfall patterns, length of growing season and high average temperatures during key growth stages. Additionally, the availability of seeds and information on risks and benefits associated with different cover and improved fallow crops reduce both direct costs and risks. Finally, population pressures, which reduce the viability of fallow-based systems and the presence of invasion species, should have a positive impact on a household's decision to plant cover crops. Population pressures will reduce the benefits of improved fallows. As above, in the list below, we only include explanatory variables that are additional to those already discussed above.

2.2.3. *Soil & Water Conservation Structures/Investments*

There are a number of fixed investments in structures for soil & water conservation, in addition to some of the agro-forestry investments discussed above. For the farmer, these structures can provide benefits by reducing water erosion, improving water quality, and promoting the formation of natural terraces over time, all of which should lead to higher and less variable yields (Blanco & Lal, 2008). Such structures also often provide benefits to neighbors and downstream water users by mitigating flooding, enhancing biodiversity, and reducing sedimentation of waterways (Blanco & Lal, 2008). Structures include contour bunds – built of either earth or stone – to reduce runoff velocity and soil loss. Blanco & Lal (2008) note that such bunds are appropriate for permeable soils on gentle to moderately sloping lands, may form the basis for terraces on steeply sloped land, and may reduce further gully erosion when built above and across gullies. However, Showers (2005) also shows that contour bunds can lead to a significant increase in gully erosion on poorly drained soils subject to heavy rainfall events. While terraces also provide water conservation and reduced soil erosion benefits, Blanco & Lal (2008) state that these benefits will be greater when undertaken in conjunction with other structures such as grassed waterways and drainage channels, both of which mitigate potential problems with waterlogging. Other water-storage specific structures (e.g. irrigation systems) are discussed separately in the companion LSMS-ISA sourcebook on climate change and water resources.

As with agro-forestry, soil and water conservation structures often entail large up-front costs, with benefits accruing – sometimes slowly – over time. Additional costs include land taken out of production (Blanco & Lal, 2008; Showers, 2005), and in certain cases (e.g. stone bunds), both initial construction and annual maintenance can entail heavy labor requirements that may be especially costly to households with few prime-age adults.

Finally, it should be noted that there remains debate in the literature regarding the benefits of these options, particularly where the design and construction of such structures does not take into account local conditions (Showers, 2005). For instance, Dutilly-Diane et al. (2003) found that farmers in semi-arid northeastern Burkina Faso who had invested in stone bunds had lower yields in high rainfall years, due to water drainage problems. Because the Sahel had experienced drought conditions starting in the late 1960's or early 1970's, the focus had been on structures that retain water; however, as built, these structures lead to lower yields when high rainfall does occur. Herweg & Ludi (1999) found similar disadvantages to waterlogging in sub-humid regions of Ethiopia and Eritrea; these authors also found that, despite significant reductions in soil erosion and runoff, yields were not significantly higher. In recent years, a number of researchers have pointed out the largely failed attempts at promoting soil and water conservation in Sub-Saharan Africa (and elsewhere); these authors claim that for such measures to be successful, they must be designed, adapted and tested in conjunction with local farmers (Showers, 2005; Hincliffe et al. 1995). Hincliffe et al. (1995) claim that there are very few projects where these structures are maintained after the project is over; information on previous soil & water conservation projects would be particularly important to enable empirical verification of this assertion. Additionally, these authors argue that few generalizations can be made to "scale-up" these measures without fairly intensive – and expensive – participatory research programs at a very local level. However, there is very limited empirical evidence; evidence from panel surveys will be critical in establishing an empirical basis for determining whether there are characteristics which lead to successful adoption over time and from which generalized lessons can be learned.

To summarize, soil and water conservation structures are more likely to produce relatively high benefits in mountainous areas where farming occurs on the slopes, where benefits to water retention are relatively great (e.g. more arid lands), and potentially where gully and rill problems have already surfaced. Such structures will yield lower net benefits, and perhaps lead to greater yield variability, where potential waterlogging problems cannot be managed at reasonable costs. The latter indicates that the incidence of extreme rainfall events will reduce incentives to invest in structures that nonetheless increase water retention in dry years.

As with other SLM practices already discussed above, high up-front costs in conjunction with delayed benefits dampens incentives to invest in soil and water conservation structures (Valentin et al., 2005). These structures also require heavy labor for construction and maintenance, so that the availability of prime-age adults in the household, perhaps particularly men, will affect costs associated with maintenance. Information on both current and previous presence of projects promoting such structures seems to be particularly important, as well as any evidence that structures promoted have been adapted to local conditions; as noted above, costly but inappropriate structures may lead to even lower yields and greater variability. Finally, as with agro-forestry, the initial stock of such structures on the farm will also be an important explanatory variable.

2.3. Grazing Land Management

The vast majority of agricultural land in Sub-Saharan Africa (and indeed, the world) is in rangelands. Rangelands include grasslands, bush, and woodland, and can include croplands where these are grazed after harvest (Homewood, 2004). Rangelands are particularly important in the arid and semi-arid regions, and there are an estimated 12.8 million km^2 of rangelands in Sub-Saharan Africa (Le Houerou, 2006), of an estimated arable area of 23.8 million km^2 (Nachtergaele, 2000). It should also be noted that over 6 million km^2 are in hyper-arid regions, some of which are still sometimes used for grazing and/or cultivation (Nachtergaele, 2000). Furthermore, about half of the arable area is in forested land, and about 2 million km^2 is in protected areas, meaning that the grazing land area is far greater than actual land used, which was estimated at just 1.5 million km^2 in 1998 (Nachtergaele, 2000). In terms of mitigation, many studies have suggested that rangelands could be a significant source of carbon sinks, mainly due to the large land area covered as opposed to the amount that could be sequestered per unit area (Smith et al., 2007; Conant & Paustian, 2002; Lal, 2002). In fact, the Fourth Intergovernmental Panel on Climate Change Assessment reports that “grazing land management” has the second highest technical potential to mitigate carbon (Smith et al., 2007). More interestingly, a widely-cited McKinsey report not only provides very large potential sequestration estimates, but also reports *negative* net costs of achieving those benefits, where net costs are calculated over a twenty year time horizon[5].

The primary reason given for increased carbon emissions and loss of soil carbon sequestered on degraded rangelands is overgrazing, and so eliminating or moderating grazing intensities is proposed to increase carbon sequestered on these rangelands (Batjes, 2004; Conant & Paustian, 2002; Nachtergaele, 2000). However, another line of researchers claim that grazing intensities have limited impact on rangeland vegetation and productivity; this claim is generally associated with the "non-equilibrium theory of rangeland dynamics" school of thought (c.f. Niamir-Fuller, 1999, chapter 9). Even within that school, it has been recognized that grazing densities could affect the replenishment of seed banks when it occurs during critical phases of the growing cycle, e.g. before the grasses/forages seed (c.f. Hiernaux, 1993). More recent work on the effects of grazing intensities from rainfall events on vegetation productivity indicate that both are important, particularly in semi-arid and dry, humid environments (Vetter, 2009; Wessels, 2007; Vetter, 2005); in arid and hyper-arid regions, grazing intensities might simply never be high enough to cause much damage, as posited by the "non-equilibrium" school. On the other hand, Derner & Schuman (2007) find that increased carbon sequestration results from reduced stocking densities only in the more arid regions (<440-600mm), which would indicate a range of between 150-440mm rain where reduced grazing intensity would increase carbon sequestered. One possible reason for the hard-to-interpret results could be because the response of the rangeland to decreased grazing intensity may also be a function of past grazing history as well as underlying agro-ecological conditions (Shrestha et al., 2005; Tennikeit & Wilkes, 2008; Smith et al., 2008). Additionally, many rangeland rehabilitation programs are aimed at reducing encroachment of invasive species, mainly non-edible bushes, which are also often seen as a sign of overgrazing. Removing these, often through burning, can lead to increased emissions in the short term, as well as lower carbon sequestration where these inedible bushes are not replaced with edible vegetation. In general, then, there remains a great deal of uncertainty over where and whether reduced grazing intensities reduce emissions and/or increase carbon sequestered, unless such measures are coupled with other activities to increase "good" plant biomass, reduced erosion and reforestation, as detailed in Woomer et al. 2004.

In terms of adaptation, grazing land management benefits are similar to those for cropland management; better soil quality and structure and better water management improves the capacity of rangelands to continue supporting livestock even under extreme weather events. Moderate grazing intensities may lead to reduced variability in overall livestock production, and increase the ability of herds to "bounce-back" after drought, although there is little long-term data to support that hypothesis (though c.f. McCarthy et al., 1999). In addition to moderating grazing intensities, rangeland improvements include many of the activities listed above under agro-forestry (silvopastoralism) and soil

[5] It appears that the McKinsey estimates were based on the USEPA's marginal abatement cost curve estimates. The report also gives negative costs for such activities as nutrient management.

& water conservation structures that lead to both increased carbon sequestration as well as increased resilience.

Unfortunately, the rosy figures given in McKinsey (2008) for “grazing land management” practices that increase carbon sequestration and reduce emissions are not likely to be relevant in the African context. Even assuming that they are, the first issue that arises is that costs will be borne immediately, while benefits will not be realized until some future time. Credit constraints will again be important. Restoration practices that include excluding livestock for some period of time are likely to be expensive and difficult to enforce (Dutilly-Diane et al., 2007; Badini et al., 2007). In essence, the choice between “working lands” restoration projects and changing land use (to exclude all livestock) will be a function of the trade-offs between maintaining livelihoods currently, the discount rate and risk preferences, and the rate of increase in productivity from exclusion (Wu et al., 2001). In the Sahelian context, Le Houerou (2006) argues that controlled access and limiting grazing intensities may produce better results, although such management plans will likely entail greater costs of enforcement (Lipper et al., 2010).

Unlike agro-forestry and investments in soil & water conservation structures that can provide both private & public benefits (when undertaken on both private and public land), controlling grazing intensities reduces a negative externality from use of communal grazing lands – and these lands characterizes much of rangelands in Sub-Saharan Africa. Incentives to provide a public good (non-rivalrous, non-excludable) are often qualitatively different from incentives to reduce a negative externality arising from shared use of a communal resource (rivalrous, non-excludable) (c.f. Dasgupta & Heal, 1979; Cornes & Sandler, 1986), and often require a greater degree of collective cohesiveness. Thus, the capacity to engage in collective action required to manage grazing land is likely to be higher than that for both private and collective investments in agro-forestry and soil & water conservation structures.

Additionally, use of communal pastures in many sub-Saharan African countries often includes rights of transhumants to use these pastures; by the same token, community members can often migrate to other grazing lands (McCarthy, 2004; Niamir-Fuller (ed), 1999). Pressure on local grazing land is thus also both a function of others’ rights to access the lands as well as community members’ capacity to move to access non-community resources. Enclosures and grazing restriction rules may pose even greater costs of establishment and enforcement when traditional users include not only locals, but non-locals as well.

Also, at the community level, poorly managed communal grazing land may lead to encroachment by those who wish to cultivate crops. Results in McCarthy (2004) show that encroachment of grazing lands by crops is often more problematic than overgrazing per se, in terms of estimated rates of “over-conversion” as opposed to “over-stocking”. As noted above, switching land use from grazing land to crops often leads to carbon emissions; and, to the extent that well managed pastures are more resilient to extreme weather events than are crops, failures in collective management will also lead to reduced adaptive capacity (Goodhue & McCarthy, 2009; Niamir-Fuller (ed), 1999).

Finally, we can raise the issue of “property rights” so prominent in the climate change as well as other strands of literature. As noted above, in systems where livestock owners move in response to different weather events as well as other transactions costs, more flexible access rights enable livestock owners to make the best use of available resources (Sandford, 1982; Coppock, 1994; Niamir-Fuller (ed), 1999). The ability to ‘weather’ weather shocks, where the main input is mobile, will depend on access rights to various resources. Here, ambiguous, ill-defined rights may well help livestock owners to absorb weather (and other) shocks (Goodhue & McCarthy, 2009; McCarthy & Di Gregorio, 2007). However, the trade-offs include both overgrazing in “good” times, and under-provision of public goods such as agro-forestry and soil & water conservation investments as well as management of invasive species. Insurance values are likely to dominate where climate events are more variable both in temporal and spatial scales; negative impacts from overgrazing and under-provision of investments are more likely to dominate where population pressures and heterogeneity amongst users are high (McCarthy et al., 1999; Turner, 1999).

To summarize, increasing carbon and resilience of grazing lands in Africa is likely to entail the need for collective action, not only amongst community members but also by others with secondary or tertiary rights of access. Benefits are only likely to be realized with both reduced grazing intensity (mitigating the “tragedy of the commons”) and increased investments on communal grazing lands (provision of public goods). The latter implies that community-level surveys will need to be far richer – in terms of both breadth and depth – than is common in surveys undertaken in countries and regions dominated by sedentary crop agriculture.

A final note regarding the definition of the “household” is also warranted. In areas where ruminant livestock production is the predominant activity, defining the household by “sharing food” is unlikely to be the best definition. In these areas (e.g. the semi-arid regions of the Sahel and the SADDC countries), there will be multiple households that will often share meals, but will also tend to have their own, separate livestock herds. Aggregating to the “shared meals” level will make accounting for livestock and its management extremely difficult; instead, defining the household by distinct herd ownership and management would be more manageable. However, given the primary focus of the LSMS surveys on the computation of a consumption-driven household welfare measure, defining household by distinct herd ownership and management to appropriately investigate grazing land management may not be possible.

3. Data Requirements to Model Determinants of Adoption of Adaptation/Mitigation Strategies

3.1. Summary Tables

In this section, we present summary tables of the data requirements needed to model the determinants of households' choices to adopt adaptation and/or mitigation strategies, following the descriptions given above. We present three tables, capturing i) household dependent variables, ii) household explanatory variables, and iii) supra-household-level explanatory variables (e.g. community, market). Columns in the first table capture the "Ideal Level of Observation", "Potential Difficulty in Measurement", and whether the variable is "Essential or Preferred". The list is necessarily non-exhaustive, and "hides" certain information that becomes clear when drawing up the questions needed to actually construct the variables, as can be seen in the sample Questionnaire Modules included in Appendix 1. For instance, the "ideal level of observation" for household dependent variables is either at the household or plot level; however, constructing information on sales or consumption variables might well include information collected at the level of the plot manager, for instance. The next two columns contain necessarily subjective assessments on potential for measurement difficulty and whether the variable is essential or preferred. Measurement difficulty will often depend on prevailing farm systems practices, and so a variable that is difficult to collect in one system may be relatively cheap to collect under another system. Ruminant livestock information provides a good example, as discussed above; in pastoral systems still reliant on transhumance, such information will be both essential but relatively difficult to collect, whereas in sedentary systems where people hold only a few large ruminants, such information will be relatively easier to collect though less essential. At the end of this section, we discuss in more detail measurement issues surrounding those variables listed as "difficult" in the tables. Likewise, whether or not a variable is "essential" or "preferred" will depend on the context.

Table 1: Household Dependent Variables

Household Dependent Variables	Ideal Level of Observation	Measurement Difficulty	Essential or Preferred
Agro-forestry (AF)			
Investments in AF seedlings, past 12 months	Plot	Low	Essential
Sales/Consumption value from AF in past 12 months	Household	Low-Moderate	Essential
Whether participated in any projects promoting AF in past 12 months	Household	Low	Preferred
Soil & Water Conservation (SWC)			
SWC practices undertaken in past growing season (e.g. no-till, crop residues incorporation, cover crops)	Plot	Low	Essential
SWC investments made in past 12 months	Plot	Low	Essential
Crop yield, revenue, sales data on plots with SWC	Household	Low	Essential
Whether participated in any projects promoting SWC in past 12 months	Household	Low	Preferred
Grazing Land Management (GLM)			
GLM practices undertaken in past growing season (e.g. cut & carry, fodder crops)	Plot	Low	Essential
GLM investments made in past 12 months (e.g. shade trees, erosion control structures)	Plot	Low	Essential
Grazing Land used by Ruminant Livestock (own, communal, transhumance)	Household	Moderate-High	Essential
Livestock Production/Sales data	Household	Moderate-High	Essential
Whether participated in any projects promoting GLM in past 12 months	Household	Low	Preferred

Table 2: Household Explanatory Variables

Household Explanatory Variables	Ideal Level of Observation	Potential Endogeneity	Measurement Difficulty	Essential or Preferred
Existing Agro-forestry (AF), 12 months before	Plot	Moderate	Moderately High	Essential
If purchased/obtained seedlings in past 12 months, where	Household	High	Low	Essential
If did not purchase/obtain seedlings, whether is aware of how to obtain	Household	High	Low	Essential
Existing Soil and Water Conservation Structures (SWC), 12 months before	Plot	Moderate	Moderately High	Essential
If purchased materials for SWC in past 12 months, where	Household	High	Low	Essential
If did not purchase materials for SWC, if is aware of how obtain	Household	High	Low	Essential
Whether has ever employed AF, SWC, grazing land management (GLM) in past	Household	Moderate	Low	Preferred
Knowledge of others use of AF, SWC, GLM (neighbors, relatives)	Household	Low	Low	Preferred
AF, SWC & GLM-specific assets held by household	Household	Low	Low	Essential
Current Soil Quality	Plot	Moderate	Moderate	
Soil Type	Plot	Low	Moderate	Essential
Water Drainage Problems	Plot	Moderate	Moderate	
Household Participation in AF, SWC and GLM projects	Household	High	Low	Essential
Skills of Farm Managers	Household Managers	Low	High	Preferred
Information sources accessed for AF, SWC and GLM	Household	High	Low	Essential
Information sources accessed on seasonal weather conditions	Household	Moderate-High	Low	Essential
Subjective Assessment of Yield Risk	Household	Low	High	Preferred
Subjective Assessment of Risk of adopting AF, SWC and GLM	Household	Low	High	Preferred
Informal Sources of Insurance	Household	Low	Low	Essential
Whether is familiar with crop insurance plans, if enrolled, if not, why not	Household	High	Low	Essential in countries with large programs

Table 3: Supra-Household Explanatory Variables

Supra-Household Explanatory Variables (Community, Institution)	Ideal Level of Observation	Measurement Difficulty	Essential or Preferred
Number of Households in Community	Community	Low	Essential
Land Allocation in community (Areas of private plots, communal grazing/forest)	Community	Moderate	Essential
Presence/% of Invasive Species on community land	Community	Low (presence)/ High (%)	Essential/ Preferred
Number of Ruminant Livestock	Community	High (in large communities)	Essential where livestock major part of economy
Number of Households undertaking AF, SWC,GLM practices at household level	Community	High (in large communities)	Preferred
Measures of Economic and Social Heterogeneity	Community	Moderate	Essential where communal resources important
Community Infrastructure	Community	Low	Essential
Community Collective Action for Maintenance and Investment of SLM	Community	Moderate	Essential where communal resources important
Community Rules and Enforcement for Natural Resources (e.g. on grazing, fires)	Community	Moderate	Essential
Governance Structure related to land and natural resource management	Community/ Institution	Moderate to High	Essential where communal resources important
Governance Structure related to land and natural resource management	Community	Low	Essential
Projects and Programs operating in Community (e.g. NGO's, Government)	Community	Low	Essential
Project and Program information on membership, activities, information shared	Institution	Low	Preferred
Number of Vendors selling AF, SWC and GLM materials in the area, prices and variety	Market	Low	Preferred

Agro-ecological characteristics & GIS-based information (Secondary sources)

The following consists of a list of variables consisting of various agro-ecological characteristics that would be advisable to collect; however, these can also generally be obtained via secondary sources. See the companion sourcebook, “Improving Household Survey Instruments for Understanding Agricultural Household Adaptation to Climate Change: Water Stress and Variability” (Bandyopadhyay et al., 2011) for a detailed discussion on the collection of some of these variables, particularly with regards to water resources.

- Normalized Difference Vegetation Index (NDVI), mean and variability
- Land degradation in period preceding survey
- Trend of degradation up to period preceding survey
- Soil quality indices (indices as described in literature, e.g. FAO)
- Density of road network (this can be captured with GIS-based information)
- GIS-based measures of water flow (coarse but generally available)
- Average daily maximum temperatures at key points in growing season
- Length of growing season
- Rainfall intensity measures during preceding 12 months (e.g. # of days receiving more than certain amount of rainfall deemed critical in the particular agro-ecological zone)
- Mean and variance of rainfall intensity measures historically

3.2. Priority Questions

Many variables identified above are already covered by standard LSMS modules. Here we discuss only those that are somewhat novel for these types of surveys. With respect to household decisions on cropping practices, land use and land use management, the literature review above highlights that underlying agro-ecological conditions are often a key factor in adoption. Thus, collecting that information should be a priority. Fortunately, a good deal of such information can be provided by GIS-based information sources, and should thus be relatively cheap, at least for surveys where households and plots are geo-referenced. Secondly, much of the literature documents the importance of obtaining information on the ability of household members to access information about these different practices and investments, not only to estimate the likely benefits and costs involved, but also to reduce the risks associated with adopting new practices. Basic information on what households know is somewhat costly, particularly if such information is collected on all possible practices and investments considered above. However, actual household information needs to be augmented by obtaining the basic information that different sources provide locally; this is a coarse but good substitute for household-level information where full household information is deemed too costly. Perhaps more importantly, community-level information can be used as an explanatory variable, since data on household information acquisition will be endogenous. Ideally, this should entail a short questionnaire for potential information sources in the communities (e.g. NGO project personnel, local community groups, local extension agents), but basic information may also be obtained at the community level, particularly in relatively small communities.

Given that many practices and investments provide local public goods (as well as global public goods) and/or are undertaken on communal lands (e.g. woodlots, pastures), the ability of the community to coordinate actions and engage in collective action is also an important determinant of household decisions. Collective action questions can be added to the community-level questionnaires relatively cheaply and should be a priority for understanding the use and management of natural resources in the context of climate change, particularly where reliance on communal resources is important for household production and incomes. The one area where such information is likely to be more costly is where households rely on non-private grazing resources for livestock, and this is particularly important where livestock products contribute significantly to household income and welfare. As discussed above, far more detail on the use and management of local pastures, as well as use of local pastures by transhumants, will be required at the community level. However, the number of households in such communities tends to be quite small, in which case community level information is easier to collect. Community populations tend to become larger as sedentary crop farming with limited livestock holdings becomes more important.

Market availability of various implements and crop varieties is also important; these can be added to market-based surveys. This is particularly true for livestock prices; many studies make the error of using total revenue per head as a "price" measure, some even using household level data. A cow in standard condition weighing 400 kg that costs $400 has the same price per kg as a standard 200 kg cow that costs $200; however, it is a common mistake to assume that the price of the first cow is double. To avoid this mistake, data on price per kg, adjusted for quality, should be obtained in the market. There are two methods: i) relying on market traders to estimate the weight and assign a condition score, with additional information on age and gender of the animal, or ii) using a measuring tape specifically designed to estimate weight, in which case the enumerators would still need the trader to assign a condition score, and would also need to collect age and gender information.

3.3. Difficult Questions

Certain information will be more difficult to collect, and will have to be carefully considered and pre-tested. At the household level, one of the more difficult pieces of information to collect concerns the underlying "skills" of the farm manager (of whom there may be more than one in a household). Various questions have been proposed, but a relatively cheap one would be a few questions on numeracy. In more advanced developing and developed countries, basic numeracy is often highly correlated with school attainment, but in poorer developing countries, where very few adults have had any formal schooling, these questions may be particularly important proxies to differentiate farm management skills. Very few empirical studies have looked at the direct implications of numeracy at the household level, although Jolliffe (2004) finds evidence of a positive effect of numeracy on total and off-farm income, though not for on-farm income. Nonetheless, basic numeracy questions could potentially prove very useful and are relatively cheap to add; as noted above, LSMS modules have already been developed and can be consulted to identify key questions (c.f. Scott et al., 2005 for country surveys with literacy/numeracy modules).

Another difficult set of information to collect concerns the “initial” stocks of on-farm infrastructure, particularly bushes and trees. This is both because it is in fact difficult to collect some of the information and because acquiring all of the information on every plot will significantly expand the survey. Information on man-made infrastructure can be obtained for the time the plot was first acquired/used; this should only prove difficult for those that have been farming for a very long time. Information on trees/bushes that were standing on plots before they were cleared is also likely to be difficult, especially for plots cleared many years ago, and impossible for those who did not clear the land themselves; in many cases, it may be sufficient to inquire only about recently cleared land. Even in the latter case, estimating the number of bushes, and to a lesser extent trees, will likely be difficult in slash-and-burn systems, and some reformulation of the questionnaire may be required in those contexts. Next, information on trees/bushes remaining on the plot when it was first cultivated is also likely to be difficult, especially for the plots that have been cultivated for many years. It may be better to simply ask about the number of trees/bushes that have been cleared over some shorter time period for plots that have been cultivated for more than 10 years, for example.

The current condition of on-farm infrastructure can also be difficult, particularly when one has to rely on subjective rankings. Above, we provided some objective indicators for specific infrastructure, but refinement with national and local extension staff should clarify key “condition” characteristics for the different types of infrastructure generally invested in by farmers.

Since many of the practices and investments identified above are hypothesized to reduce yield variability, information on risk preferences and subjective risk assessments will be difficult. Above, we outlined various GIS-based information, including NDVI[6], that could be used to proxy objective risk assessments. These should unquestionably be collected, as should data on price variability, which is relatively easy to capture from a variety of sources but nonetheless remains rarely used. Risk preferences may be elicited via hypothetical questions (Binswanger, 1980) or even via experiments, but designing such questions to elicit comparable measures across many different agro-ecological zones and farming systems is likely to be very time-consuming, as would be training the enumerators and eliciting this information for at least one, and perhaps more family members, i.e. all who are considered plot managers. This methodology may be better employed in targeted areas once basic LSMS data from earlier rounds becomes available and is analyzed. Subjective assessments on yield and price variability can be collected using a triangle distribution (e.g. least and most favorable yields/prices and most likely yield/price). Collecting this type of data tends to require good enumerator training, although farmers

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[6] While NDVI often does a poor job as a proxy for absolute measures of net primary productivity and with rainfall measures where these can be directly compared, it correlates more highly with measures of variability in rainfall, which is particularly important as a potential proxy for objective measurements of rainfall risk.

generally understand the questions clearly. Many surveys, including some versions of the LSMS, already collect a long list of perceptions of risk; while the value of these still appears to be limited, these sections do cover the most likely risks and respondents' perceptions of them. One reason for the limited explanatory power of these variables may be that many risks co-vary, and most questionnaires do not account for this covariance. Again, objective data on price and yield variability and co-variance are probably both easier to collect from secondary sources, and are more precise.

Livestock information is among the most difficult of agricultural production information to collect. First, households can have many animals, particularly in semi-arid regions, making asking questions about every animal prohibitively expensive. However, it is relatively straightforward to pick up simple information on monogastrics, and information by a limited set of age-categories for ruminants. Ownership and management responsibilities over different animals can be quite complicated, and a basic accounting for animals held or given out under different terms should be obtained, at least for large ruminants and where livestock production is the main livelihood strategy. Though time-consuming, the data itself is relatively straightforward to collect. A livestock grazing "calendar" over the previous relevant time period can be somewhat time-consuming, but is also often straightforward to collect, particularly for those who do not split their herds. Finally, obtaining milk production data can also be time-consuming and difficult where households have multiple animals lactating over any given period. It is easier to obtain data to value milk used for home consumption or sale, but the value of "total milk production" will be obscured by the fact that some of the milk will be left for the offspring (an investment), and the amount that is left is ultimately a choice variable for the household. There are few easy ways to account for the "investment" value left on the cow for the offspring; however, leaving more for the offspring should show up in future valuations, and thus panel data may be able to tease this out more easily than cross-sectional data. With regards to the collection of any of the livestock information detailed above, it is important to note that additional enumerator training will be required, particularly in accounting for herd structures and/or livestock grazing calendars.

The last set of difficult questions concerns the collection of aggregate household information at the community level. This includes information on the proportion of households who engage in certain activities or have undertaken certain investments, e.g. practicing zero tillage or having made investments in stone bunds. These variables are meant to capture the extent of practical experience and knowledge in the community, which in turn should reduce information costs and risks associated with adopting new techniques at the household level. This type of data is often relatively easy to collect in communities of 100 households or less. In larger communities, this data may need to be collected by neighborhood.

For many of the remaining endogenous variables, community-level variables can serve as instruments; this includes the number and types of groups in the community, as well as the number and types of external programs operating in the community, in order to proxy for household participation in these groups and programs. Information available at the community level can also proxy for information accessed by the household. As noted above, omitting "farm management skill" is often hypothesized to give biased results; the use of household fixed effects can help reduce this type of bias.

4. Conclusion

This note has attempted to provide guidance for researchers and practitioners interested in contributing to some of the key gaps in knowledge on household behavior with regards to climate change adaptation and mitigation strategies. Specifically, this note has focused on the development of a set of key indicators and modules to supplement the existing LSMS and LSMS-ISA survey instruments in order to facilitate the collection of data on practices and investments broadly associated with sustainable land management that also generate climate change adaptation benefits, and in some cases, mitigation benefits as well. The tables and modules developed in this note should not be seen as the final model for designing survey questions; instead, they should be modified when applied to any specific country to reflect country-specific climatic conditions, the pattern of local agriculture and livestock practices, and local land and water resources.

As noted previously, climate change is predicted to have effects both in the short and long-term, with changes in both climate trends and climate shocks (variability). The adaptive capacity of farming systems, including the smallholder agricultural systems that provide sustenance for the majority of the world's poor, will be impacted significantly by household investments and practices as well as public and private sector initiatives. It is therefore imperative that we strive for a clearer understanding of the dynamics of household behavior in order to identify the tradeoffs and synergies between food security, adaptation and mitigation that are generated by various transformation pathways for smallholder agriculture. Most importantly, further knowledge creation should focus on identifying and ascertaining the potential impacts of key policy and institutional arrangements that support such smallholder transformations.

In the course of this knowledge creation, this note should serve as guidance with regards to a wide spectrum of decisions that must be made when conducting a survey effort. It is hoped that the reader will find the various discussions of tradeoffs with regards to survey and questionnaire design of use when considering prioritization in the face of time and monetary constraints. In particular, the discussion of key variables affecting the adoption of adaptation and mitigation practices is intended to shed light on expected measurement difficulties, as well as methods for addressing such issues. Further information on conducting surveys on household behavior with regards to climate change can be found in the companion sourcebook on climate change and water resources, or by contacting the LSMS team directly at lsms@worldbank.org.

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Annex 1. Sample Household Modules for LSMS-ISA Surveys

In this annex, we present a collection of questions organized into sample modules for the household questionnaire that can be used to complement existing LSMS-type household surveys, as well more specialized surveys. Additionally, we have developed a similar set of questions organized into sample modules for community questionnaires, which can be found in Annex 2; as discussed in the text, community-level information is likely to be very important for understanding household choices on whether to practice and/or invest in land management activities.

These modules do not include all of the detailed information contained in the text; for this, a "long" module will need to be developed. As noted below, in many cases, the exact questions will need to be adapted to country-specific conditions. Additionally, certain practices and investments are likely to be very limited in certain countries and so these do not need to be added in those cases, which could considerably reduce the number of questions necessary.

The standard LSMS-ISA surveys already contain a great deal of information on plot characteristics, crop yields, sales, input use, and to a lesser extent on livestock, and so we do not reproduce any questions that are generally already found in such surveys. Instead, the modules given below can be integrated into such surveys in the relevant sections, e.g. plot-level production, plot-level sales, household-level information, etc. We have also tried to maintain the style of the LSMS-ISA surveys. For instance, when plots are listed in rows, column questions use the convention [PLOT] to refer to the row-by-row questions; similarly, survey designers will need to determine the season or time period over which some question will refer, in which case the convention is to use [REFERENCE SEASON] or [TIME PERIOD] to indicate that the term is elsewhere defined. Finally, sample modules for other information relevant to climate change, such as access to weather information, water availability and water stress, are contained in the LSMS-ISA companion sourcebook on water stress and variability (Bandyopadhyay et al. 2001).

Section 1: Basic Plot Characteristics

Plot ID	1.1 What proportion of the [PLOT] has compacted soils?	1.2 What proportion of the [PLOT] has crusted soils?	1.3 Have you ever experienced waterlogging problems on this [PLOT]?	1.4 When was the last time you experienced waterlogging problems on this [PLOT]?	
	PERCENTAGE	PERCENTAGE	YES..1 NO...2>>NEXT SECTION	MONTH	YEAR [4-DIGITS]

JAN..1
FEB..2
MAR..3
APR..4
MAY..5
JUN..6
JUL..7
AUG..8
SEP..9
OCT..10
NOV..11
DEC..12

Section 2: Agro-forestry and Soil & Water Conservation Structures

Plot ID	2.1 How many trees and bushes are on [PLOT]? (including border) IF NONE, RECORD ZERO IN BOTH, >> **2.7**		2.2 How many trees or bushes were planted in the past year on [PLOT]? (including border) IF NONE, RECORD ZERO IN BOTH, >> **2.6**		2.3 From what source did you obtain tree or bush seeds/seedlings? *1=Relative* *2=Neighbor* *3=Project/NGO* *4=Government Extension* *5=Private Nursery* *6=Other (specify)* ______________		2.4 How many kilometers did you travel to obtain seeds/ seedlings?		2.5 How many labor days were used to plant trees and bushes?		2.6 How many trees or bushes were removed in the past year from [PLOT]? (including border) IF NONE, RECORD ZERO. **(THEN >> 2.10)**		2.7 Do you know where you can obtain seedlings? YES..1 NO...2>>2.9	2.8 How many kilometers would you have to travel to obtain seeds/ seedlings?	2.9 What is your main reason for not having trees or bushes? *1= Takes too much land out of crop production* *2=Too difficult to obtain seedlings* *3=Too expensive* *4=Too difficult to protect seedlings* *5=Too risky/uncertain* *6=Other (specify)*
	#TREES	#BUSHES	#TREES	#BUSHES	TREES	BUSHES	TREES	BUSHES	TREES	BUSHES	#TREES	#BUSHES		KILOMETERS	

Plot ID	2.10 What type of structure(s) are on [PLOT]? *1=Stone bunds* *2=Earth bunds* *3=Terraces* *4=Ditches* *5=Grass barriers* *5=Other (specify)* ______________ LIST UP TO TWO STRUCTURES. IF NONE, RECORD ZERO IN BOTH, >> **2.17**		2.11 Last year, how many labor days were spent on construction on [S1] on [PLOT]? What was the total cost of labor for the construction of [S1] on [PLOT]? IF NONE, RECORD ZERO IN BOTH. ESTIMATE THE CASH VALUE OF IN-KIND PAYMENTS.				2.12 Last year, how many labor days were spent on construction on [S2] on [PLOT]? What was the total cost of labor for the construction of [S2] on [PLOT]? IF NONE, RECORD ZERO IN BOTH. ESTIMATE THE CASH VALUE OF IN-KIND PAYMENTS.				2.13 Last year, how many labor days were spent on maintaining [S1] on [PLOT]? What was the total cost of labor for the maintenance of [S1] on [PLOT]? IF NONE, RECORD ZERO IN BOTH. ESTIMATE THE CASH VALUE OF IN-KIND PAYMENTS.				2.14 Last year, how many labor days were spent on maintaining [S2] on [PLOT]? What was the total cost of labor for the maintenance of [S2] on [PLOT]? IF NONE, RECORD ZERO IN BOTH. ESTIMATE THE CASH VALUE OF IN-KIND PAYMENTS.			
			FAMILY LABOR	HIRED LABOR			FAMILY LABOR	HIRED LABOR			FAMILY LABOR	HIRED LABOR			FAMILY LABOR	HIRED LABOR		
	S1	S2	DAYS	DAYS	CASH	IN-KIND	DAYS	DAYS	CASH	IN-KIND	DAYS	DAYS	CASH	IN-KIND	DAYS	DAYS	CASH	IN-KIND

Plot ID	2.15 What is the main source from whom you purchased building materials for soil and water conservation structures? *1=Relative* *2=Neighbor* *3=Project/NGO* *4=Government Extension* *5=Private Company* *6=Other (specify)* ____________	2.16 How many kilometers did you travel to obtain building materials for soil and water conservation structures? **(THEN >> NEXT SECTION)**	2.17 Do you know where you can obtain the building materials for soil and water conservation structures? YES..1 NO...2>>2.19	2.18 How many kilometers would you have to travel to obtain soil and water conservation materials?	2.19 Have you ever had any soil and water conservation structures on any plots owned and/or cultivated by the household during [REFERENCE SEASON]? YES..1 NO...2>>2.21	2.20 Why did you remove the soil and water conservation structures? *1=Expand land in crops* *2=Problems with waterlogging* *3=Problems with water breaching structure* *4= Other (specify)* _______________ **(THEN >> NEXT SECTION)**	2.21 What are the main reasons you have never had soil and water conservation structures on any plots owned and/or cultivated by the household during [REFERENCE SEASON]? *1=Requires too much labor* *2= Materials not available* *3=Materials too costly* *4=No soil or water erosion problems on any plots* *5=Too risky / benefits unclear* *6= Other (specify)* ________________ LIST UP TO TWO REASONS.	
		KILOMETERS		KILOMETERS			REASON 1	REASON 2

Section 3: Post-Harvest Cover & Land Preparation

Note: Need to explain definition of "incorporate" with regards to crop residue.

Plot ID	3.1 Was [PLOT] left fallow for more than one year before [REFERENCE SEASON]? YES..1 NO...2>>3.4	3.2 What year did the fallow period begin, the last time [PLOT] was left fallow? YEAR [4-DIGITS]	3.3 For how many years was [PLOT] left fallow? NUMBER OF YEARS	3.4 At the end of [REFERENCE SEASON], did you have cover crops remaining on [PLOT]? YES..1 NO...2>>3.6	3.5 What type of cover crop was left on [PLOT]? *1=Mucuna* *2=Pigeon pea* *3=Lablab* *4=Sesbania Sesbans* *5=Other (specify)* _____________	3.6 Did you incorporate crop residue into [PLOT] in the post-harvest period of [REFERENCE SEASON]? YES..1 NO...2	3.7 Did animals graze on [PLOT] in the post-harvest period of [REFERENCE SEASON]? YES..1 NO...2

Plot ID	3.8 Did you apply mulch to [PLOT] immediately after the harvest for [REFERENCE SEASON]? YES..1 NO...2	3.9 Have you applied manure to [PLOT] immediately after the harvest for [REFERENCE SEASON]? YES..1 NO...2	3.10 Did you burn [PLOT] before cultivation for [REFERENCE SEASON]? YES..1 NO...2	3.11 Did you practice contour ploughing or planting on [PLOT] during [REFERENCE SEASON]? YES..1 NO...2	3.12 How did you prepare the seedbed on [PLOT] during [REFERENCE SEASON]? *1=Hand hoe* *2=Animal, mouldboard plough* *3=Animal, disc plough* *4=Tractor, mouldboard plough* *5=Tractor, disc plough* *6=Ridge tillage* *7=Tied Ridge tillage* *8=Planting pits* >> **3.13** *9=Zero tillage* >> **3.13** *10=Strip/zonal tillage* **(THEN >> 3.14)**	3.13 In what year did you first begin to practice zero or minimum tillage on [PLOT]? **(THEN >> 3.17)** YEAR [4-DIGITS]

<table>
<tr>
<td rowspan="2">Plot ID</td>
<td rowspan="2">3.14 Have you ever practiced zero or minimum tillage on any of the plots that were owned and/or cultivated by the household during [REFERENCE SEASON]?

YES..1
NO...2>>3.16</td>
<td rowspan="2">3.15 What is the major reason that you stopped practicing zero or minimum tillage?

1=Weeding problems increased
2=Problems with waterlogging
3=Yields did not improve
4=Too difficult/more labor to seed
5=Other (specify)
____

(THEN >> 3.17)</td>
<td colspan="2">3.16 What are the main reasons you have never tried zero/minimum tillage practices] on any of the plots that were owned and/or cultivated by the household during [REFERENCE SEASON]?

1=It seems too risky
2=Believes will lead to lower yields
3=requires more labor for seeding and/or weeding
4=Requires special implement to seed; too expensive
5= Other (specify)
____

LIST UP TO TWO REASONS.</td>
<td rowspan="2">3.17 ENUMERATOR: Check the answers to 3.6. Did the household incorporate crop residue into any plot owned and/or cultivated by the household in the post-harvest period of [REFERENCE SEASON]?

YES..1>>NEXT SECTION
NO...2>>3.20</td>
<td rowspan="2">3.18 Have you ever incorporated more residue into any of the plots that were owned and/or cultivated by the household during [REFERENCE SEASON]?

YES..1
NO...2>>3.20</td>
<td rowspan="2">3.19 What is the major reason that you stopped incorporating crop residue?

1=Residue more valuable as livestock fodder
2=Too difficult to keep animals out of field
3=Didn't see yield improvements
4= Other (specify)
____

(THEN >> NEXT SECTION)</td>
<td colspan="2">3.20 What are the main reasons you have never incorporated more crop residue on any of the plots that were owned and/or cultivated by the household during [REFERENCE SEASON]?

1=Residue more valuable as livestock fodder
2=Too difficult to keep animals out of field
3=Doesn't believe will give large yield improvements
4= Other (specify)
____

LIST UP TO TWO REASONS.</td>
</tr>
<tr>
<td>REASON 1</td><td>REASON 2</td>
<td>REASON 1</td><td>REASON 2</td>
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</table>

Section 4: Sources of Information & Project Participation

4.1 Has any member of the household received information on agro-forestry in the past [TIME PERIOD]? YES..1 NO...2>>4.3	4.2 What was the primary source of agro-forestry information? *1=Gov't Extension* *2=Pvt. Extension* *3=Farmer Field School* *5=Market Traders* *6=Radio Programs* *7=Relative* *8=Neighbor* *9=NGO (specify)* ________________ *10= Other (specify)* ________________	4.3 How many of your neighbors and relatives have invested in agro-forestry? NUMBER	4.4 Has any member of the household received information on zero or minimum tillage practices in the past [TIME PERIOD]? YES..1 NO...2>>4.6	4.5 What was the primary source of tillage information? *1=Gov't Extension* *2=Pvt. Extension* *3=Farmer Field School* *5=Market Traders* *6=Radio Programs* *7=Relative* *8=Neighbor* *9=NGO (specify)* ________________ *10= Other (specify)* ________________	4.6 How many of your neighbors and relatives have ever practiced zero or minimum tillage? NUMBER	4.7 Has any member of the household received information on cover crops or mulches in the past [TIME PERIOD]? YES..1 NO...2>>4.9	4.8 What was the primary source of cover crop/mulch information? *1=Gov't Extension* *2=Pvt. Extension* *3=Farmer Field School* *5=Market Traders* *6=Radio Programs* *7=Relative* *8=Neighbor* *9= NGO (specify)* ________________ *10= Other (specify)* ________________

4.9 How many of your neighbors and relatives use cover crops or mulches? NUMBER	4.10 Has any member of the household received information on soil and water erosion control in the past [TIME PERIOD]? YES..1 NO...2>>4.12	4.11 What was the primary source of soil/water erosion control information? *1=Gov't Extension* *2=Pvt. Extension* *3=Farmer Field School* *5=Market Traders* *6=Radio Programs* *7=Relative* *8=Neighbor* *9= NGO (specify)* ________________ *10= Other (specify)* ________________	4.12 How many of your neighbors and relatives have invested in soil and water erosion control structures? NUMBER	4.13 Has any member of the household participated in any projects promoting agro-forestry in the past [TIME PERIOD]? YES..1 NO...2	4.14 Has any member of the household participated in any projects promoting soil and water conservation in the past [TIME PERIOD]? YES..1 NO...2	4.15 Has any member of the household participated in any projects promoting grazing land management in the past [TIME PERIOD]? YES..1 NO...2

Section 5: Yield Risk Perceptions

Note: The following questions are at plot-crop-level. They should be asked during the visit that corresponds to the pre-harvest/post-planting period of [REFERENCE SEASON]. This module is administered for all crops planted on all plots, but time can be saved by narrowing down to major crop(s) or largest plot(s) as preferable.

Plot ID	Crop Name	Crop Code	5.1 At the end of [REFERENCE SEASON], how much [CROP] are you most likely to harvest from [PLOT]?		5.2 What is the lowest amount of [CROP] you expect to harvest from [PLOT]?		5.3 What is the highest amount of [CROP] you expect to harvest from [PLOT]?	
			QUANTITY	UNIT	QUANTITY	UNIT	QUANTITY	UNIT

Section 6: Crop Price Perceptions

Note: The following questions are at crop-level, to be asked of each crop reported to be cultivated by the household during the visit that corresponds to the pre-harvest/post planting period of [REFERENCE SEASON]. Unit and crop codes will be context-specific. This module is administered for all crops cultivated by the household, but time can be saved by narrowing down to major crop(s) as preferable.

Crop Name	Crop Code	6.1 At the end of [REFERENCE SEASON], what do you think the price of [CROP] is likely to be?		6.2 What do you think the lowest price of [CROP] could be?		6.3 What do you think the highest price of [CROP] could be?	
		UNIT	PRICE	UNIT	PRICE	UNIT	PRICE

Section 7: Sustainable Land Management Specific Assets and Implements

Note: These questions can be added to the modules already found in standard LSMS-ISA instruments. The list of assets/implements will be context-specific. The list below is simply suggestive.

ASSET/ IMPLEMENT NAME	ASSET/ IMPLEMENT CODE	7.1 Does your household currently own any [ASSET/ IMPLEMENT]? YES..1 NO...2>>NEXT ASSET/IMPLEMENT	7.2 How many [ASSET/ IMPLEMENT] are owned by your household? NUMBER
Jabber/Planting Stick	201		
Ripper	202		
Disc Plough – animal	203		
Disc Plough – tractor	204		
Animal drawn knife roller	205		
Herbicide application equipment (specify____________)	206		

Section 8A: Large Ruminants' Grazing Calendar Over Past [TIME PERIOD]

Note: The following questions complement the existing livestock questions in standard LSMS-ISA instruments. They should be asked of households that report to have owned and/or raised large ruminants over the past [TIME PERIOD]. Note that intra-[TIME PERIOD] seasons need to be defined for each context. In the table below, we presume that during the last [TIME PERIOD], two distinct periods are shown, perhaps corresponding to the cropping season and post-harvest seasons.

TIME PERIOD	8.1 During the [TIME PERIOD], please tell us the proportion of time that the majority of your herd (ruminants) spent: RECORD ZERO IF NONE.						
	On own pastures or lands left fallow	At homestead (pegged near house, corralled)	On own crop fields, post-harvest	On community crop fields, post-harvest	On community pastures (used only by community members)	On communal pastures (used by community and neighboring community members)	In transhumance
Period 1 (Month 1-4)							
Period 2 (Month 5-6)							

Section 8B: Grazing Resources: Basic Characteristics & Maintenance Over Past [TIME PERIOD]

GRAZING RESOURCE	8.2 How many trees were on [GRAZING RESOURCE] at the end of [TIME PERIOD]? IF NONE, RECORD ZERO.	8.3 How many water sources were on [GRAZING RESOURCE] at the end of [TIME PERIOD]? IF NONE, RECORD ZERO, >> **8.5**	8.4 How many labor days were spent to maintain water sources on [GRAZING RESOURCE] over the past [TIME PERIOD]? What was the total cost of labor to maintain water sources on [GRAZING RESOURCE] over the past [TIME PERIOD]? IF NONE, RECORD ZERO IN BOTH. ESTIMATE THE CASH VALUE OF IN-KIND PAYMENTS.				8.5 Were improved fodder grasses sown on [GRAZING RESOURCE] at the end of [TIME PERIOD]? YES..1 NO...2	8.6 How many soil and water conservation structures were there on [GRAZING RESOURCE] at the end of [TIME PERIOD]? IF NONE, RECORD ZERO, >> **8.8**	8.7 How many labor days were spent to maintain soil and water conservation structures on [GRAZING RESOURCE] over the past [TIME PERIOD]? What was the total cost of labor to maintain soil and water conservation structures on [GRAZING RESOURCE] over the past [TIME PERIOD]? IF NONE, RECORD ZERO IN BOTH. ESTIMATE THE CASH VALUE OF IN-KIND PAYMENTS.			
			FAMILY LABOR	HIRED LABOR					FAMILY LABOR	HIRED LABOR		
			DAYS	DAYS	CASH	IN-KIND			DAYS	DAYS	CASH	IN-KIND
Own Pastures												
Community Pastures												

Section 8C: Grazing Resources: Investments Over Past [TIME PERIOD]

GRAZING RESOURCE	8.8 Did you plant any trees/shrubs on [GRAZING RESOURCE] in the past [TIME PERIOD]? YES..1 NO...2>>8.10	8.9 How many labor days were spent to plant trees/shrubs on [GRAZING RESOURCE] over the past [TIME PERIOD]? What was the total cost of labor to plant trees/shrubs on [GRAZING RESOURCE] over the past [TIME PERIOD]? IF NONE, RECORD ZERO IN BOTH. ESTIMATE THE CASH VALUE OF IN-KIND PAYMENTS.				8.10 Did you seed [GRAZING RESOURCE] with fodder grasses in the past [TIME PERIOD]? YES..1 NO...2>>8.12	8.11 How many labor days were spent to seed [GRAZING RESOURCE] with fodder grasses over the past [TIME PERIOD]? What was the total cost of labor to seed [GRAZING RESOURCE] with fodder grasses over the past [TIME PERIOD]? IF NONE, RECORD ZERO IN BOTH. ESTIMATE THE CASH VALUE OF IN-KIND PAYMENTS.				8.12 Did you invest in any soil or water conservation structures on [GRAZING RESOURCE] in the past [TIME PERIOD]? YES..1 NO...2>> NEXT SECTION	8.13 How many labor days were spent to invest in soil or water conservation structures on [GRAZING RESOURCE] over the past [TIME PERIOD]? What was the total cost of labor to invest in soil or water conservation structures on [GRAZING RESOURCE] over the past [TIME PERIOD]? IF NONE, RECORD ZERO IN BOTH. ESTIMATE THE CASH VALUE OF IN-KIND PAYMENTS.			
		FAMILY LABOR	HIRED LABOR				FAMILY LABOR	HIRED LABOR				FAMILY LABOR	HIRED LABOR		
		DAYS	DAYS	CASH	IN-KIND		DAYS	DAYS	CASH	IN-KIND		DAYS	DAYS	CASH	IN-KIND
Own Pastures															
Community Pastures															

Annex 2. Sample Community Modules for LSMS-ISA Surveys

Section 1: Community Characteristics

Note: For 1.8, examples of local invasive species should be provided to the respondent.

1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
How many households live in this community?	What share of land is allocated to crop farming?	What share of land is allocated to woodlands / forest?	What share of land is allocated to pastures?	What share of land is irrigated by surface water?	Does this community share land with any neighboring communities?	What share of communal land is shared land with other communities?	Is the communal land affected by the presence of any invasive species?	What is the extent of the problem?
	ALMOST NONE...1 1/4....2 1/2....3 3/4....4 ALMOST ALL....5	ALMOST NONE...1 1/4....2 1/2....3 3/4....4 ALMOST ALL....5	ALMOST NONE...1 1/4....2 1/2....3 3/4....4 ALMOST ALL....5	ALMOST NONE...1 1/4....2 1/2....3 3/4....4 ALMOST ALL....5	YES..1 NO...2 >>1.8	ALMOST NONE...1 1/4....2 1/2....3 3/4....4 ALMOST ALL....5	YES..1 NO...2 >>1.10	MINOR......1 MODERATE...2 SEVERE.....3
# OF HHs								

Crop Farming

1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17
Approximately how many households in the community currently practice zero or reduced tillage?	Approximately how many households in the community sow seeds in planting pits?	Approximately how many households in the community keep crop residues on fields post harvest?	Approximately how many households in the community currently have earth or stone bunds?	Approximately how many households in the community currently have terraces?	Do any households in the community currently have "other structures"?	Do any households in the community currently have permanent cover crops?	Do any households in the community currently intercrop?
RECORD ZERO IF NONE.	RECORD ZERO IF NONE.	RECORD ZERO IF NONE.	RECORD ZERO IF NONE.	RECORD ZERO IF NONE.	YES..1 NO...2	YES..1 NO...2	YES..1 NO...2
# OF HHs	# OF HHs	# OF HHs	# OF HHs	# OF HHs			

1.18	1.19	1.20	1.21	1.22	1.23	1.24	1.25
Approximately how many households in the community currently practice irrigated agriculture? RECORD ZERO IF NONE.	How is the most important source of irrigation water managed in this community? Privately managed by households......1 Private irrigation service provider...2 Managed by the community, irrigation association, etc...3 Public irrigation service provider...4 Unmanaged..........5 Other, specify.....6	What is the most important source of irrigation water for this community? Rivers, Streams...1 Lakes, Ponds.....2 Wells.....3 Boreholes.4 Other, specify...5	Is water available year-round from this most important source of irrigation? YES..1 >> 1.26 NO...2	During which month does the water run dry? JAN..1 FEB..2 MAR..3 APR..4 MAY..5 JUN..6 JUL..7 AUG..8 SEP..9 OCT..10 NOV..11 DEC..12	Until which month does this irrigation source remain dry? JAN..1 FEB..2 MAR..3 APR..4 MAY..5 JUN..6 JUL..7 AUG..8 SEP..9 OCT..10 NOV..11 DEC..12	During which month did the water run dry in the last dry season? JAN..1 FEB..2 MAR..3 APR..4 MAY..5 JUN..6 JUL..7 AUG..8 SEP..9 OCT..10 NOV..11 DEC..12	Until which month did this irrigation source remain dry in the last dry season? JAN..1 FEB..2 MAR..3 APR..4 MAY..5 JUN..6 JUL..7 AUG..8 SEP..9 OCT..10 NOV..11 DEC..12
# OF HHs							

1.26	1.27	1.28	1.29	1.30	1.31
Among the households that own and/or cultivate land, what is the size of the smallest landholding?	Among the households that own and/or cultivate land, what is the size of the average landholding?	Among the households that own and/or cultivate land, what is the size of the largest landholding?	Among the households that own and/or keep large ruminants, what is the smallest herd size?	Among the households that own and/or keep large ruminants, what is the average herd size?	Among the households that own and/or keep large ruminants, what is the largest herd size?
AREA IN HAS.	AREA IN HAS.	AREA IN HAS.	NUMBER	NUMBER	NUMBER

Community Pastures

1.32	1.33	1.34	1.35	1.36	1.37	1.38
How many cattle are held by all households? RECORD ZERO IF NONE.	How many goats are held by all households? RECORD ZERO IF NONE.	How many sheep are held by all households? RECORD ZERO IF NONE.	How many camels are held by all households? RECORD ZERO IF NONE.	How many donkeys are held by all households? RECORD ZERO IF NONE.	How many mules/ horses are held by all households? RECORD ZERO IF NONE.	ENUMERATOR: Does the community have any area allocated to pastures? YES..1 NO...2 >> 1.40
NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	

1.39	1.40	1.41				1.42			
Is any part of the community pasture fenced? YES..1 NO...2	Do community members have access to nearby pastures that are also shared with neighboring communities? YES..1 NO...2	In the rainy season, what is the percentage of community herd that grazes on: RECORD ZERO IF A GIVEN SOURCE IS NOT UTILIZED.				In the dry season, what is the percentage of community herd that grazes on: RECORD ZERO IF A GIVEN SOURCE IS NOT UTILIZED.			
		Community pastures?	Shared/buffer pastures?	Crop land post-harvest?	External resources (migration/trans-humance)?	Community pastures?	Shared/buffer pastures?	Crop land post-harvest?	External resources (migration/trans-humance)?

Note: For 1.44 and 1.45, answer categories should be tailored to the local context. Possible categories for 1.44 include village head, local district chief, etc. Categories for 1.45 should be obtained from local methods of enforcement.

		1.43	1.44	1.45	1.46	1.47
RULE DESCRIPTION	**RULE CODE**	Is there a rule on [RULE] in the community? YES..1 NO...2 >> NEXT RULE	Who enforces [RULE]? ANSWER CATEGORIES	What is the enforcement mechanism for [RULE]? ANSWER CATEGORIES	How many infractions against [RULE] were there in the past relevant season? RECORD ZERO IF NONE, >> NEXT RULE.	How many times were enforcement mechanisms on [RULE] applied in the past relevant season? RECORD ZERO IF NONE.
Rotational grazing within communal pasture areas	101					
Seasonal grazing (including rules on cropland post-harvest)	102					
Prohibitions on grazing by sick animals	103					
Cut/carry of grasses	104					
Cutting bushes/felling trees	105					
Use of community pastures by neighbors	106					
Use of community pastures by transhumants	107					

Section 2: Community Restrictions & Actions

RESTRICTION DESCRIPTION	RESTRICTION CODE	2.1 Does the community require: [RESTRICTION]? YES..1 NO...2 >> NEXT RESTRICTION	2.2 What types of penalties accompany this restriction? ANSWER CATEGORIES	2.3 How many infractions against this restriction were there in the past relevant season? RECORD ZERO IF NONE, >> NEXT RESTRICTION	2.4 How many penalties were levied on the restriction in the past relevant season? RECORD ZERO IF NONE.
Fields open to community animals post-harvest, no fencing allowed	201				
Fields open to community animals post-harvest, can fence permanent crops	202				
Transhumants can enter fields post-harvest	203				
Bush Fires prohibited	204				
Bush Fires limited	205				
Prohibitions on cutting live trees	206				

ACTION DESCRIPTION	ACTION CODE	2.5 In the past 12 months, has the community . . . YES..1 NO...2 >> 2.7	2.6 What proportion of households contributed to the [ACTION] in the last 12 months in labor time, cash, and kind? RECORD PERCENTAGE. RECORD ZERO IF NONE.			2.7 Was there any cash penalty for not contributing to the [ACTION] in the last 12 months? YES..1 NO...2 >> NEXT ACTION	2.8 How much cash penalty was actually collected for not contributing to the [ACTION] in the last 12 months?
			HOURS	CASH	IN-KIND		CASH
Planted any trees/bushes on communal pastures?	301						
Invested in any soil erosion control structures?	302						
Invested in water sources for livestock?	303						
Spent resources maintaining pasture resources or structures?	304						
Invested in road repair?	305						
Invested in bridge maintenance?	306						
Invested in agro-forestry on communal lands?	307						
Made any other conservation investment on communal land?	308						

Section 3: Access to Information Services

SOURCE DESCRIPTION	SOURCE CODE	3.1 Did you ever receive any information from [SOURCE]? YES..1 NO...2 >> NEXT SOURCE	3.2 Does [SOURCE] provide information on benefits and costs of: YES..1 NO...2 Soil quality	Weed control	Planting techniques	Agro-forestry	Crop residue incorporation	Planting pit sowing
Government Extension	401							
Private Extension	402							
Farmer Field Schools	403							
Donor Projects	404							
NGO Projects	405							
Market Traders	406							
Radio Programs	407							

SOURCE DESCRIPTION	SOURCE CODE	3.2, cont. Does [SOURCE] provide information on benefits and costs of: YES..1 NO...2 Zero tillage	Permanent cover crops	Intercropping	New/improved varieties	Bunds/ terraces	Drains/ ditches	Other, specify
Government Extension	401							
Private Extension	402							
Farmer Field Schools	403							
Donor Projects	404							
NGO Projects	405							
Market Traders	406							
Radio Programs	407							

3.3. Are there agro-forestry-based projects operating in the community? [ ] YES..1 NO...2 >> 3.8

3.4 What is the name of the agro-forestry-based project? RECORD NAMES BELOW.	**PROJECT CODE**	3.5 When was the project established?		3.6 Does [PROJECT] provide information on benefits and costs of different species, such as: YES..1 NO...2					
		MONTH	YEAR [4-DIGIT]	Survival rates	Time to maturity	Products for home consumption	Products for production	Products for livestock feed	Selecting, planting & protecting seedlings
	501								
	502								
	503								
	504								
	505								

PROJECT NAME COPY NAMES FROM PREVIOUS ROSTER.	**PROJECT CODE**	3.7 Does the project provide additional incentives/ benefits, such as: YES..1 NO...2				
		Credit subsidies	Free seeds / seedlings	Free extension advice	Visits to farms in other areas	Payments to farmers (PES-type)
	501					
	502					
	503					
	504					
	505					

MONTH CODES FOR 3.5

JAN..1
FEB..2
MAR..3
APR..4
MAY..5
JUN..6
JUL..7
AUG..8
SEP..9
OCT..10
NOV..11
DEC..12

Note: For 3.11, refer to country-specific context to compile a list of local conservation agriculture implements.

3.8	3.9	3.10	3.11	3.12	3.13
How many vendors/ nurseries sell tree/bush seedlings in the community? RECORD ZERO IF NONE.	What is the distance to the nearest identified vendor/ nursery? RECORD ZERO IF IN COMMUNITY.	Do the nearest seedling vendors/ nurseries offer credit? YES..1 NO...2	How many vendors sell conservation agriculture implements in the community? RECORD ZERO IF NONE.	What is the distance to the nearest identified vendor? RECORD ZERO IF IN COMMUNITY.	Does the nearest identified vendor offer credit? YES..1 NO...2
NUMBER	KILOMETERS		NUMBER	KILOMETERS	

3.14	3.15	3.16	3.17	3.18	3.19
How many vendors sell herbicides in the community? RECORD ZERO IF NONE.	What is the distance to the nearest identified vendor? RECORD ZERO IF IN COMMUNITY.	Does the nearest identified vendor offer credit? YES..1 NO...2	How many vendors sell crop varieties suitable as permanent cover crops and intercrops in the community? RECORD ZERO IF NONE.	What is the distance to the nearest identified vendor? RECORD ZERO IF IN COMMUNITY.	Does the nearest identified vendor offer credit? YES..1 NO...2
NUMBER	KILOMETERS		NUMBER	KILOMETERS	