Improving Household Survey Instruments for Understanding Agricultural Household Adaptation to Climate Change: Water Stress and Variability

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1. Introduction

Global climate change is predicted to adversely affect agriculture, which provides the principle source of income for the world's poor populations. A large body of country-level studies have confirmed that the impacts on agriculture due to changes in precipitation patterns and water stress caused by warming temperature are expected to be negative, with the most severe losses occurring in Africa, Latin America, and India (Parry et al. 2004). Climate change thus poses a serious threat to food security, in particular among populations in low-income countries.

Effective adaptation in the agricultural sector is increasingly recognized as a critical policy component for reducing vulnerability and mitigating adverse climatic impacts (Rosenzweig and Parry 1994; Downing 1992; Downing et al. 1993; Bradshaw et al. 2004; Wang et al. 2009). Studies using data for India show that adaptation can reduce the damage to agriculture by about 10 – 20 percent (Mendelsohn and Dinar 1999; Jacoby et al. 2010). There is an extensive literature on the impact of climate change on agriculture, but relatively limited research on adaptation to climate variability,[1] particularly empirical studies on adaptation to water stress and variability at the farm level. In part, this research gap reflects the difficulties in collecting reliable and long-term climatic data at the local level, which can then be combined with farm-level agricultural practices and crop production patterns to analyze farm-level adaptation behavior in response to weather variability.

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. The LSMS surveys have been used to assess household welfare, to understand household behavior, and to evaluate the welfare impact of various government policies. These surveys, however, lack well-designed instruments for understanding farm-level adaptation behavior to climate variability, in particular water resource variability and stress in agriculture.[2]

For the purpose of improving the quality, relevance and sustainability of smallholder agricultural data in Sub-Saharan Africa, the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) project was started with a grant from the Bill and Melinda Gates Foundation, and is implemented by the LSMS team in the Development Research Group (DECRG) of the World Bank. Under the LSMS-ISA initiative, the World Bank is supporting seven countries in Sub-Saharan Africa, 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

[1] A few studies on adaptation to climate variability include Mendelsohn et al. (1999) on India and Brazil; Wang et al. (2009) on China; Nhemachena and Hassan (2007) on Southern Africa, Zambia, and Zimbabwe; Maddison (2007) and Seo and Mendelsohn (2008) on Africa; and Smit et al. (2000) on Canada.

[2] LSMS survey questionnaires can be found at: <<http://iresearch.worldbank.org/lsms/lsmssurveyFinder.htm>>.

understanding of economic development in Africa, particularly with regards to agriculture and linkages between farm and non-farm activities.[3]

As part of the LSMS-ISA project, a separate guidance note (McCarthy, 2011) was developed on the design and implementation of survey instruments for understanding smallholder adaptation and mitigation responses to climate change, with a focus on agro-forestry, terrestrial-based soil and water conservation, and grazing. McCarthy (2011) also discusses mitigation roles of local public and private institutions and related data collection issues.

The present guidance note on adaptation, complementing McCarthy (2011), focuses on smallholder adaptation responses to weather variability, as well as the measurement of local water resources. On adaptation, the focus is mainly on expanding the existing modules to collect key information related to household-level adaptation choices in response to local weather variability. For local water resources, the data collection includes rainfall, surface water, and groundwater. In the future, the survey instrument will be integrated into LSMS surveys to enable systematic data collection on adaptation to climate variability in agriculture, thus providing an important public source of information for policy analyses in low-income countries.

Particularly in Africa, rainfall variability has an important impact on household incomes; rainfed agriculture accounts for over 80 percent of total agricultural output in the region. This note thus provides some guidance in designing survey instruments for measuring local water resources during critical cropping seasons. It includes a review of various rainfall data sources, including in situ gauge stations and satellites. It also includes an assessment of the recently developed remote-sensing-based precipitation products, as well as their suitability for providing local-level precipitation estimates.

The guidance note has seven sections. Section 2 summarizes analytical issues related to household adaptation choices, including model specification and data issues. Section 3 focuses on LSMS surveys, including the key features and gaps in the survey instrument. Section 4 focuses on survey instrument design for collecting data on (a) farmers' perceptions of weather variability, and (b) household water-related adaptation to weather variability. Section 5 develops survey instruments for measuring village-level water resources, including rainfall, groundwater, and surface water. Section 6 provides a review of recently developed remote-sensing-based precipitation products and assesses their suitability as an alternative measurement of local precipitation. Section 7 presents concluding comments.

Audience and background

Weather refers to the instantaneous state of the atmosphere, or to the atmosphere's evolution over short periods of time (i.e., days). Climate is the expected distribution of weather (Auffhammer et al. 2011). Climate change refers to changes in the parameters of the statistical distribution of weather occurring over decades and centuries. Given its long-term nature, climate change can be more easily

[3] For more information on the LSMS-ISA initiative, visit www.worldbank.org\lsms-isa.

understood by focusing on long-term and short-term climate variability. However, due to inaccuracy associated with recall over long periods of time, it is more reasonable to capture farmer adaptation to climate change as it is reflected by responses to weather variability, also defined as short-term climate variability, which is most appropriately considered over the course of several weeks or months.
This guidance note is for use by researchers and evaluators of projects and programs whose primary focus is on collecting data on adaptation choices by households in response to weather variability, in particular water resource stress and variability. It is also intended for researchers who wish to study the determination of farm-level adaptation decisions and their impact on households.

Many of the key survey questions on adaptation suggested in the note are generic. Therefore, users of this guidance note are expected to make necessary modifications to the survey instrument and questions, taking into account local climatic and water resource conditions, as well as the local patterns of agricultural and livestock practices.

The module design is based on several surveys and lessons learned from studies that have used surveys with adaptation questions and modules. These include:

a) A 2003/04 household survey of 10,000 farms, conducted across 11 countries in Africa as part of the research project entitled "Climate, water and agriculture: Impacts on and adaptation of agro-ecological systems in Africa." In this report, it is referred to as the 2003/04 household survey of 11 African countries.
b) A 2008/09 household survey on adaptation to climate change for smallholder agriculture in Kenya conducted by International Food Policy and Research Institute (IFPRI).
c) A 2004/05 household survey of the Nile Basin in Ethiopia conducted by IFPRI.
d) A 2003/04 integrated land and water management survey in Ghana, focusing on watersheds in Vea and Bolinga, conducted by IFPRI.
e) A 2002/03 plot-level survey on linkages between poverty and natural resource management in Uganda, conducted by IFPRI.

2. Analytical issues

2.1. Background

The interplay between agriculture and climate is not a new phenomenon; in fact, farmers around the world have responded and adapted to climate and weather variability for centuries. The heightened focus on agricultural adaptation to climate change and variability is largely due to the growing concern over climate change within the policy and research communities (Belliveau et al. 2006). Research methods in this area have evolved from a "top-down" scenario-based approach to a "bottom-up" approach.

The top-down approach focuses on estimating the net impact on agricultural incomes of future climate scenarios, using methods such as spatial analysis, climate impact modeling, and Ricardian analysis (Schulze at al. 1993; Erasmus et al. 2000; du Toit et al. 2001; Kiker 2002; Poonyth et al. 2002; Deressa

2003; Gbetibouo and Hassan 2005). One of the key limitations of this approach is that adaptation measures are treated as primarily technical policy adjustments. They represent possible or potential adaptation strategies implemented by the government in order to effect societal change, generally via improved regulatory standards (Belliveau et al. 2006; Bryant et al. 2000). More recent research has shifted to the "bottom-up" approach, focusing on farm-level adaptation strategies by collecting household survey data (Nhemachena and Hassan 2009 on South Africa, Zambia, and Zimbabwe; Seo and Mendelsohn 2008 on Africa; and Smit and Skinner 2002 on Canada).

In the rapidly growing literature on adaptation to climate change, the term adaptation has been used in a very broad context. Broadly, adaptation to climate variability can be categorized by the types of responses, including (a) reactive (or autonomous) adaptation, and (b) precautionary (or planned) adaptation (Dinar et al. 2008). Reactive adaptation refers to ex-post temporary coping strategies taken at the household and community level in the event of weather shocks. Precautionary adaptation includes long-term ex-ante response strategies—for example, the development of rainfall prediction systems, or the introduction of a drought-tolerant seed variety—that are often considered the responsibility of the government because of the public good nature of these activities. The empirical literature also distinguishes between different elements of adaptation, including climate-related stimuli, adaptive capacity (of the system that is adapting), and the process and outcome of adaptation (Smit et al. 1996; Wheaton and MacIver 1999; Smit et al. 2000). This guidance note focuses mainly on farm-level adaptation decisions and their impact on household outcomes, as measured by income or consumption.

The types of adaptation strategies taken by households in response to multiple risks, including climate variability, may vary by country or by region within countries depending on local climate conditions, natural resource endowments, and the patterns of agricultural and livestock activities. In general, household-level adaptation practices can be grouped into four categories: (a) income diversification, including non-farm income and mixed crop-livestock farming systems; (b) crop diversification; (c) investment in soil and water conservation and management; and (d) use of irrigation (Nhemachena and Hassan 2009; Bradshaw et al. 2004, Orindi and Eriksen 2005; Baethgen et al. 2003; Dinar et al. 2008; Kurukulasuriya and Rosenthal 2003).

Table 1 provides a summary of the generic adaptation options at the farm and community level based on a review of the literature.

Table 1. Selected Examples of Adaptation: Farm-Level and Community-Level

A. Farm-level adaptation strategies		
1.1 Production adjustment	***1.2 Land use practices***	***1.3 Water use practices***
▪ Diversify from crops to livestock and between different types of livestock ▪ Crop diversification, or from single to multiple crops ▪ Change of planting dates; change seasonal migration patterns ▪ Fodder cultivation and fodder banks ▪ Diversify to non-farm income sources ▪ Adopt different varieties of the same crop ▪ Water-stress-related migration ▪ Change seasonal migration patterns	▪ Change to different cultivation or grazing sites ▪ Private versus community land use changes for crops and grazing ▪ Use alternative fallow and tillage practices ▪ Investment in soil conservation	▪ Change between surface and groundwater irrigation ▪ Investment in water conservation and rainwater harvesting ▪ Change seasonal water use patterns

B. Community-level adaptation options			
▪ Community-level investment in irrigation, water and soil conservation	▪ Community-level self-regulatory conservation measures	▪ Collective action groups	▪ Local weather information system

Sources: Nhemachena and Hassan 2009; Wang et al. 2009; Smit and Skinner 2002; Kurukulasuriya and Rosenthal 2003.

Fundamentally, understanding how small farmers adapt to weather variability requires answering the following key questions:

a) Are farmers aware of short- and long-term (cross-season and intra-season) weather variability?
b) What types of adaptation strategies do farmers adopt?
c) What factors determine the specific adaptation choices of small farmers?
d) What types of public policies are effective in enhancing a household's capability to adapt to and cope with increased weather variability and water stress caused by warming temperatures?

2.2. The conceptual framework

Household decisions on how to adapt to weather variability are influenced by a wide range of household as well as community-level factors. These include household socioeconomic conditions, asset ownership, access to information (weather forecast, new seed variety), access to credit and insurance markets, local resource endowments, and the overall economic environment in which they make decisions. For example, studies have found that the pace of adoption of new technologies—an important form of adaptation—is largely determined by factors such as farm size, tenure status, the level of education of household members, access to markets, access to extension services, availability of credit, and availability of water (Maddison 2007). Recent literature also highlights the importance of social capital on adaptation practices (Isham 2002).

In addition, government-supported adaptation policies also influence farm-level adaptation decisions. The impact of these public policies on households' adaptation behavior depends critically on how these public programs are implemented at the local level. For example, how are community programs – such as agricultural extension services, dissemination of weather forecast information, input subsidies (e.g. fertilizer and new seeds), and social safety nets – geographically targeted?

Many studies have examined reactive household-level adaptation to weather variability, in particular rainfall variability, within the framework of risk management and vulnerability assessment (Heltberg et al. 2009; Baez and Mason 2008). Figure 1 illustrates the channels through which these factors at different levels interact with each other and the pathways through which they impact household adaptation decisions and welfare outcomes.

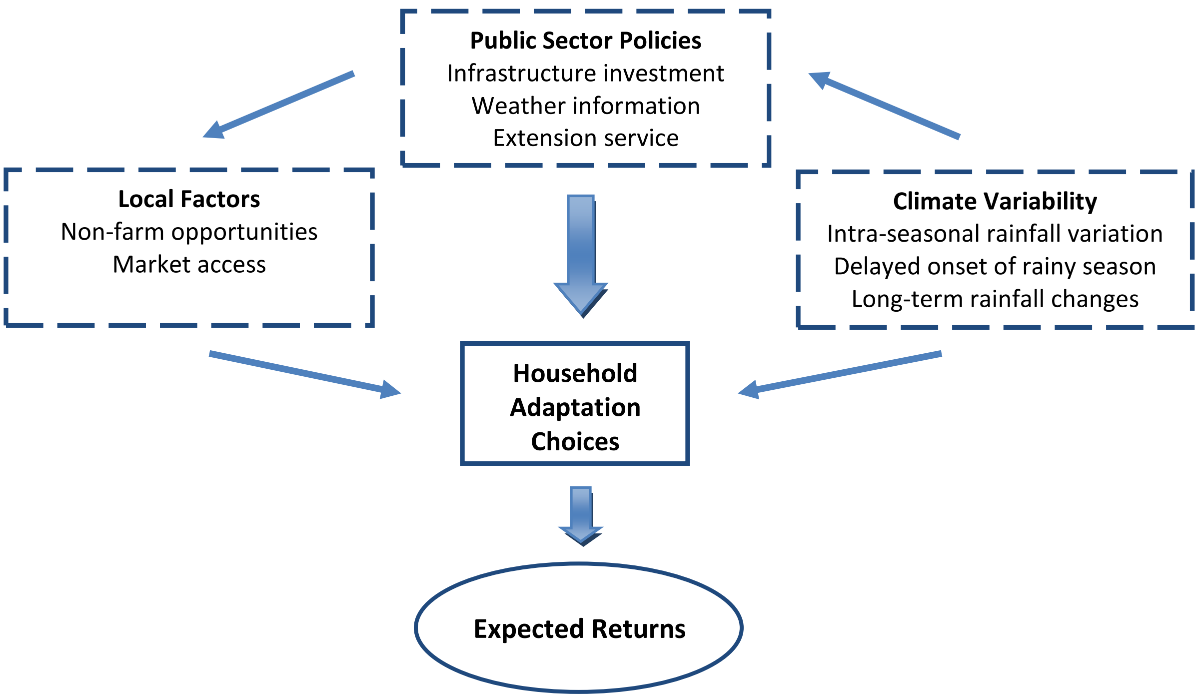

Figure 1. An analytical framework

2.3. Model specification

Households' adaptation decisions in response to weather variability—and consequently their welfare outcomes—are jointly determined. Households make decisions on what types of adaptation practices to adopt in response to weather shocks and observed changes in long-term climate trends, which in turn affect household incomes (controlling for other factors). Therefore, the structural model approach, which simultaneously models both adaptation choices and their impact on household welfare, is helpful in analyzing farm-level adaptation behavior.

One of the analytical challenges in the above model specification is the omitted variable issue. Factors that affect household adaptation choices, such as a farmer's capability to manage farm production and build up various assets or to acquire information – generally referred to as household heterogeneity – are difficult to measure, so they often are not collected in household surveys. The estimated impact of adaptation choices on household incomes will be biased by using cross-sectional household data because adaptation choices are likely correlated with the unobservable household heterogeneity.

The same analytical issue arises when researchers aim to assess the impact of community programs on household adaptation choices and welfare. The estimation bias, in this case, results from the fact that many community-based programs are not randomly placed in villages. The issue of endogenous program placement poses one of the main challenges in program impact evaluation (Rosenzweig and Wolpin 1984). Collecting household panel data, such as the LSMS surveys, provides some solutions to address the analytical issues associated with omitted variables or endogenous program placement.

2.4. Data issues

The information needed to estimate the structural model should include (a) farmers' perceptions of short- and long-term weather variability; (b) detailed information on farm-level adaptation choices; and (c) farm-level climatic and water resource information. While many LSMS surveys collect some information on farm-level adaptation, they do not collect information on farmers' perceptions of weather-related questions. Information on local water variability, which is most relevant for understanding smallholder farmers' adaptation behavior, is not available to be integrated into any LSMS surveys.

In rainfed agriculture, both the onset of the rainy season and the distribution of rainfall during the wet season are critically important to crop yields. Studies show that intra-season dry spells can cause more crop failure than low cumulative annual rainfall in dry lands (Rockstrom and de Rouw 1997). Detailed temporal and spatial weather data collection at the local level, in particular during planting seasons, is thus essential for understanding farmers' short-term adaptation strategies because of the importance of intra-seasonal factors.

The review of empirical literature in the area of farm-level adaptation and the impact of climate change and variability on agricultural income shows clearly that the key data gap lies in the lack of local-level water resource measurement. Table 2 summarizes the existing farm-level studies using household surveys from different countries. The common feature of these studies is the lack of local climate data. All studies were conducted under the assumption that farm-level rainfall was the same as that recorded at distant weather stations that were dispersed across the country. On the other hand, a few studies that use local rainfall data to study the impact of household adaptation choices on farm incomes (Thomas et al. 2007; Molua 2002; Dercon and Krishnan 2000) focus on a small number of villages, limiting the ability to extrapolate their findings to other localities.

One of the key lessons that can be drawn from reviewing the existing literature on adaptation to climate variability is the importance of developing methods for collecting local-level climate data, in particular rainfall, as part of LSMS survey development. In combination with data collected using the agricultural module, such information can significantly strengthen the usefulness of LSMS surveys, particularly with regards to understanding farm-level adaptation behavior in response to weather variability and water stress.

Table 2. Summary of studies on adaptation to climate change and variability

Study country	**Farm-level data**	**Climate data**	**Data limitations**
Southern Africa (Nhemachena and Hassan 2007)	1,719 farmers for South Africa, Zambia, and Zimbabwe	Temperature data come from satellites Precipitation data interpolated from ground stations (ARTES) for the three countries	Climate data are not a precise measure of farm-level climate conditions Does not allow seasonality No measurement of local water availability by season
Africa (Seo and Mendelsohn 2008)	5,000 livestock farmers across 10 countries in Africa	Temperature data come from satellites Precipitation data interpolated from ground stations (ARTES)	Same as above
Africa (Kurukulasuriya and Mendelsohn 2007)	7,000 farmers across 11 countries in Africa	Temperature data come from satellites Precipitation data interpolated from ground stations (ARTES)	Same as above
South Africa (Gbetibouo 2009)	794 farmers in 19 districts of 4 provinces	Mean precipitation and temperature data are calculated from weather stations located in each province	Same as above
China (Wang et al. 2009)	8,405 households in 915 villages across 124 countries	Mean monthly temperature and precipitation calculated from 753 national meteorological stations located throughout China	Same as above
India (Jacoby et al. 2010)	Households from two national household surveys	Monthly temperature is daily gridded with a resolution of 1x1 based on 370 weather stations throughout India Precipitation data are from the district weather stations	Same as above
Ethiopia (Dercon and Krishnan 2000)	Panel household data from 15 villages in Ethiopia	Rain stations near the sample villages	

3. Improving LSMS survey instruments

Survey instruments that analyze farmers' adaptation decisions to weather variability should incorporate two key climatic phenomena: (a) the likelihood of increased short-term weather variability, as well as increased frequency and intensity of extreme weather events such as droughts and floods; and (b) the likelihood of long-term changes in weather patterns, including changes in rainfall patterns such as the delayed onset of rainy seasons and/or changes in average precipitation and temperature (Baez and Mason 2008).

The LSMS module design should, therefore, distinguish between short-term weather variability (intra-season and between seasons) and changes in long-term trends (rainfall patterns, mean temperature and average rainfall), although there likely exists an overlap between short-term and long-term adaptation options. In the context of short-term weather variability, the questionnaire design focuses on collecting household information on weather-related risk management and adaptation strategies. Data collection on household adaptation to longer-term climate change should focus on farmers' perceptions of weather variability over a 5-year period, adaptation actions undertaken, as well as the constraints and barriers facing farmers in the implementation of adaptation measures.

In the following sections, we present the key features of LSMS-ISA surveys, summarizing existing questions as well as missing questions related to adaptation to climate and water variability that should be included in the survey module for analyzing farmers' adaptation decisions.

3.1. Key features of LSMS-ISA surveys

Compared to standard LSMS surveys, the LSMS-ISA surveys have several additional features. First, the LSMS-ISA surveys are carried out every three years or less for at least two rounds to generate a panel data set, with baseline sample households tracked and revisited after the first survey.[4] Second, gender-specific questionnaire design is incorporated into the survey to facilitate gender-specific data collection and policy analysis on gender issues in agriculture and rural development.

Third, the survey implementation is designed to be closely linked with cropping seasons. In most countries, households are interviewed twice during the 12-month reference period, as opposed to only once as in the standard LSMS surveys. In Tanzania the surveys were conducted in a single post-harvest visit after the main cropping season. Two six-month agricultural seasons were captured with two post-harvest visits in each year in Uganda. In the rest of the countries, each round of surveys were divided into post-planting and post-harvest visits with respect to the main agricultural season.

Finally, the LSMS-ISA project also aims to collect household information that supports data validation experiments. For example, the measurement of selected plot size based on digital pictures produced by satellites will be validated against the ground measurement implemented during field work using GPS devices.

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[4] The interval between rounds and the number of rounds are different for different countries. For example, four annual surveys are planned for Uganda while two rounds with a three year interval are planned for Malawi.

The core indicators in the agriculture module cover the following areas[5]:

- Basic crop and livestock production, storage and sales
- Productivity of main crops
- Landholdings
- Access to and use of services, infrastructure, and natural resources
    - Agricultural extension services
    - Infrastructure
    - Credit
    - Market access
    - Access to information
    - Access to natural and common property resources
- Input use and technology adoption
- Shocks
- Farming practices
    - Mechanization
    - Soil and environmental management
    - Water management
    - Adaptation to climate changes

The community questionnaire covers topics such as access to public services and infrastructure, social networks, institutions, and retail prices.

Despite the strong focus on agriculture in the surveys in the LSMS-ISA program, significant gaps exist in the questionnaire design with regard to adaptation to climate change and variability. For example, the modules do not include sufficient questions for analyzing household adaptation behavior in response to short-term weather shocks and longer-term climate variability, particularly water resources stress and variability. The review of questionnaires of the LSMS-ISA project countries identifies four sources of data gaps, including (a) lack of data collection on farmers' perceptions of weather variability; (b) insufficient coverage of questions related to adaptation to weather variability and local water resource stress; (c) no data collection on households' access to weather forecast information before planting seasons; and (d) lack of survey instruments for collecting local water resource data. In the following sections, the existing and missing questions on adaptation to local water variability are summarized.

3.2. Existing questions on adaptation to water stress and variability

Household and Agriculture Questionnaires

The existing questions related to climate and weather changes can be grouped into two topics: (a) weather-related ex-ante risk management and adaptation, and (b) ex-post weather shocks and outcomes.

[5] The agriculture module is complemented by the core household module that includes household characteristics such as education and health of household members.

(a) Weather-related ex-ante risk management and adaptation:

   a. *Cropping practices:* All LSMS agricultural questionnaires ask farmers about different crops they plant in their various plots. The name of the crop is followed by questions about area planted and harvested, as well as questions about various input use.
   b. *Changes in cropping practices:* The agricultural questionnaires do not directly ask questions about changes in cropping patterns. However, the questionnaires contain detailed information about current cropping practice at the plot level.
   c. *Diversify crops to livestock and between different types of livestock:* Theory suggests that farmers may diversify from crops to livestock or between different types of livestock to adapt to climate changes. LSMS agricultural questionnaires collect data about both crop cultivation and livestock rearing.
   d. *Diversify to non-farm income sources:* LSMS agricultural and household questionnaires collect detailed information about farm and non-farm household income.
   e. *Irrigation at plot level:* LSMS agricultural questionnaires collect plot level information about access to and recent use of irrigation water. Some questionnaires identify irrigation systems by sources or types.
   f. *Soil and water conservation:* Soil and water conservation measures can be divided into long-term investments and short-term management practices. LSMS agricultural questionnaires focus on investments in soil and water conservation measures.

(b) Ex-post weather shocks and outcomes:

   a. *Reported floods and droughts in the last 5 years:* Some LSMS-ISA household questionnaires include a shocks section. This section collects data on many types of shocks. Floods and droughts are the only two shocks directly associated with changes in weather variability.
   b. *Loss of assets, income, and consumption:* The outcome of shocks is often measured as loss of assets, income, and consumption. LSMS household questionnaires collect data on such outcomes.
   c. *Coping Strategies:* LSMS household questionnaires sometimes collect data on coping strategies of households to mitigate shocks. These strategies may include consuming seed stock or taking up extra loans.

Community Questionnaire

(a) Principal economic activities in the village: Information collected about the principal economic activities in the village provides a community-level indicator of economic activities and their changes resulting from changes in weather variability.

(b) Access to irrigation water in the village: Some LSMS community questionnaires include information about irrigation and drinking water use at the village level. The data collected may not include details such as community-based water management institutions and water adequacy.

(c) Role of cooperatives for farmers in the village: Some LSMS community questionnaires include the role of farmer cooperatives in input provisions and product marketing.

3.3. Missing questions on adaptation to water stress and variability

The LSMS surveys in their current form do not include information about farmers' perceptions of weather variability, recall of weather, and access to and reliability of weather forecasts. The plot-level information on access to irrigation and their sources are collected, but key information on the availability of irrigation water sources that depends critically on local weather conditions (e.g. amount of precipitation during wet season, groundwater level) is not included. Quantitative measures of irrigation water use are also missing.

Household and Agriculture Questionnaires

(a) *Perception of weather variability in the last five years:* Though some LSMS household questionnaires include flood and drought information in the shocks section, the focus on such extreme weather situations ignore more subtle weather changes that may have significant effects on crops and livestock and how households may take various actions to mitigate these negative effects. Additional data should be collected in the following areas: (a) rainfall trends; (b) droughts and flood frequencies; and (c) delays in the start of the rainy season and early ends of the rainy season. A twenty-year recall is typically appropriate for capturing climate change trends; however, as recall data over such long periods may be inaccurate, a five-year recall period is advised (Maddison 2007).

(b) *Coping with perceived changes in rainfall patterns:* Coping strategies may range from planting drought-resistant seeds to changes in occupation or migration. Coping strategies may relate to a shorter period such as five years to reduce recall errors. These relatively long-term responses are distinct from short-term strategies used in the last cropping season discussed below.

(c) *Access to weather forecasts from various sources:* Access to weather forecast information is important for making informed farming decisions. It is important to understand how and where households get their weather forecasts. Understanding the specific sources for weather information used by farmers may allow policy makers to focus on specific weather information distribution channels.

(d) *Accuracy of forecasts:* Perceived accuracy of forecasts may affect households' adaptive decision making.

(e) *Access to expert advice on crop and livestock management based on weather forecasts:* Extension services, farmers' cooperatives, and public media may help households interpret weather forecasts and provide specific crop and livestock management strategies. Where literacy is low and information is scarce, expert advice may help guide farmers toward appropriate adaptation strategies.

(f) *Irrigation at plot level:* Irrigation can be an important strategy to cope with changing climate variations faced by farmers. LSMS agricultural questionnaires identify irrigated plots and their sources of irrigation water. However, the availability of irrigation water is dependent on cumulative rainfall. Understanding irrigation water use and its sustainability would require more data on water use quantities, and whether the irrigation water is adequate to meet farmers' current needs. Quantitative data on irrigation water use may be difficult to collect from small-scale irrigation delivery systems. The frequency of irrigation water may serve as a proxy for quantity if recall or diary-based data collection on the quantity of water use is not practical. Additional data are to be collected in the following areas: (a) details of irrigation water use (diary or recall); (b) frequency of irrigation water use; and (c) adequacy of irrigation water by different sources.

(g) *Crop cultivation:* All LSMS agricultural questionnaires include a detailed crop cultivation section with information about various crops cultivated at the plot level. However, there are a few key areas that need more attention in the context of farmers' adaptation to weather variability. For example, though different crops are identified, LSMS surveys do not collect data on crop varieties. The choice of different crop varieties is an important coping mechanism to weather and climate change. For example, famers may use drought-resistant varieties of crops if available when faced with the prospects of low rainfall.

(h) *Soil and moisture conservation and management:* Some LSMS survey crop sections include information about investments in soil and water conservation measures. Plot-level data on soil and moisture conservation and management measures are often not collected. These include covering of fallow land with cover crops. Cover crops may not have high harvest value, but they preserve soil moisture and may be used as fodder. Planting two or more different types of crops at the same time in the same plot (inter-cropping) is another moisture retention management technique. Though LSMS agricultural modules collect data on different crops planted on a plot, they do not distinguish between sequential cropping and inter-cropping. Additional data are to be collected in the following areas: (a) use of different (such as drought-resistant) varieties of seed; (b) investments in soil and water conservation measures (last five years); and (c) moisture conservation management (cover crops, fodder crops, inter-cropping). See the companion guidance note for details (McCarthy 2011).

(i) *Livestock:* The LSMS agricultural questionnaires include detailed information on livestock inputs, stock, products, and harvest. However, little information is collected on livestock management practices as they pertain to fodder and water conservation. Fodder crop cultivation in fallow plots serves the dual purpose of conserving soil moisture and feeding livestock. The water conservation in the plots may be improved if the fodder is cut and livestock is not allowed to graze directly on the fallow land. Community-based cultivation and storage of fodder (fodder banks) may be prevalent in some areas. In other regions, fodder and water scarcity may lead to seasonal migration of farmers and livestock. Households may increase their contribution to fodder banks or change their seasonal migration patterns when faced with changing weather variability. Additional data are to be collected in the following areas: (a) fodder crop cultivation on fallow land; (b) the practice of grazing on fallow land versus cut and carry fodder; (c) access to fodder banks; (d) contributions to fodder banks; and (e) seasonal migration with livestock due to fodder and water scarcity.

Community questionnaire

(a) *Local water resource availability and quantity measurement:* LSMS community questionnaires do not collect any data on the aggregate availability of local water resources at the village level. Rainfall is likely to be the main source of water in the wet seasons. Measurement of ground and surface water in the wet and dry season at the village level is needed for understanding farmer's adaptation in response to water constraints. Additional data are to be collected in the following areas:

   a. Rainfall and temperature
   b. Groundwater depths
   c. Surface water flows

(b) *Irrigation at village level:* Some LSMS community questionnaires collect information about access to irrigation at the village level. Community based irrigation management may be one of the coping strategies used by the villagers. Information about existing irrigation management institutions (e.g. public, private, or community managed) may provide useful insight on community-based adaptation measures. Information about adequacy of irrigation water will identify binding constraints and help frame available strategies. Additional data are to be collected in the following areas:

   a. Private, public, and community managed sources of irrigation water
   b. Adequacy of irrigation water at village level
   c. The month when water runs dry at the irrigation source

(c) *Community based fodder bank creation and maintenance:* Creation and management of fodder banks by community may help meet seasonal fodder scarcity in some areas. Community level fodder bank related questions are to complement household level fodder-related questions.

4. Guidance on survey design for collecting adaptation questions

4.1. Collecting data on farmers' perceptions and long-term adaptation responses

Perception data over a five-year recall period should be included in LSMS surveys for the purpose of understanding farm-level adaptation behavior. Perception data surveys are often conducted using open-ended questions. Farmers are asked whether they had noticed short and long-term changes in precipitation and temperature, the frequency of floods and droughts, and the distribution of rainfall during rainy seasons.

Past survey experience in collecting perception data on climate variability and long-term trends revealed several problems associated with perception data collection (Maddison 2007; Gbetibouo 2009). First, respondents can be influenced by interviewers when answering the weather-related questions. Some farmers may feel obliged to reply that they had witnessed some forms of weather variability, when in reality they had not. In addition, farmers often cannot provide a good assessment of the past climate trends over a long time horizon, such as 10–20 years, although they have a clear memory of extreme events that led to the destruction of crops and production.

For example, Maddison (2007) found that despite the fact that local weather records showed no evidence that precipitation had changed over Egypt, Kenya, and South Africa, a large number of farmers claimed that the climate had become drier over the past 20 years. Gbetibouo (2009) collected farm-level data from 795 households in the Limpopo River basin in South Africa for the 2004–05 farming season.

While data from weather stations showed no statistically significant trend in rainfall between 1960–2003, except for a substantial decrease between 2001 and 2003, he found that a high proportion of farmers thought there had been an overall decrease in precipitation throughout the full time period. This confirms the general belief that farmers place more weight on recent climate information, but may not be able to use long-term information in forming climate-related perceptions. In another study of the Danagou watershed in China, Hageback et al. (2005) found that farmers' perceptions of climatic variability corresponded relatively well with the climatic data records, although the sample size of 38 farmers is too small to draw firm conclusions.

Two clear patterns emerge from these studies. First, farmers are able to observe trends in temperature and rainfall patterns within a short period of time (e.g. about five years or less), but their long-term perceptions of climate trends (e.g. over 20 years) are likely to be unreliable, except for the timing of extreme events. Second, farmers in all the studies tended to claim that the climate is getting hotter and drier, which might be due to the fact that they anticipated what the interviewers wished to hear (Maddison 2007; Gbetibouo 2009; Thomas et al. 2007).

The above experience indicates that validation of perception data collected in household surveys is particularly needed. The validation can be carried out by comparing the perception data with weather data collected from weather stations or remote sensing techniques over a five-year period. It is also possible to validate farmers' perception data using different survey instruments. For example, both structured questions and semi-structured interviews (or focus groups) may be conducted for the purpose of cross-checking. The semi-structured interviews involve only key informants who have more local knowledge, typically people who work for local extension services.

4.2. Collecting data on adaptation to short-term climate variability

The perception module discussed above collects general information about household adaptation strategies using open-ended questions over a multi-year time frame. However, it is also important to collect more detailed questions on farm-level adaptation decisions—such as production adjustments, land and water use practices, and investments—within the LSMS survey implementation period (that is, after the planting and harvest seasons, which is likely to provide more reliable data because of the shorter time horizon). The panel nature of the surveys conducted under the LSMS-ISA project provides spatial and some temporal variations for analyzing a farmer's response to weather and water variability when the local weather data, particularly precipitation, can be collected and integrated into the household surveys. However, the short time-series aspect and the relatively short gap between the rounds of these surveys imply that changes in long term investment as a response to adaptation to climate change may not be adequately captured.

The LSMS survey design also includes a separate module to collect information on shocks that may have affected households over the past five years, although this module does not include sufficient questions on household responses to climatic shocks. Since the existing LSMS-ISA modules are already very lengthy and a significant amount of time is needed for respondents to complete the questionnaire, it is important to identify only the most relevant questions on local climatic and weather shocks to avoid substantially expanding the questionnaire. Augmented LSMS surveys with added adaptation-related questions for Niger and Nigeria are presented in Annexes 1 and 2.

The choice of Niger and Nigeria was driven by their respective differences in climate patterns and water resource management practices by smallholder farmers, which illustrate how different adaptation questions should be developed to adjust according to local conditions. Niger is a landlocked country with a typically hot and dry climate. The two distinct seasons include (a) a long dry season of eight months, and (b) a short rainy season of four months, which usually starts in May or June. The rainfall across the country is low, variable, and unpredictable. Cultivating crops and keeping livestock are the most important activities in the rural areas (practiced by 90 percent of the rural population). Agriculture in Niger is highly dependent on rain and irrigation is seldom practiced.

In contrast, Nigeria has a varied climate, with three distinct climate zones moving from the southern part to the northern part of the country. The southern region has an equatorial monsoon climate, the central region has a tropical humid climate, and the northern part of the country is characterized by a tropical dry climate. Although current irrigation use is far from reaching its full potential, Nigeria has a long tradition of irrigation practices. Three main categories of irrigation development exist in Nigeria today: (a) public irrigation schemes; (b) farmer-owned and operated irrigation schemes, which receive some government assistance and subsidies; and (c) traditional irrigation practices.

As illustrated by the modified Niger and Nigeria LSMS survey questionnaires in Annexes 1 and 2, the differences in the climate patterns, water resources, and agricultural practices between regions should be reflected in the questionnaire design for adaptation choices in response to local weather and water variability.

5. Measuring local water resources

5.1. Background

Local water resource availability is probably the most important determinant of incomes that households derive from crops and livestock in many rural areas. Depending on climatic and geographical conditions, local water resources can be present in different forms, including (a) precipitation, (b) surface water (lakes, streams, and rivers), and (c) groundwater.

Rainfall is only one form of precipitation; others include snow, hail, sleet, and droplets of water deposited from fog as dew. However, in lower and medium latitudes rainfall is by far the most predominant form of precipitation (Gunston 1998). In the following, precipitation and rainfall are used interchangeably. The availability of each of the forms of local water resources varies throughout the year and from year to year. Farmers may have access to one, several, or all of these resources.

Local water resource availability at any given time depends on the local hydrologic cycle, as depicted in Figure 2. Rainfall that falls on the watershed will (a) flow overland in the form of runoff feeding surface water bodies (lakes, streams, rivers); (b) infiltrate, replenishing soil moisture and potentially recharging groundwater; and (c) return to the atmosphere in the form of evapotranspiration.

An assessment of local water resources, therefore, should include measurement of rainfall, groundwater, and surface water and reflect their variability over time.

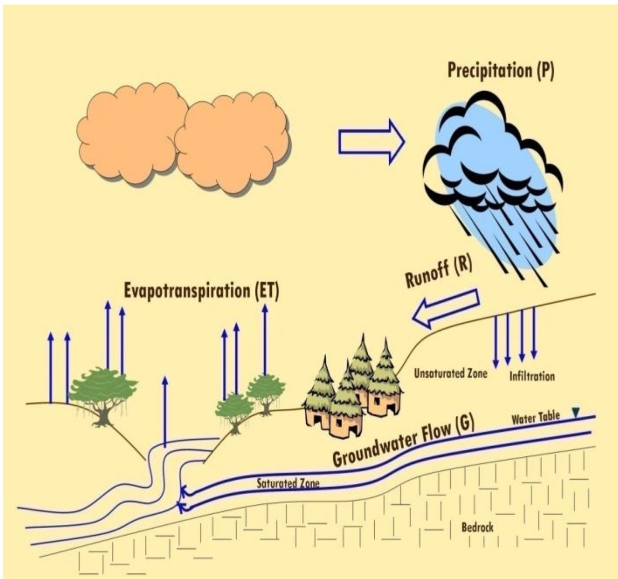

Figure 2. Local hydrologic cycle

***Source*: Shonsey (2009)**

5.2. Design of Water Resources Survey

Measuring water resource availability requires regular monitoring of the different components of the local water resources (rainfall, surface water and groundwater) throughout the farming seasons. Since the monitoring of each of the components involves the use of instruments of different levels of sophistication and requires a significant amount of time and resources, the water resources survey should be planned carefully. In addition, the storage, transfer and interpretation of measurement data requires additional resources in the form of equipment, communication costs and expert time which needs to be planned as well.

The logistics of the survey will depend directly on the scope of the survey, including the (a) number of rainfall measuring points and frequency of rainfall measurements; (b) number of surface water measuring points and frequency of surface water measurements; and (c) number of groundwater measuring points and frequency of groundwater measurements.

The resources needed in the form of manpower, equipment, transport, communication, and data processing can increase rapidly with the number of observation points and the frequency of measurement. It is important to plan the scope of the survey in such a way that the variability of the resource in time and in space is reasonably well-covered, without overly expanding the dimensions of the survey. The dimension of the water resource measurement component is closely related to the spatial and temporal variability of the different components of the water resources in the survey areas. In the case of LSMS surveys, villages—or the statistical enumeration areas—will be the unit of reporting.

Spatial variability

Spatial variability of rainfall depends primarily on the local climate and topography. In temperate climates, rainfall mainly follows the pattern of oceanic depressions and continental high-pressure areas. The amount of rainfall received changes gradually over an area. Under semi-arid and tropical climates, where a large share of rainfall falls during thunderstorms, spatial variability is generally much higher. Topography strongly influences rainfall patterns. If the survey areas have distinct and varied topographical features, the density of rainfall measuring points should be increased. As a basic rule of thumb, for tropical and semi-arid regions, one rainfall measuring point for every 1,000 km^2 is generally sufficient, although the density should be adapted to rainfall variability in the region and resources available. In the context of LSMS surveys, one rainfall measurement in each village is appropriate.

Surface water will not be available in all villages and may be monitored when available, but the same streams and rivers need not be monitored in each village. Groundwater is not available or accessible in all regions, depending on local geology, topography, the depth of the water table, and the availability of wells. Within similar geological units, groundwater availability generally varies gradually within a region. The best approach would be to select representative wells for different types of local conditions (wells with a shallow water table, deep water table, near rivers or streams, uphill, etc.).

Temporal variability

In general, rainfall, having the highest temporal variability, must be monitored more frequently throughout the year. Surface water shows a lesser degree of temporal variability; for the purposes of monitoring the availability of the resources (not flood monitoring), a lower frequency of measurement (e.g., weekly during planting seasons only) is sufficient. The temporal variability of groundwater is in most cases limited, so it can be measured a few times during the year. We suggest the following frequencies: (a) rainfall: daily; (b) surface water: weekly; and (c) groundwater: monthly.

Once the monitoring networks have been determined and the frequency of measurements for each component is well-defined, the logistics of the water measurement should be planned based on the following considerations:

- The duration of the period of measurement (rainy/cropping season).
- The use of trained villagers/farmers or survey teams to conduct the measurements.[6]

[6] The use of trained villagers/farmers to conduct the measurements has the advantage of involving them in the survey and making them more aware of resource variability. But such arrangements mean an increased number of instruments needed for measurement. For low frequency measurements like groundwater, it can be an option to

- The choice of different types of equipment to be used.
- The training of villagers/farmers or staff to be involved in the survey and quality control.
- The data processing—including data recording, transferring, interpretation, and storing—and the identification of qualified staff assigned to these tasks.

Rainfall

Rainfall is widely regarded to be the most challenging meteorological parameter to measure due to its spatial and temporal variability. Along the spatial dimension, rainfall can vary over very short distances, and the spatial variability of rainfall is further complicated by the interaction with the earth's surface. For example, rainfall can be enhanced on windward slopes or reduced on the sheltered side of hills and mountains (Kidd et al. 2009).

Reliable local rainfall measurement is a key indicator for measuring local water resource variability because of the predominance of rainfed agriculture in developing countries. In Africa, agricultural production and livestock activities rely heavily on rainfall for water supply, with less than 4 percent of cultivated land under irrigation (World Bank 2008). Consequently, small farmers are particularly vulnerable to fluctuations in precipitation levels and distribution.

Given the importance of local rainfall for agriculture, different data sources and techniques have been developed to estimate local rainfall. In general, local-level rainfall data can be obtained in several ways. These include direct measurement from rain gauges installed in the village, interpolation of local rainfall data from nearby weather stations, and rainfall estimation using various algorithms from remote sensing data or a combination of gauge and remote sensing data sources. This section focuses on rain gauge measurement. A review of recently developed techniques for measuring rainfall, focusing particularly on remote-sensing-based precipitation products, is presented in section 6.

Croplands in many areas, particularly in Africa, are characterized by low annual rainfall concentrated in one or two rainy seasons. Rainfall can be highly erratic, often characterized by very high rainfall intensity (such as convective storms) and extreme spatial and temporal variability (Rockstrom 2000). This leads to a high risk of annual droughts and intra-seasonal dry spells. The study of a semi-arid maize area in eastern Africa (Barron et al. 2003) shows that sufficient long dry spells (around 15 days) occurred in nearly three-quarters of the growing seasons, causing significant maize yield loss (up to 75 percent in some areas).

Daily measurement of local rainfall during planting/growing seasons is thus particularly critical to capturing local water availability from rainfall as well as for monitoring drought and food security. The importance of intra-seasonal factors indicates that detailed temporal and spatial weather data collection at the local level is also essential for understanding farmers' short-term adaptation strategies.

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use roaming survey teams that travel from survey point to survey point, reducing the number of water level measuring instruments to be purchased.

The rainfall data collection should include the timing of the onset of the rainy season, as well as the distribution and periodicity of rainfall events during the rainy season (Mortimore and Adams 2001; Usman and Reason 2004). Within the LSMS framework, daily rainfall monitoring can be conducted at selected sample households within each village or at the selected locations in the sampled villages (e.g. schools, churches, or community centers). The choice of village location for installing a rain gauge depends on the availability of community members (teachers, vicars, or community members) who can be assigned with the responsibility of recording daily rainfall data. Some precautions must be taken when selecting a site to install a rain gauge:

- Select an open area away from trees, houses, or other objects that may influence the amount of rainfall recorded due to turbulence and the effects of rain shadow.
- The rain gauge should be installed at a height ranging between 1 and 2 m above the ground.
- Select preferably a closed area to avoid vandalism or animals drinking collected water.

The rainfall measurement standards are also important to ensure reliability of rainfall data. It is important to follow the same protocol at all the observation points in the survey. Normally, rainfall readings are made in the early morning. A small amount of oil can be added to the rain gauge to reduce the effect of evaporation during the day. Observers should note the recorded rainfall amounts on paper records and send/transfer copies of the collected data sheets to the project office. If internet connections exist, the rainfall data can be directly entered and files can be easily transferred to the project office. The records, either digital or paper, should list the following basic information about the measuring station:

- Name of village and location within village
- If available, geographical coordinates (longitude, latitude) measured by GPS and elevation (in meters above sea level) that may be estimated from maps, digital elevation models, or GPS
- Year/month of recording
- Name of operator

Different models of rain gauges can be used depending on climatic zones. In tropical and semi-arid regions, the rain gauge should be selected based on the maximum expected daily amount of rainfall (to avoid overflowing in case of extremely heavy showers) but should at the same time be able to read smaller amounts of rainfall precisely during the dry season. Costs range from \$10 to \$30.

Digital rain gauges can record daily rainfall and total rainfall (weekly, monthly, or more) as well as temperature. They have the capacity for wireless transmission of rain and temperature data over a short distance (generally less than 100 m). The cost of these products is relatively low, ranging between \$50–70 (e.g., the RGR126 remote rain gauge produced in South Africa or the Oregon Scientific rain gauge produced in the United States). The relatively easy administration and low cost of the new rain gauges makes possible collecting local rainfall data with relatively high frequency (e.g. daily during the planting/growing season), as well as integrating local rainfall data collection into LSMS surveys.

Surface water

Surface water can be available in different forms, including rivers, streams, canals, lakes, village ponds, and other types of man-made reservoirs. Surface water storage systems are frequently managed at the village or community level, and the use of surface water is often regulated by user rights. Because of the wide variety of surface water bodies and regulations about their use, the assessment of available surface water resources to individual farmers should include questions regarding their membership of water use groups.

Surface water is naturally replenished by precipitation and lost through discharge to the oceans, evaporation, and subsurface seepage. For natural streams and rivers, records of streamflow or discharge are the basic data used in measuring reliable surface-water availability and temporal and spatial variability (Gunston 1998). Discharge (expressed in cubic meters per second) is the water flow rate at a specific cross-section of the river/stream (Maidment 1992). Discharge is generally determined at a gauging station by measuring the height of the water level at a fixed point (known as a *stage*) and calculating the corresponding discharge with the help of a rating curve that describes the relationship between stage and discharge for this particular gauging station. Gauging stations are generally constructed at geometrically controlled sections of a river either specifically constructed for measuring the streamflow or carefully selected (bridges or other infrastructures). The rating curve is determined by carefully measuring the streamflow via numerous measurements at different discharge rates using the velocity-area method. See Chapter 5 of Gunston's "Field Hydrology in Tropical Countries" for a more extensive technical discussion of streamflow measurement.

Currently, in situ gauge stations are the most cost-effective and reliable option for river discharge measurement at the national or subnational level in developed countries, but they are very sparsely distributed in Africa (Looser 2009). For very small streams, calibrated constructions/devices with known rating curves can be used to measure surface water. Remote sensing synthetic aperture radars (SAR) are considered suitable for estimating instantaneous discharge over bigger channels of rivers (Smith et al. 1996; Smith 1997), but are not generally regarded as suitable for smaller rivers/streams in a village setting (Looser 2009).

In the environment of dry and semi-arid regions of tropical and subtropical countries, many rivers/streams are seasonal and do not flow continuously throughout the year (Mati et al. 2006). For example, in seasonal rivers, water flow occurs only during rainy seasons. Therefore, the frequency of measuring streamflow should vary by season during the year. For example, during planting and growing seasons, streamflow should be measured daily or weekly, but should be measured monthly throughout the rest of year to capture intra-annual and intra-seasonal variation.

In general, measurement of the streamflow of natural rivers and streams is difficult and costly because it requires the establishment of permanent structures, unless in situ gauge stations are already installed. Moreover, surface water may be present in other bodies—like lakes, tanks, or ponds—where the discharge is not a good measure of surface water availability. Therefore, in the context of a household survey, it is recommended to simplify the assessment of surface water availability by recording qualitative parameters that would apply to all types of surface water bodies.

These records require the installation of a scale with centimeter or inch marks in the stream, lake, or pond that can be used to record only the water height on a relative scale, preferably the bottom of the water body as a measure of (a) the presence of water at a given date during the year; (b) the variation of water level between different dates; and (c) comparison between similar dates of different years (onset and duration of flow/storage).

The scale should preferably be attached to a permanent structure like a bridge, dam, or stairs. In their absence, a wooden pole can be installed in the water. The measurements can be recorded at the required time step and noted on a paper record. Paper records should mention basic data about the measuring station: (a) the name of the village and location (river name, pond, dam, etc.); (b) if available, geographical coordinates (longitude, latitude) measured by GPS and elevation (in meters above sea level) that may be estimated from maps, digital elevation models, or GPS; (c) the year/month of recording; and (d) the name of the operator.

A copy of recorded data should be sent to the project office at predetermined time intervals.

Given the monetary constraints associated with the implementation of large-scale LSMS-type surveys, conducting independent surface water measurements may well be unfeasible. Another complication may be related to the need for specialized survey staff, whose availability will be country-specific. If basic (qualitative) measurements cannot be realized, questions related to the availability of surface water can be integrated into survey modules, such as:

Q1. Did the river (NAME) have water flow during the entire rainy season? If yes => question 2; If no, how many weeks has the river been dry during the season?

Q2. Is the water flow in the river during the rainy season same/less/more than normal years?

Groundwater

Groundwater is present below the surface in most places on earth. However, depending on the geological, climatic, and topographical conditions, as well as economic constraints, groundwater may not always be easily accessible or exploitable with standard technical means. A subsurface layer that contains an exploitable amount of groundwater is called an aquifer. Aquifer recharge occurs through downward seepage of water from the surface, either as infiltrated rainwater that percolates through the unsaturated soil layers to the groundwater body, or as seepage from rivers or lakes. Natural aquifer discharge occurs through springs or by drainage into rivers, lakes, or the sea. In addition to natural drainage, groundwater in aquifers can be extracted through wells and boreholes. Depending on the local geology, several aquifers may be present (one on top of the other) and separated by impervious layers.

The total available volume of groundwater is difficult to determine. Generally, the available amount of groundwater is equal to the annual rate of groundwater recharge. Groundwater recharge and discharge cannot be measured directly; they are generally deducted from groundwater balance calculations. The characteristic of groundwater that can be most easily measured and that reflects changes in groundwater storage is the groundwater level. Groundwater levels can be measured in wells and boreholes. The groundwater level is measured by depth in meters below the surface and can be expressed as a height above sea level if the ground elevation is known. Expressing groundwater levels as elevation (in meters above sea level) makes it possible to determine groundwater flow directions. Monitoring of groundwater levels allows the estimation of groundwater temporal variability and spatial distribution.[7]

At the village level, groundwater monitoring activities involve measuring the water level of wells or boreholes. When boreholes are equipped with a hand pump or motor pump, measurement of the water level may not be possible (

Box 1). The recently developed small-size groundwater level probes with digital memory and a connection for data transmission are widely used in Europe, North America, Australia, and India (Jousma and Roelofsen 2004). However, these devices currently cost about $1,500 to $2,000 and thus may not be suitable for groundwater data collection as part of LSMS surveys.

Box 1. Water measurement instruments

Instruments	**Key Features**	**Cost ($)**
A measuring tape	The basic water-level measuring device is a steel tape, which is considered accurate at moderate depths	$50
A tape with electric sensor	Electric sensors are suspended on the end of a market cable. When the sensor encounters conductive fluid, the circuit is completed and an audible or visual signal is displayed at the surface	$100
Acoustic well probes	This device uses the reflective properties of sound waves to calculate the distance from the probe at the wellhead to the water surface. Acoustic probes are designed for well diameters as small as 4 inches and are limited to water depth greater than 25 feet	$100–$200
Source: (Jousma and Roelofsen 2004)		

For measurement of groundwater levels, representative wells in villages should be selected.[8] The number of wells should reflect the variability of the groundwater conditions. In regions where multiple aquifers exist, different monitoring wells should be selected tapping different aquifers, since each aquifer may act differently and more or less independently. Groundwater-level measurements can be recorded at the required time interval and noted on a paper or digital record, and should include the following basic data:

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[7] In many countries, systematic monitoring of groundwater quantity or quality, even at the subnational level, is extremely limited or nonexistent, according to the report produced by the International Groundwater Resources Assessment Centre (IGRAC) (Jousma and Roelofsen 2004).

[8] In coastal regions or regions with salinity problems, parameters such as groundwater conductivity should be monitored as part of the assessment of groundwater availability, although these measurements are not necessary in standard household surveys.

- Name of village and location (e.g., school, farm, etc.)
- Geographical coordinates (longitude, latitude) measured by GPS and elevation (in meters above sea level) that may be estimated from maps, digital elevation models, or GPS
- Type of well (open well, borehole), diameter of well, depth of well, and height of reference point above ground level
- Year/month of recording
- Name of operator

5.3. Implementation of water data collection

The village-level water resource data collection will need to be implemented at a different periodicity from the household surveys. Table 3 provides a template for local-level water data collection by water source, location, duration, and frequency.

Table 3. Village water resource measurement module

Water Source	Location	Duration	Frequency	Data type
Precipitation in the village:				
Rain	In village	Season or year-round	Daily during cropping season	Rain (mm) and Temperature
Public irrigation water sources:				
Wells	In village	Year-round	Weekly during dry/wet season, monthly rest of the year	Availability and depth of water (m)
Boreholes	In village	Year-round	Same as above	Availability
Ponds, Tanks	In village	Year-round	Same as above	Availability and depth of water
Rivers, Streams	In village	Year-round	Same as above	Availability and depth / water flow
Private irrigation water sources (Crop Card):				
Wells	Plot specific	Year- round	Monthly	Availability and depth of water
Boreholes	Plot specific	Year round	Monthly	Availability
Ponds, Tanks	Plot specific	Year round	Monthly	Availability and depth of water
Irrigation Water Use:				
Quantity of Water Used	Plot specific	Dry season and main planting seasons	Monthly	Whether have access Water sources/availability Total days of use

In general, the local water data need to be collected daily/weekly during planting and growing seasons. This is different from the time frame of LSMS surveys, in which households are visited twice during the survey period (post-planting and post-harvest seasons). The water module may use the diary method (similar to crop card), where daily or weekly rainfall and water resources data can be collected at the community level by appointed village members and submitted to the survey team personnel at required intervals. Data can be transferred to the project office by making paper copies or in digital format (by email if internet access is available, or by text through mobile phones). However, power or hardware failure may result in electronic data loss and keying data is a potential source for errors. Paper copies should be kept as backups and for quality control.

Village members that are selected for water resource monitoring tasks for the measurement of rainfall, surface water, or groundwater, need to be trained and quality control needs to be ensured by the survey team. Past experience shows that the measurement of water resources by trained villagers can be prone to various sources of error, despite the fact that the principles of measurements are clear and simple to follow. The water resources data – including rainfall, surface water, and groundwater – collected at all measuring points should be centrally managed by the household survey team.

Given the high volume of water resource data, it is important to establish a well-designed structure and/or geographic information system (GIS) that facilitates data storage, management, and interpretation in relation to the results of the household survey. Database/GIS management requires support by a trained technician or expert.

6. Remote sensing techniques for local precipitation measurement

In recent decades, advances in satellite remote sensing data techniques have made it possible to generate precipitation products across the globe at a relatively high temporal and spatial resolution (Kidd et al. 2009). One of the advantages of satellite precipitation estimates is their global coverage and closeness to real time, providing rainfall information in regions where gauge observations are absent or sparsely located (Gruber and Levizzani 2008). In Africa, the rain gauge measurement networks are particularly sparse, unevenly distributed, and often unreliable. Any significant improvement in the ground-based gauge measurement in Africa is unlikely in the near future due to resource limitations, as well as the lack of institutional set-up for systematic collection of climate information (Dinku et al. 2008). Remote sensing products thus provide a potentially important alternative to supplementing the traditional methods of using networks of rain gauges and weather radar systems for rainfall monitoring.

6.1. Key sources of satellite data

The remote-sensing-based precipitation products are generated by combining information from a wide range of data sources. These include satellites – infrared images (IR), microwave images such as the special sensor microwave imager (SSM/I), radars such as the tropical rainfall measuring mission (TRMM) – and rain gauges installed on the ground (Kidd 2001; Dinku et al. 2007; Adeyewa and Nakamura 2003).

Dinku et al. (2007) provide a review of the ten most widely used satellite products. Box 2 summarizes the key features of these satellite rainfall products, including temporal and spatial resolution and the period of data availability. The detailed information for the satellite centers that produce these precipitation products is summarized in Box 3.

Box 2. Satellite precipitation products

Products		**Temporal resolution**	**Spatial resolution** (degree°)	**Availability period** starting
(1)	***Global Precipitation Climatology Project (GPCP)***	monthly	2.5°	1979
	(http://www.gewex.org/gpcp.html)	5-day (pentad)	2.5°	1979
		daily	2.5°	1979
(2)	***National Oceanographic and Atmospheric Administration (NOAA) - Climate Prediction Center (CPC)***			
	CPC Merged Analysis of Precipitation (CMAP)	5-day	2.5°	1979
		monthly	2.5°	1979
	RFE	daily	0.1°	2001
	ARC	daily	0.1°	1995
(3)	***The Climate Prediction Center morphing method (CMORPH)***	30 minutes	8 km	2002
	(http://www.cpc.ncep.noaa.gov/products/fews/data.html)			
(4)	***Tropical Rainfall Measuring Mission (TRMM)***			
	(http://precip.gsfc.nasa.gov/rain_pages/3hrly.html)			
	TRMM-3B42	3-hourly	0.25°	1998
	TRMM-3B43	monthly	0.25°	1998
(5)	***TAMSAT (http://www.met.reading.ac.uk/~tamsat/data/rfe.html)***	10-day	0.0375°	1993
		monthly	0.0375°	1993
		seasonal	0.0375°	1993

Source: Dinku et al. (2007)

In Africa, satellite rainfall estimates have been considered a promising solution for providing adequate temporal and spatial rainfall coverage (Kidd 2001). Several recently developed techniques use multiple satellites to estimate rainfall over Africa. Over the Sahelian region of West Africa alone, satellite rainfall estimation techniques include the Tropical Applications of Meteorology using SATellite and other data sources (TAMSAT), the Polar-orbiter Effective Rainfall Monitoring Integrative Techniques (PERMIT), the

Agricultural Drought Monitoring Integrated Technique (ADMIT), the Environmental Analysis and Remote Sensing methods (EARS), and TRMM (Lamptey 2008).

Box 3. Satellite Centers

NOAA-Climate prediction Center (NOAA-CPC) products include CMAP, RFE, ARC, and CRORPH.

CMAP is the Climate Precipitation Center Merged Analysis of Precipitation data set. The precipitation estimates are produced from rain gauges, merged with precipitation estimates from several IR and PMW satellite-based algorithms. For detailed information, see Xie and Arkin (1997).

RFE is developed by CPC for the USAID Farming Early Warning Systems (FEWS) to support drought monitoring activities over Africa. RFE Version 2 (RFE2) has been operational since 2001. The data inputs for the RFE2 algorithm include estimates from passive microwave sensors (PM), Infrared (IR) data from METEOSAT, and daily rainfall data from Global Telecommunication System (GTS) stations (Herman et al. 1997).

ARC is very similar to RFE. Its objective is to present daily precipitation over Africa. The data input is similar to RFE . It uses 3-hourly instead of 30 minutes, but does not use PM estimates (Love et al. 2004).

CRORPH dataset is based on the Climate Precipitation Centre morphing technique. This relatively new method combines different PM rain estimates and IR information and produces global precipitation analysis at very high spatial (8km) and temporal (20 min) resolution (Joyce et al. 2004).

TRMM products, including 3B42 and 3B43, use information from a multi-satellite precipitation analysis algorithm. The input into TRMM products are IR data from geostationary satellites, and various advanced microwave information (Huffman et al. 2003).

TAMSAT products are produced by the TAMSAT group at Reading University in the UK. The TAMSAT method is based on the assumption that cold cloud-top temperatures of tropical storms identify raining clouds. The TAMSAT has been used extensively for operational and real-time rainfall monitoring for Northern Africa since 1988 and for Southern Africa since 1993 (Thorne et al. 2001).

6.2. Reliability

While satellite-based rainfall estimates have many attractive features, they are indirect estimates of rainfall and can be subject to large measurement errors. In the case of IR algorithms, the rainfall measurement is inferred based on the position and the cloud-top temperature. Although passive microwave imagers can provide more direct inferences of precipitation based on cloud liquid and ice content, they suffer from poor temporal sampling – most polar-orbiting satellites provide a full scan of the earth less than once per day (Sapiano and Arkin 2009).

In addition, the reliability of satellite based precipitation products depends on many local factors, such as the level of elevation, climate regions, and the local topography (Ali et al. 2005). Validation of satellite rainfall estimates against gauge data is thus much needed to provide some level of confidence in using satellite data for the end users. This is particularly relevant for researchers who intend to combine local rainfall data with household surveys for conducting policy analysis.

The Program to Evaluate High Resolution Precipitation Products was established in 2003 under the auspices of the International Precipitation Working Group. This program aims to evaluate, compare, and validate the various high-resolution satellite-based precipitation products across the globe (Turk et al. 2008). Table 4 summarizes the key findings from the global validation studies that have been published in science journals, covering a wide range of countries, including Ethiopia, West Africa, Mali, Senegal, Burkina Faso, Sahel region, the United States, Bangladesh, and India.

These validation studies are carried out by evaluating rainfall estimates from different satellites against the "ground truth" under the assumption that direct gauge observations are more reliable. In reality, gauge observations differ over different parts of the globe in numerous ways, including data quality and the length of observations, data quality checking and error correction procedures, and interpolation techniques. Caution is advisable in interpreting findings from validation studies that cover regions where the gauge observations are likely of lower quality, which is likely the case in many parts of Africa.

The complex topography of Africa shows that the findings of validation results can vary by region and by season. For example, over the Ethiopia highlands, the performance of these products (TRMM-3B43 and CMORPH) is best during the wettest season (June to August), and relatively poor during the dry season (December to February) (Dinku et al. 2007). The study for five climatic regions in Africa also confirms that TRMM precipitation estimates are only reliable in the wettest seasons of the northern savanna and southern semiarid regions (Adeyewa and Nakamura 2003). In general, validation studies of satellite-based precipitation products over specific geographic and climatic regions are particularly useful in providing information both for the product developers and users of these products (Dinku et al. 2008) because of the sensitivity of these products to local conditions.

The general consensus that can be reached from the assessment of the existing global validation studies is that satellite-based precipitation products that are based on combinations of infrared images, passive microwave images, and ground-gauge observations are most successful in measuring local rainfall (Dinku et al. 2008; Dinku et al. 2007; Yin et al. 2004; Ali et al. 2005). These products include TRMM-3B43, CMORPH and TAMSAT, and CMAP. Kidd et al. (2009) conclude that precipitation products derived from satellite observations have reached a high level of maturity over the past decade. The ongoing research and development that aims to address the accuracy and the resolution of these products will further enhance the potential to use satellite information for local-level water resource assessment.

6.3. Access to satellite data

Many of the satellite products can be accessed through the public domain satellite data archives free of charge. Below is an illustration of the procedures needed for accessing RFE daily precipitation estimates produced by CPC of NOAA.

- Step 1: Go the website http://www.cpc.ncep.noaa.gov/products/fews/data.shtml

The website provides a technical description of different rainfall estimates in Box 4.

Box 4. Africa rainfall estimation 2.0, technical description

daily estimates:	01/01/2001–current		
10-day totals:	12/01/1999–current		
Mozambique RFE:	01/01/2002–current		
GrADS tools:	.gs script	.ctl file	other items
other:	daily readme	10-day readme	
	convert_rfe2.f (header incl)		

- Step 2: Select the rainfall estimate by time, i.e. filename (all_products.bin.YYYYMMDD)

YYYY == 4 digit year
MM == month
DD == date

The description of the data:

rain == daily precipitation analysis by merging
GTS gauge observations and three kinds of satellite estimates
(GPI,SSM/I, and AMSU); units are in millimeters (mm)

Data files are written in binary data format and consist of one record (one array) of floating point rainfall estimates in mm (after unzipping). Each array equals 751*801 elements, pertaining to 751 pixels in the x direction, and 801 pixels in the y direction. After reshaping to a 0.1 degree grid, this will yield a spatial domain spanning -40S to 40N in latitude, and -20W to 55E in longitude, encompassing the Africa continent. Missing data is denoted as -999.0.

- Step 3: Use the program to download the data

Example program

program : example.f
objective : to read the daily estimates dimension rain(751,801)

1. Open the data file

```
open  (unit=10,file='all_products.bin.20000601', #
access='direct',status='readonly',recl=751*801)
```

2. Read the data

```
read (10,rec=1)   rain

stop
end
```

The downloaded daily precipitation estimates can be then matched with sample villages included in an LSMS sample using the GIS code.

6.4. Suggestions for data collection

The availability of low-cost modern rain gauges and advances in remote-sensing-based precipitation products that provide global and high-resolution precipitation estimates make local-level validation studies possible. In particular, the spatial resolution of the satellite-based products may have become less a concern, with several precipitation products (including RFE, ARC and CMORPH) achieving a high spatial resolution of 0.1 x 0.1 (degree) (covering an area of about 11 km x 11 km). Such a level of resolution is likely adequate for measuring village-level precipitation in many rural areas.

However, the choice of methods for collecting local rainfall data in the context of household surveys remains an open question. On the one hand, the newly developed rain gauges, such as the RGR126 remote rain gauge or the Oregon Scientific rain gauge – which record daily rainfall for up to nine days with the capacity for wireless transmission of rainfall data – enable survey teams to record daily rainfall (during planting and growing seasons) with relatively low implementation costs. But the feasibility of scaling up such operations to collect village rainfall data for national household surveys remains to be field tested.

On the other hand, while the satellite precipitation products can be downloaded freely from the internet, the reliability of these products at the village level has yet to be validated. The only study (Hafeez et al. 2007) found in the literature, which assesses the precipitation data generated from TRMM using rain gauges distributed within 1–2 km at the Tamale site, in the Volta basin of West Africa, confirms good agreement between TRMM and gauge data with a goodness of fit of 0.99. Local-level validation studies that cover a wide range of local conditions (e.g., climate conditions, the level of elevation and the types of topography) in Africa are necessary to provide users with some degree of confidence about the reliability of remote-sensing-based precipitation products for local rainfall estimates.

This suggests that the collection of village-level weather data using rain gauges as part of LSMS data collection is particularly important for validation purposes. The sample village selection for collecting local rainfall data should take into account that the reliability of rainfall estimates depends on local geographical conditions, one of the key findings of the validation studies. One possible village sample selection is through stratification based on local geographical features, such as climate, the level of elevation and the types of topography across LSMS survey countries. Integrating village rainfall data collection into the LSMS module provides an important data source for validating satellite precipitation products in a wider range of climatic and geographical conditions in Africa, which would help further assess the feasibility of using remote sensing techniques for village-level rainfall monitoring.

7. Conclusion

This note has attempted to provide some guidance for developing a set of key questions and modules to improve the LSMS survey instruments for collecting data on smallholder farmers' adaptation decisions in response to both long-term and short-term (intra-season and cross-season) weather and water resource variability. The questionnaire design is intended to collect data for addressing key policy questions in the area of climate change and adaptation, including: (a) Are farmers aware of short and long-term weather variability? (b) What types of adaptation strategies do farmers adopt? (c) What factors determine small farmers' specific adaptation choices? and (d) What types of public policies are effective in enhancing the capability of households to adapt to and cope with increased weather variability and water stress caused by warming temperature?

The design of survey instruments is based on the conceptual framework developed in this note, which outlines the channels through which climate variability and other economic factors impact household decisions on the adoption of various adaptation strategies. The development of the key questions draws on a large body of literature that has recently emerged in the area of household adaptation to climate variability as well as several existing household surveys.

The sample questions 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 water resources.

The most serious data gap for understanding household adaptation behavior to climate variability is the lack of local water resource measurement, in particular precipitation, given that the majority of farmers in low-income countries depend on rainfed agriculture. It is thus particularly valuable to record lessons learned from the field testing of survey instruments for measuring local water resources. The rapid advances in remote-sensing-based precipitation products have created the opportunity to cost-effectively monitor local water resources, as well as to integrate such information with household surveys. The overview of major satellite products presented in this note should be regarded as an introduction. As technologies and new satellite products for climate monitoring are constantly evolving, readers can stay abreast of new products by conducting online searches for the most recent precipitation products. In short, this note should serve as a generic guidance. It will be a living document that should be updated regularly with the release of new lessons learned from field testing and new information on various climate monitoring technologies.

Table 4. Key findings from validation studies of satellite based rainfall data

Country	Key findings	Rain gauge data	Satellite data	Reference
Ethiopia	At low resolution (monthly and 2.5), TRMM-3B43 performs better than GPCP and CMAP; at high resolution (10-day and 1, 0.5 or 0.25), CMORPH performs better. TAMSAT performs as well as CMORPH and better than TRMM-3B42 and REF.	120 stations from National Meteorological Agency of Ethiopia (1990-2004)	GPCP, CMAP,TRMM-3B43, RFE, TAMSAT, CRORPH	Dinku et al. (2007)
All Africa	All satellite estimates generate larger bias in the dry seasons when rainfall is minimal. TRMM 3B43 has the closet agreement with rain gauge data.	from Global Precipitation Climatology Centre (GPCC) based on 540 stations	TRMM-3B43, GPCP-1DD, TRMM PR	Adeyewa and Nakamura (2003)
West Africa (Volta Basin)	Good agreement between TRMM and gauge data with a goodness of fit of 0.99.	rain gauges distributed below 1-2 km at the Tamale site	TRMM	Hafeez et al. (2007)
West Kenya	Good agreement between RFE and gauge observation with Rsq=0.8.	134 stations during long rain season (March-May) 1996-98	RFE	Funk and Verdin (2003)
Mali, Senegal and Burkina Faso	RFE and ARC performed the best overall: particularly good at detecting a rain event and identifying the magnitude of rainfall for weak and extreme totals.	133 weather stations during the summer season 2008,	RFE, ARC, TRMM 3B42, CROMRPH, PERSIANN,TAMSAT	Novella et al. (2009)
Sahel region	CMAP is the better product overall, followed by GPCC, GPCP, and GPI. All these products underestimate the frequency of small rain, which is better documented by gauge networks.	650 rain gauge data from the Comite Inter-Etats de Lutte Contre la Secheresse au Sahel (CILSS) network	GPCP, CMAP, GOES	Ali et al. (2005)
U.S. land and tropical Pacific Ocean	CRORPH and TRMM are effective at measuring high-resolution precipitation; biases are high over land and oceans, with a general tendency to overestimate warm season rainfall over land.	rain gauge data over southern Great Plains	CORPH, TRMM Multisatellite Precipitation Analsysi (TMPA), NESDIS, NRL, and PERSIANN	Sapiano and Arkin (2009)
U.S. land	The comparison is based on the explanatory power of temperature and precipitation measures on land values. Satellite temperature does a better job of describing the farmland values across U.S. landscapes than data from weather stations, but ground station precipitation data are more significant than the satellite wetness index in the regression of land values.	5511 weather stations (Jan, April, July and Oct 1961–90)	US Defense Meteorological Satellite Program (DMSP) from 1987–2002	Mendelsohn et al. (2007)
Bangladesh	TRMM products are able to measure up to 97 percent of the surface rain in Bangladesh, although they tend to overestimate the rain dates in the pre-monsoon period, but underestimate them in the monsoon period.	Gauge data from Bangladesh Meteorological Dept (1998–2002)	TRMM-3B42, 3B43	Islam and Hiroshi (2007)
India	GPCP and TRMM-3B42-v5 may be considered inadequate for measuring rainfall in India; 3B42-v6 measurement of mean monsoon rainfall are reasonably close to the observed patterns from gauge data.	daily rainfall data set with 1x1 grid based on 1803 stations over India land (1951–2003)	GPCP, TRMM-3B42	Rahman and Sengupta (2007)

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Annex 1. Adaptation Modules for LSMS-ISA: Niger

Introduction

Rising global temperatures are likely to impact local climate through two climatic phenomena (Baez and Mason 2008). First, many regions will experience an increased short-term weather variability (e.g. precipitation and water availability during the rainy season) and increased frequency and intensity of extreme weather events (i.e. droughts and floods). Second, there will be long-term changes in weather patterns, including changes in rainfall patterns (e.g. delayed onset of rainfall and/or changes in average precipitation and temperature).

In the context of short-term weather variability, information on weather-related risk management at the household level is critical. Survey instrument design in this area (e.g. IFPRI surveys) is limited. The proposed work will focus on identifying gaps in existing LSMS survey instruments and developing a module for collecting information on risk management, coping, and adaptation to short-term weather-related risks. The second dimension of climate change is about long-term adaptation. LSMS surveys can be used to collect farmers' perceptions about long-term climate change and their adaptation strategies, but based on existing studies, the reliability of such information decreases as the length of the recall period increases beyond five years; a five-year recall period for weather variability perceptions is therefore recommended.

The following outlines the key information on (1) weather-related risk management, and (2) adaptation to climate variability, to be incorporated into the existing LSMS modules for pilot testing:

1. Access to weather information before and during planting season

a. Farmers' access to weather information before/during planting season

b. Information sources and reliability

2. Farmers' recall of weather during planting season

a. Onset of rainfall (late, early, on time)

b. Quantity relative to long-term average (significantly below, slightly below, average, slight above, and significantly above)

c. Distribution during the season

3. Household-reported shocks during past 5 years (existing module)

4. Outcome of shocks (existing module)

a. Loss of asset

b. Loss of income

c. Food shortage

d. Decline in consumption (panel data needed)

5. Weather-related risk management and adaptation questions (ex-ante risk management)

a. Cropping practices **(existing module)**

b. Different varieties of the same crop

c. Different crops, and from single to multiple crops **(existing module)**

d. Livestock practices

e. Fodder cultivation and fodder banks

f. Diversification from crops to livestock and between different types of livestock **(existing module)**

g. Diversification to non-farm income sources **(existing module)**

i. Usage of alternative land management practices

j. Investment in soil and water conservation

k. Water use

6. Weather variability perceptions

General Instructions

The following questions are to be inserted in the Post-Harvest Questionnaire for Panel Households (Visit 2) of the General Household Survey, Niger. The questions follow the order of insertion in the main module.

Conventions

Section and question number refer to the original questionnaire such as Section 3: LAND, Q24. Modifications to existing questions are in ***bold italics.***

New questions in an existing section have two-part numbers. The first part refers to the original question, after which the new question is to be inserted. The second part refers to the order of insertion. For example, Q27 +2 indicates that this is the second question to be inserted after question 27.

Similarly, new sections have two-part numbers. The first part refers to the original section, after which the new section is to be inserted. The second part refers to the order of insertion. For example, **SECTION 3.1 WATER** indicates it is the first section to be inserted after Section 3.

Insertion points are marked by a ***italicized header*** that refers to topics in the introduction section. These are for our references and are not to be inserted in the main module.

(Insertion locations and related information are in parentheses.)

New section titles where needed are in **BOLD CAPS**.

Section and question numbers are to be modified on the basis of their final location.

5. Weather-related risk management and adaptation questions: Water use

(Insert in **Visit 1** Section 1: ACCESS TO LAND)

- Modify code for Q35 as: 1=River, Stream, 2=Lake, Pond, 3=Well, 4=Boreholes, 5=Other, 6=Not Applicable
- Modify code for Q36 as: 1=River, Stream, 2=Lake, Pond, 3=Well, 4=Boreholes, 5=Rain, 6=Other, 7=Not Applicable
- Insert between Q35 and Q36.

	35.+1		35.+2	35.+3	35.+4
Plot ID	How many times (per season /month /week) did you irrigate this [PLOT] in the last dry season?		Was there sufficient water in the irrigation system of this [PLOT] in the last dry season?	If no, did you use any other sources of water for the crops in this [PLOT] in the last dry season?	If yes, what was the second most important source of water for this [PLOT] in the last dry season?
	Number	Per unit: 1-Season 2-Month 3-Week 4-Day 5-Other (Specify)	YES….1 >> Q36 NO….2	YES….1 NO….2 >> Q36	1=River, Stream 2=Lake, Pond 3=Well 4=Boreholes 5=Other 6=Not Applicable

5. Weather-related risk management and adaptation questions: Fodder cultivation

(Insert in **Visit 1** Section 1: ACCESS TO LAND between Q39 and Q40)

	39.+1	39.+2	39.+3	39.+4
Plot ID	Have you planted any cover crop (to retain soil and moisture) while you keep this [PLOT] fallow?	Have you planted any fodder crop while you keep this [PLOT] fallow?	Does your livestock graze on fallow during the time this [PLOT] is lying fallow?	Is the fodder from this [PLOT] cut and carried to feed livestock?
	YES…1 NO…2	YES…1 NO…2	YES…1 NO…2	YES…1 NO…2

5. Weather-related risk management and adaptation questions: Different varieties of same crops, fodder cultivation

(Insert in **Visit 1** Section 2B: TYPE OF CROPS AND SEEDS USED DURING THE RAINY SEASON)

- Modify codes for Q7 to include code for fodder crops as well as sorghum and cow pea varieties known by local names, particularly local and hybrid varieties resistant to drought, pests, etc.
- Insert two questions between Q8 and Q9 and then one question between Q10 and Q11:

	8.+1	8.+2	10.+1
Plot ID	Did you incorporate crop residue, mulching, green manure, or cover crop before planting on this [PLOT]?	Did you use contour planting or contour plowing on this [PLOT]?	Why did you use this type of seed in this [PLOT]?
	YES…1 NO…2	YES…1 NO…2	1=Only type available 2=Needs less water (drought resistant) 3=Pest resistant 4=Disease resistant 5=High yield 6=Other (Specify____)

Note: These modifications can be made for both visit 1 and 2.

5. Weather-related risk management and adaptation questions: Different varieties of same crops, fodder cultivation

(Insert in **Visit 1** Section 3B: TYPE OF CROPS AND SEEDS USED DURING THE OFF-SEASON)

- Insert two questions between Q6 and Q7 and then one question between Q7 and Q8:

	6.+1	6.+2	7.+1
Crop ID	Did you incorporate crop residue, mulching, green manure, or cover crop before planting this [CROP]?	Did you use contour planting or contour plowing with this [CROP]?	Why did you use this type of seed for this [CROP]?
	YES…1 NO…2	YES…1 NO…2	1=Only type available 2=Needs less water (drought resistant) 3=Pest resistant 4=Disease resistant 5=High yield 6=Other (Specify____)

Note: These modifications can be made for both visit 1 and 2.

5. Weather-related risk management and adaptation questions: Livestock practices and fodder banks

(Insert new section between Sections 4E and 5) **SECTION** 4F **– LIVESTOCK: ACCESS TO FODDER AND WATER**

1	In the last 12 months did you have access to any communal fodder banks?	YES…………..1 NO…………..2 >> Q7	
2	Did you use the communal fodder bank in the last 12 months?	YES…………..1 NO…………..2 >> Q7	
3	Which months did you use the communal fodder banks?	Month code below	
4	Did you contribute to the maintenance of the communal fodder bank in the last 12 months?	YES…………..1 NO…………..2 >> Q7	
5	How did you contribute?	Cash…………………………1 In kind (seed, sapling, manure etc)……………..2 Labor……………………….3 Other (specify_____) ………………..……………..4	
6	How much did you contribute in total in the last 12 months? [IF IN KIND, LABOR, OR OTHER, ESTIMATE VALUE IN CFA FRANC]	CFA Franc	
7	In the last 12 months, did you need to move any cattle to different grazing sites because of scarcity of fodder or water?	YES, both fodder and water…………………………1 YES, fodder only………..2 YES, water only………….3 NO……………………………..4	
8	How many times did you move the cattle?	Number	
9	In which months did you move the cattle?	Month code below	

MONTH CODE: Jan=1, Feb=2, Mar=3, Apr=4, May=5, Jun=6, Jul=7, Aug=8, Sep=9, Oct=10, Nov=11, Dec=12

10.	Did the whole household move to a different location in the last dry season?	YES……….1 NO………..2 >>Q18	
11.	How far did the household move?	Distance: _________ Unit: _________	
12.	In which month and year did the household start to move to the dry season location?	Month: __________ Year: __________	
13.	In which month and year did the household return to the current location?	Month: __________ Year: __________	
14.	Did the move to the dry season locations include any livestock?	YES………..1 NO…………2 >> NEXT SECTION	
15.	How many cattle went with the household?	Number	
16.	How many cattle returned with the household?	Number	
17.	Did any member of the household move to a different location in the last dry season?	YES………..1 NO…………2 >> NEXT SECTION	

Questions 18-23 refer to each member of the household (or household members above 10 or some good cutoff age)

Member ID	10. How far did the member move?		11. In which month and year did the member start to move to the wet season location?		12. In which month and year did the member return to the current location?		13. Did the move to the wet season location include any cattle?	14. How many cattle went with the member?	15. How many cattle returned with the member?
	Distance	Unit	Month	Year	Month	Year	YES……….1 NO……….2 >> NEXT ROW		

1. Access to weather information

(Insert this new section between section 6 and 7) **SECTION 6+1: WEATHER**

	1	2	3	4	5		6
Source	Did you receive information about the forecasted date of onset of the rainy season from this [source]?	How would you classify the forecasted rainfall for this season from this [source]?	If yes, was the forecast of expected rainfall accurate?	Did you receive information about the forecasted amount of rain from this [source] before the planting season?	How often do you get weather forecasts from this [source]?		Did you use any of the advice and information about when to plant crops from this [source]?
	YES…1 NO…2	Poor rain…..1 Good rain….2 Heavy rain…3	YES…1 NO…2	YES…1 NO…2	Number	PER DAY…1 WEEK…….2 MONTH…3 SEASON…4	YES…1 NO…2
State agricultural extension services							
NGO							
Cooperative							
Producers' Association							
Supplier							
Neighbor or Relative							
Electronic media (TV, Radio, etc.)							
Mobile phone service							
Paper media							
Other (Specify___________)							

6. Weather variability perceptions

SECTION 6+1: WEATHER (Continued from previous page)

Long-term changes in weather and adaptation undertaken

			1.			2.	3.
	[Change]		Over the last 5 years have you noticed [change]?		[Adaptation]	Has any member of your household [made adaptation] to cope with long-term shifts in temperature?	Has any member of your household [made adaptation] to cope with long-term shifts in rainfall?
		CODE				YES…1 NO…2	YES…1 NO…2
a.	No change in rain	…1		a.	Changed crop variety		
	Less rain	…2		b.	Built a water harvesting scheme		
	More rain	…3		c.	Bought insurance		
d.	More frequent droughts	YES…1 NO…2		d.	Planted shade trees		
e.	More frequent floods	YES…1 NO…2		e.	Irrigated more		
f.	Delay in the start of the rainy seasons	YES…1 NO…2		f.	Changed from crop to livestock		
g.	The rainy seasons end sooner	YES…1 NO…2		g.	Increased number of livestock		
h.	No change in number of hot days	…1		h.	Reduced number of livestock		
	Increase in hot days	…2		i.	Migrated to another area		
	Decline in hot days	…3		j.	Found off-farm jobs		
				k.	Leased your land		

2. Farmers' recall of weather during planting season

SECTION 6+1: WEATHER (Continued from previous page)

4.	In your view did the rainy season begin early, on time, or late this year?	Early…………………………………………………1 On time…………………………………………….2 Late…………………………………………………3		
5.	In which month did the rainy season begin this year?	January……………..1 February…………..2 March……………...3 April…………………4 May………………….5 June………………….6	July……………………7 August………………8 September……….9 October…………..10 November……….11 December……….12	
6.	How would you characterize the amount of rain in the rainy season this year relative to the average rainy season?	Significantly below average……………………1 Slightly below average…………………………..2 Average…………………………………………………3 Slight above average…………………………….4 Significantly above average……………………5 Do not know…………………………………………6		
7.	In which month in the rainy season this year did you get the most rain?	January……………..1 February…………..2 March……………...3 April…………………4 May………………….5 June………………….6	July……………………7 August………………8 September……….9 October…………..10 November……….11 December……….12	

5. Weather-related risk management and adaptation questions: Water Use

(Insert in **Visit 2** Section 1: ACCESS TO LAND)

- Modify code for Q36 as: 1=River, Stream, 2=Lake, Pond, 3=Well, 4=Boreholes, 5=Rain, 6=Other, 7=Not Applicable
- Insert between Q36 and Q37

	36.+1		36.+2	36.+3	36.+4
Plot ID	How many times (per season /month /week) did you irrigate this [PLOT] in the last wet season?		Was there sufficient water in the irrigation system of this [PLOT] in the last wet season?	If no, did you use any other sources of water for the crops in this [PLOT] in the last wet season?	If yes, what was the second most important source of water for this [PLOT] in the last wet season?
	Number	Per unit: 1=Season 2=Month 3=Week 4=Day 5=Other (Specify)	1=Yes >> Q36 2=No	1=Yes 2=No >> Q36	1=River, Stream 2=Lake, Pond 3=Well 4=Boreholes 5=Rain 6=Other 7=Not Applicable

5. Weather-related risk management and adaptation questions: Fodder cultivation and fodder banks

(Insert in **Visit 2** Section 2E: QUANTIFICATION OF RAINY SEASON PRODUCTION ACCORDING TO CROP TYPE)

- Modify codes for Q6 to include code for fodder crops as well as sorghum and cow pea varieties known by local names, particularly local and hybrid varieties resistant to drought, pests, etc.
- Add follow-up questions for fodder crops after Q31.

	31.+1	31+2	31.+3	31.+4
Plot ID	Did the livestock graze on fallow, on crop residue, or fodder crop in this [PLOT] since the last interview?	ENUMERATOR: USING CROP CODES FROM Q6 FILL IN THE ANSWER*:* Was [PLOT] planted with fodder crops?	During which months did the livestock use crop residue or fodder from [PLOT]? ENTER ALL MONTHS	Is the fodder from this [PLOT] cut and carried to feed livestock?
	YES…1 NO…2	YES…1 NO…2 (>> NEXT SECTION)	January…1 February…2 March…..3 April………..4 May………5 June………..6 July……….7 August…….8 Sept…….9 Oct…………10 Nov…….11 Dec………..12	YES…1 NO…2

HOUSEHOLD QUESTIONNAIRE

Insert in SECTION 2 PART A: EDUCATION AND ACCESS TO INFORMATION TECHNOLOGY

- Add the following choices to Q2.30. For what reasons has [NAME] used the internet during the last 12 months?
    - (a) Weather and rainfall forecast, (b) Crop cultivation advice, (c) Livestock advice.

COMMUNITY QUESTIONNAIRE

Insert and modify in SECTION 5: AGRICULTURE

- Note: Q5.9 and Q5.33 are similar. Drop Q5.33.

Insert after Q5.9:

5.9+1.	How many farmers practice irrigated agriculture?	Number	
5.9+2.	Are the main sources of irrigation water owned by private individuals?	1=Yes, 2= No	
5.9+3.	What is the most important source of irrigation water for this community?	1=River, Stream, 2=Lake, Pond, 3=Well, 4=Boreholes, 5=Other	
5.9+4.	Is water available year-round from this most important source of irrigation water?	1=Yes, 2= No	
5.9+5.	If not, during which month does the water run dry in this most important source of irrigation water?	Jan…1 Feb…2 Mar…3 Apr…4 May…5 Jun…6 Jul…7 Aug…8 Sep…9 Oct…10 Nov…11 Dec…12	
5.9+6.	During which month did the water run dry in this most important source of irrigation water 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	

Q5.10 and 5.30 are similar. We suggest dropping 5.10 and keeping 5.30.

Annex 2: Adaptation Modules for LSMS-ISA: Nigeria

Introduction

Rising global temperatures are likely to impact local climate through two climatic phenomena (Baez and Mason 2008). First, many regions will experience an increased short-term weather variability (e.g. precipitation and water availability during the rainy season) and increased frequency and intensity of extreme weather events (i.e. droughts and floods). Second, there will be long-term changes in weather patterns, including changes in rainfall patterns (e.g. delayed onset of rainfall and/or changes in average precipitation and temperature).

In the context of short-term weather variability, information on weather-related risk management at the household level is critical. Survey instrument design in this area (e.g. IFPRI surveys) is limited. The proposed work will focus on identifying gaps in existing LSMS survey instruments and developing a module for collecting information on risk management, coping, and adaptation to short-term weather-related risks. The second dimension of climate change is about long-term adaptation. LSMS surveys can be used to collect farmers' perceptions about long-term climate change and their adaptation strategies, but based on existing studies, the reliability of such information decreases as the length of the recall period increases beyond five years; a five-year recall period for weather variability perceptions is therefore recommended.

The following outlines the key information on (1) weather-related risk management, and (2) adaptation to climate variability, to be incorporated into the existing LSMS modules for pilot testing:

1. Access to weather information before and during planting season

a. Farmers' access to weather information before/during planting season

b. Information sources and reliability

2. Farmers' recall of weather during planting season

a. Onset of rainfall (late, early, on time)

b. Quantity relative to long-term average (significantly below, slightly below, average, slight above, and significantly above)

c. Distribution during the season

3. Household-reported shocks during past 5 years (existing module)

4. Outcome of shocks (existing module)

a. Loss of asset

b. Loss of income

c. Food shortage

d. Decline in consumption (panel data needed)

5. Weather-related risk management and adaptation questions (ex-ante risk management)

a. Cropping practices **(existing module)**

b. Different varieties of the same crop

c. Different crops, and from single to multiple crops **(existing module)**

d. Livestock practices

e. Fodder cultivation and fodder banks

f. Diversification from crops to livestock and between different types of livestock **(existing module)**

g. Diversification to non-farm income sources **(existing module)**

i. Usage of alternative land management practices

j. Investment in soil and water conservation

k. Water use

6. Weather variability perceptions

General Instructions

The following questions are to be inserted in the Post-Harvest Questionnaire for Panel Households (Visit 2) of the General Household Survey, Nigeria. The questions follow the order of insertion in the main module.

Conventions

Section and question number refer to the original questionnaire such as Section 3: LAND, Q24. Modifications to existing questions are in ***bold italics.***

New questions in an existing section have two-part numbers. The first part refers to the original question after which the new question is to be inserted. The second part refers to the order of insertion. For example, Q27 +2 indicates the second question to be inserted after question 27.

Similarly, new sections have two-part numbers. The first part refers to the original section, after which the new section is to be inserted. The second part refers to the order of insertion. For example, **SECTION 3.1 WATER** indicates it is the first section to be inserted after Section 3.

Insertion points are marked by a ***italicized header*** that refers to topics in the introduction section. These are for our reference and are not to be inserted in the main module.

(Insertion locations and related information are in parentheses.)

New section titles where needed are in **BOLD CAPS.**

Section and question numbers are to be modified on the basis of their final location.

5. Weather-related risk management and adaptation questions: Different varieties of same crops, fodder cultivation

(Modify in Section 3: LAND page 13)

- Modify Questions 24 and 25 to include fodder crops.
- Modify codes for Q25 to include codes for fodder crops as well as food crop varieties known by local names, particularly local and hybrid varieties resistant to drought, pests, etc.

	24	25
Plot ID	Did you plant any ***fodder or food*** crops on this [PLOT] during the last dry season (since the last interview)?	What ***fodder or food*** crop did you mainly plant on this [PLOT]? USE CROP CODE
	YES…1 No…2 >>SECTION 4	CROP CODE

Note: These modifications can be made for both visit 1 and 2.

5. Weather-related risk management and adaptation questions: Use alternative land management practices

(Insert in Section 3: LAND page 14 between Q27 and Q28)

	27.+1	27.+2	27.+3
Plot ID	Did you incorporate crop residue, mulching, green manure, or cover crop before planting on this [PLOT] since the previous interview?	Did you use contour planting or contour plowing on this [PLOT] since the previous interview?	Did you use zero tillage or deep tillage on this [PLOT] since the previous interview?
	YES…1 NO…2	YES…1 NO…2	YES…1 NO…2

Note: These questions can be added to both visit 1 and 2.

5. Weather-related risk management and adaptation questions: Fodder cultivation and fodder banks

(Add follow-up questions for fodder crops after Q29)

	29.+1	29+2	29.+3	29.+4
Plot ID	Did the livestock graze on fallow, on crop residue, or fodder crop in this [PLOT] since the last interview?	ENUMERATOR: USING CROP CODES FROM Q25 FILL IN THE ANSWER*:* Was [PLOT] planted with fodder crops?	During which months did or will the livestock use fodder from [PLOT]? ENTER ALL MONTHS	Is the fodder from this [PLOT] cut and carried to feed livestock?
	YES…1 NO…2	YES…1 NO…2 >> SECTION 4	January….1 February…2 March……3 April………..4 May………5 June……….6 July……….7 August……8 Sept….…9 Oct….…..10 Nov….….11 Dec………12	YES…1 NO…2

5. Weather-related risk management and adaptation questions: Water use

(Insert new section between SECTION 3: LAND and P4: HARVEST LABOR) **SECTION 3.1 WATER**

	S11bQ24.	S11bQ25.	S11bQ26.	1.		2.	3.	4.
Plot ID	Is this [PLOT] irrigated? Prefilled from previous survey	What is the source of water on this plot? Prefilled from previous survey:	What is the system of irrigation on this [PLOT]? LIST UPTO 2 Prefilled from previous survey:	How many times (per season /month /week) did you irrigate this [PLOT] since the last interview?		Was there sufficient water in the irrigation system of this [PLOT] since the last interview?	If no, did you use any other sources of water for the crops in this [PLOT] since the last interview?	If yes, what was the second most important source of water for this [PLOT] since the last interview?
	YES…1 NO…2 >> NEXT SECTION	Well…………..1 Borehole…..2 Lake/natural pond…………3 Created pond…………4 River/ stream……..5 Other (specify)…..6	Divert stream…………1 Bucket…………2 Hand pump….3 Treadle pump…………..4 Motor pump…5 Gravity…………6 Shadouf……….7 Sprinkler………8 Other (specify)………9	Number	Per unit: 1=Season 2=Month 3=Week 4=Day 5=Other (Specify)	YES…1 >> NEXT SECTION NO…2	YES…1 NO…2 >> NEXT SECTION	Well…………..1 Borehole…..2 Lake/natural pond…………3 Created pond…………4 River/ stream……..5 Other (specify)……6

SECTION 3.1 WATER (Continued from previous page)

If the crops you cultivated received any form of irrigation in the last 12 months, please answer the following: (ENTER IN THE TABLE BELOW)

5. How many days in [MONTH] did you irrigate this [PLOT]?

6. How many hours per day in [MONTH] did you irrigate this [PLOT]?

7. What was the flow rate per hour in [MONTH] for this [PLOT]? (Select flow rate unit here)

HEAPS PER HOUR ………………….1
RIDGES PER HOUR……..............2
STANDS PER HOUR………………..3
PLOTS PER HOUR…………………..4
ACRES PER HOUR…………………..5
HECTARES PER HOUR……………6
SQUARE METERS PER HOUR….7
OTHER (SPECIFY)_______.........8

SECTION 3.1 WATER (Continued from previous page)

			1	2	3	4	5	6	7	8	9	10	11	12
Plot ID			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Plot 1	5.	No. of days in the month												
	6.	No. of hours per day												
	7.	Flow rate/hour												
	8.	Depth in mm												
	9.	Water amount applied/day												
Plot 2	5.	No. of days in the month												
	6.	No. of hours per day												
	7.	Flow rate/hour												
	8.	Depth in mm												
	9.	Water amount applied/day												
Plot 3	5.	No. of days in the month												
	6.	No. of hours per day												
	7.	Flow rate/hour												
	8.	Depth in mm												
	9.	Water amount applied/day												
Plot 4	5.	No. of days in the month												
	6.	No. of hours per day												
	7.	Flow rate/hour												
	8.	Depth in mm												
	9.	Water amount applied/day												
Plots 5	5.	No. of days in the month												
	6.	No. of hours per day												
	7.	Flow rate/hour												
	8.	Depth in mm												
	9.	Water amount applied/day												
Plot 6	5.	No. of days in the month												
	6.	No. of hours per day												
	7.	Flow rate/hour												
	8.	Depth in mm												
	9.	Water amount applied/day												

5. Weather-related risk management and adaptation questions: Livestock practices and fodder banks

(Insert new section between Sections P7 and P8) **SECTION P7+1 -ANIMAL: ACCESS to FODDER and WATER**

1.	In the last 12 months did you have access to any communal fodder banks?	YES………………1 NO………………2 >> Q7	
2.	Did you use the communal fodder bank in the last 12 months?	YES………………1 NO………………2 >> Q7	
3.	Which months did you use the communal fodder banks?	MONTH CODE BELOW	
4.	Did you contribute to the maintenance of the communal fodder bank in the last 12 months?	YES………………1 NO………………2 >> Q7	
5.	How did you contribute?	Cash……………………………1 In kind (seed, sapling, manure etc)……………….2 Labor…………………………..3 Other (specify_____)….4	
6.	How much did you contribute in total in the last 12 months? [IF IN KIND, LABOR, or OTHER, ESTIMATE VALUE IN NAIRA]	NAIRA	
7.	In last 12 months, did you need to move any cattle to different grazing sites because of scarcity of fodder or water?	YES, both fodder and water……………………………1 YES, fodder only………..…2 YES, water only……………3 NO………………………………4	
8.	How many times did you move the cattle?	NUMBER	
9.	In which months did you move the cattle?	MONTH CODE BELOW	

MONTH CODE: Jan=1, Feb=2, Mar=3, Apr=4, May=5, Jun=6, Jul=7, Aug=8, Sep=9, Oct=10, Nov=11, Dec=12

5. Weather-related risk management and adaptation questions: Investment in soil and water conservation

(Insert this new section between section 15 and 16): **SECTION 15+1: SOIL AND WATER CONSERVATION**

	1.	2.	3.	4.	5.	6.	7.	8.
Plot ID	Did you invest in terraces in this [PLOT] in the last 12 months?	How much did you invest in terraces in this [PLOT] in the last 12 months?	Did you invest in stone bunds in this [PLOT] in the last 12 months?	How much did you invest in stone bunds in this [PLOT] in the last 12 months?	Did you invest in drains or ditches in this [PLOT] in the last 12 months?	How much did you invest in drains or ditches in this [PLOT] in the last 12 months?	Did you invest in barriers/fences (live) in this [PLOT] in the last 12 months?	How much did you invest in barriers/fences (live) in this [PLOT] in the last 12 months?
	YES….1 NO….2 >> Q3	NAIRA	YES….1 NO….2 >>Q5	NAIRA	YES….1 NO….2 >> Q7	NAIRA	YES….1 NO….2 >> NEXT SECTION	NAIRA
Plot 1								
Plot 2								
Plot 3								
Plot 4								
Plot 5								
Plot 6								

Note: This table of questions should also be included in the post-planting implementation of the survey after Q28 in section 11B-LAND INVENTORY

1. Access to weather information

(Insert this new section between section 15 and 16) **SECTION 15+2: WEATHER**

	1.	2.	3.	4.		5.	6.
Source	Did you receive information about the forecasted date of onset of the rainy season from this [source]?	If yes, was the forecast of expected rainfall accurate?	Did you receive information about the forecasted amount of rain from this [source] before the planting season?	How often do you get weather forecasts from this [source]?		Did you use any of the advice and information about when to plant crops from this [source]?	Do you get advice and information on **livestock activities** from this [source]?
	YES…1 NO…2	YES…1 NO…2	YES…1 NO…2	Number	Per day…1 Week…2 Month…3 Season…4	YES…1 NO…2	YES…1 NO…2
Government agricultural extension service							
Private agricultural extension service							
Government fishery extension service							
NGO							
Agricultural COOP /farmers' association							
Lead farmer							
Peer farmer (Neighbor/Relative)							
Electronic media (TV, Radio, etc)							
Paper media							
Other (Specify___________)							

6. Weather variability perceptions

SECTION 15+2: WEATHER (Continued from previous page)

			4.			5.	6.
	[Change]		Over the last 5 years have you noticed [change]?		[Adaptation]	Has any member of your household [made adaptations] to cope with long-term shifts in temperature?	Has any member of your household [made adaptations] to cope with long-term shifts in rainfall?
		CODE				YES…1 NO…2	YES…1 NO…2
a.	No change in rain	…1		a.	Changed crop variety		
	Less rain	…2		b.	Built a water harvesting scheme		
	More rain	…3		c.	Bought insurance		
d.	More frequent droughts	YES…1 NO…2		d.	Planted shade trees		
e.	More frequent floods	YES…1 NO…2		e.	Irrigated more		
f.	Delay in the start of the rainy seasons	YES…1 NO…2		f.	Changed from crop to livestock		
g.	The rainy seasons end sooner	YES…1 NO…2		g.	Increased number of livestock		
h.	No change in number of hot days	…1		h.	Reduced number of livestock		
	Increase in hot days	…2		i.	Migrated to another area		
	Decline in hot days	…3		j.	Found off-farm jobs		
				k.	Leased your land		

2. Farmers' recall of weather during planting season

SECTION 15+2: WEATHER (Continued from previous page)

4.	In your view did the last rainy season begin early, on time, or late?	Early……………………………………………………1 On time………………………………………………2 Late……………………………………………………3		
5.	In which month did the last rainy season begin?	January……………..1 February…………..2 March………………3 April…………………4 May…………………..5 June…………………..6	July……………………7 August………………8 September……….9 October…………..10 November……….11 December……….12	
6.	How would you characterize the amount of rain in the last rainy season relative to the average rainy season?	Significantly below average…………………1 Slightly below average…………………………2 Average…………………………………………….3 Slight above average……………………………4 Significantly above average…………………5 Do not know…………………………………………6		
7.	In which month in the last rainy season did you get the most rain?	January……………..1 February…………..2 March………………3 April…………………4 May…………………..5 June…………………..6	July……………………7 August………………8 September……….9 October…………..10 November……….11 December……….12	