AGRICULTURAL ADAPTATION TO CLIMATE CHANGE IN THE SAHEL:
AN APPROACH TO EVALUATING THE PERFORMANCE OF AGRICULTURAL PRACTICES

JULY 2014

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African and Latin American Resilience to Climate Change (ARCC)

JULY 2014
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<td>CAN</td>
<td>Aménagement en Courbes de Niveau</td>
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<tr>
<td>ARCC</td>
<td>African and Latin American Resilience to Climate Change</td>
</tr>
<tr>
<td>BCA</td>
<td>Benefit-Cost Analysis</td>
</tr>
<tr>
<td>CC</td>
<td>Climate Change</td>
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<tr>
<td>CCAFS</td>
<td>Climate Change, Agriculture and Food Security Challenge Programme</td>
</tr>
<tr>
<td>CEA</td>
<td>Cost-Effectiveness Analysis</td>
</tr>
<tr>
<td>CGIAR</td>
<td>The Consultative Group on International Agricultural Research</td>
</tr>
<tr>
<td>DIARPA</td>
<td>Diagnostic Rapide Pré-Aménagement</td>
</tr>
<tr>
<td>DSSAT</td>
<td>Decision Support System for Agrotechnology Transfer</td>
</tr>
<tr>
<td>EPIC</td>
<td>Erosion Productivity Impact Calculator</td>
</tr>
<tr>
<td>FEER</td>
<td>Fonds de l'eau et de l'équipement rural</td>
</tr>
<tr>
<td>FMNR</td>
<td>Farmer Managed Natural Regeneration</td>
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<tr>
<td>GCM</td>
<td>Global Circulation Models</td>
</tr>
<tr>
<td>ICRISAT</td>
<td>International Crops Research Institute for the Semi-Arid Tropics</td>
</tr>
<tr>
<td>IPCC/AR5</td>
<td>Intergovernmental Panel on Climate Change Fifth Assessment Report</td>
</tr>
<tr>
<td>ITCZ</td>
<td>Intertropical Convergence Zone</td>
</tr>
<tr>
<td>MCA</td>
<td>Multi-Criteria Analysis</td>
</tr>
<tr>
<td>MCC</td>
<td>Millennium Challenge Corporation</td>
</tr>
<tr>
<td>NGO</td>
<td>Nongovernmental Organization</td>
</tr>
<tr>
<td>PDS</td>
<td>Pierres Dressées avec Sous-Solage</td>
</tr>
<tr>
<td>RAISE Plus</td>
<td>Rural Agricultural Income and Sustainable Environment Plus Program</td>
</tr>
<tr>
<td>SOM</td>
<td>Soil Organic Matter Content</td>
</tr>
<tr>
<td>SRI</td>
<td>System of Rice Intensification</td>
</tr>
<tr>
<td>SST</td>
<td>Sea Surface Temperatures</td>
</tr>
<tr>
<td>SWOT</td>
<td>Strengths, Weakness, Opportunities, and Threats Analysis</td>
</tr>
<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
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<tr>
<td>USD</td>
<td>United States Dollars</td>
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</table>
ABOUT THIS SERIES

THE STUDIES ON CLIMATE CHANGE VULNERABILITY AND ADAPTATION IN WEST AFRICA

This document is part of a series of studies produced by the African and Latin American Resilience to Climate Change (ARCC) project that address adaptation to climate change in West Africa. Within the ARCC West Africa studies, this document falls in the subseries on Agricultural Adaptation to Climate Change in the Sahel. ARCC has also developed subseries on Climate Change and Water Resources in West Africa, Climate Change and Conflict in West Africa, and Climate Change in Mali.

THE SUBSERIES ON AGRICULTURAL ADAPTATION TO CLIMATE CHANGE IN THE SAHEL

Upon the request of the United States Agency for International Development (USAID), ARCC undertook the Sahel series of studies to increase understanding of the potential impacts of climate change on agricultural productivity in the Sahel and to identify means to support adaptation to these impacts. Other documents in the Agricultural Adaptation to Climate Change in the Sahel series include: An Approach to Conducting Phenological Screening, Profiles of Agricultural Management Practices, A Review of 15 crops Cultivated in the Sahel, Expected Impacts on Pests and Diseases Afflicting Selected Crops, and Expected Impacts on Pests and Diseases Afflicting Livestock. Two documents produced under the Climate Change in Mali subseries are also related to this study: Organizational Survey and Focus Groups of Adaptive Practices and Impact Modeling of Selected Agricultural Adaptive Practices.

AN APPROACH TO EVALUATING THE PERFORMANCE OF AGRICULTURAL PRACTICES

ARCC produced An Approach to Evaluating the Performance of Agricultural Practices in conjunction with the companion paper, An Approach to Conducting Phenological Screening. The objective of the latter study was to develop and describe an approach to using phenological screening to gain a better understanding of how changes in rainfall and temperature might affect crop productivity in the Sahel. In the present study, ARCC responds to a parallel USAID request to develop an approach to better understand the effectiveness of adaptive measures currently being adopted by rural producers in the Sahel, as well as how this effectiveness may be affected by climate change.

The approach described in the current document proposes three basic components to an evaluation of adaptive practices: defining expected changes in climate, defining adaptation objectives and identifying the practices to be assessed, and conducting the evaluation of the defined practices. Further ARCC studies in the Agricultural Adaptation to Climate Change in the Sahel series complete elements of the approach for a specific location in the region of Mopti, Mali. Profiles of Agricultural Management Practices contributes to the definition of adaptation objectives and the Organizational Survey and Focus Groups of Adaptive Practices helped identify the practices to be assessed. Finally, the study Impact Modeling of Selected Agricultural Adaptive Practices implements a form of technical evaluation of practices. In this study, researchers present the process and results of an effort to model the impact of climate change on the productivity of crops and four corresponding agricultural practices grown under four soil types in the Mopti region of Mali.
EXECUTIVE SUMMARY

Climate change (CC) will impact the performance of agricultural systems worldwide. In different locations, some practices will become less useful and others more effective. Understanding how these changes will impact agriculture in the Sahel will be important for governments, donors, research institutions, and other organizations investing in helping farmers to adapt their agricultural practices in response to changing weather conditions.

The assessment of agricultural adaptation is a potentially vast area of inquiry. Factors that will influence the success of adaptive measures include international trade, domestic policies, large-scale infrastructure investments, the strength and functioning of research and extension organizations, and local social structures, among others. This paper focuses on the assessment of the tools and management techniques that offer farmers viable alternatives in adjusting their agricultural systems in response to the biophysical stressors of CC. It proposes an approach for assessing the adaptive capacity of practices being promoted to assist farmers in the southern Sahel and sub-Saharan zones (400–750 mm of rainfall), in response to the anticipated slight increase in precipitation levels, rising temperatures (.5–1.0°C), and increased frequency of extreme events (floods, droughts, and heat waves) by 2025.

The paper reviews current literature and presents an overall framework, as well as specific steps for conducting an evidence-based evaluation of the performance of agricultural practices commonly promoted to address the conditions of expected climate change in the Sahel. The proposed approach contains three general steps:

1. Defining dominant features of future climate conditions (2025) and stressors that adaptive agricultural practices must respond to;

2. Identifying the adaptive practices to be assessed, creating “adaptation profiles” of each practice, and defining farmers’ adaptation objectives and prioritizing practices for assessment; and

3. Selecting/developing assessment procedures for the different classes of practices and carrying out the evaluation of the responsiveness of adaptive practices to anticipated CC conditions.

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1 The term “adaptive practice(s)” is used throughout this report to refer the assemble of tools, techniques, and management options that are being offered to, and developed by, farmers as a means of making adjustments to their farming systems in response to climate change.

2 These zones are selected as they represent the most climatologically insecure areas where rainfed crop-based agriculture predominates. While cultivation takes place in areas receiving less the 400mm of annual rainfall (e.g., northern Sahel, 250–400 mm), it is of declining importance as one transitions to drier areas.
1.0 OVERVIEW OF ADAPTIVE AGRICULTURAL PRACTICES IN THE SAHEL

Agriculture in the Sahel is inherently “diverse, complex, and risk-prone,” and farmers in the sub-region have long struggled to respond to challenging environmental conditions. Depending on the location and year, they face either moisture or soil fertility constraints as their central challenge (Brower and Bouma, 1997). The majority of crop-based agricultural technologies that have been developed and extended generally target these constraints and can be loosely clustered into three categories responsive to climate stressors—moisture capture, supplemental water supply, and soil fertility enhancement. Many of the technologies contribute to more than one core function, while others represent composite technology packages, composed of several related practices. Example practices include contour plowing, zai holes, rock-lines, check dams, compost and manure applications, and conservation agriculture.

The list is not static. Historically, farmers have been the major source of adaptive practices within the sub-region (Simpson, 1999); they will likely continue to lead the development of additional practices as further climate change (CC) impacts materialize.
2.0 THE THREE ELEMENTS OF THE PROPOSED APPROACH

Historically, much effort has been expended in developing research methods to assess agricultural innovations. Formal methodologies include the use of:

- Crop, soil, and hydrologic models;
- On-station and on-farm trials managed by researchers, on-farm trials managed by farmers, and on-station trials managed by researchers and assessed by farmers; and
- National and sub-regional multi-locational trials (used to assess the off-station performance of crop varieties to various stresses, and determine recommendation domains), among others.

The diversity of assessment methods reflects the multiple goals new agricultural technologies are asked to meet (see Table 2.1).

<table>
<thead>
<tr>
<th>Research Goals</th>
<th>Example Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing farm profits</td>
<td>Partial and whole-farm budgeting</td>
</tr>
<tr>
<td>Productivity increases or loss reduction</td>
<td>Plot, station, field trials</td>
</tr>
<tr>
<td>Reduction in the use of scarce resources</td>
<td>Deficit irrigation modeling</td>
</tr>
<tr>
<td>Reduction in negative environmental impacts</td>
<td>Environmental impact assessments</td>
</tr>
<tr>
<td>Achievement of equity goals</td>
<td>Gender assessments</td>
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</tbody>
</table>

The remainder of the paper focuses on assessing the adaptive potential of practices to mediate the impact of CC on the biophysical responses of crops. As a result, this approach represents only a portion of the overall assessment considerations that will need to be employed before investment decisions are made. In particular, it excludes the assessment of contextualizing factors that reside beyond the immediate focus on the field, farm, agro-ecological zone, commodity value-chain, or national levels, often outside of the agricultural sector. Such external factors can have a profound influence on the immediate and long-term viability of the intervention choice ultimately made.

The proposed approach contains the three following elements:

1. **Future climate parameters:** The first task concerns defining the potential future climate(s) to which agricultural practices must adapt, and over what time period. The development of evidence-based climate scenarios is essential in order to establish a concrete statement of the forcing elements against which the relative “adapted-ness” of different practices is measured. First-order CC indices are weather-related parameters, such as temperatures (daytime/nighttime highs and lows) and precipitation patterns (inter-annual volumes and intra-seasonal distribution). These can include interpreted values, such as “seasonality,” and “extreme events,” involving the definition of what constitutes “season,” “drought,” “excessive,” and so on, as well as the anticipated temporal on-set of these conditions. The ability to assess the adaptive-ness of alternative practices accurately will improve with the accuracy and specificity of these climate parameters.
2. **Adaptation objectives:** The second essential element in carrying out an adaptation assessment involves the definition of the criteria used to answer the question of “how we will know when adaptation has been achieved?” Imbedded within this question is the issue of whose perspective is used in determining the objective(s)—farmers’, researchers’, policy-makers’, or donors’. Seemingly simplistic in nature, defining what constitutes “adaptation” is critical as it establishes the measures against which technologies and practices are assessed. Criteria can be first-order physical changes, such as increased moisture infiltration; second-order biophysical changes, such as crop responses to physical changes in the environment; or tertiary measures, such as changes in farm profitability. In general, the higher in the impact chain one goes (soil, to crop, to farm) the more additional variables are involved, and the greater the difficulty in attribution. In addition, farmers also assess innovations with regard to other factors (risk, resource demands, tenure considerations, etc.); thus farmers’ inclusion in setting the assessment objectives is critical if selected technologies are to enjoy widespread adoption.

3. **Assessment method(s):** The third element required is the selection method(s) used in examining the “goodness-of-fit” of specific technologies with regard to anticipated climatic conditions and the adaptation objective(s). Choices (influenced by time and money) that affect the depth and quality of the assessment outcomes will need to be made.

In following sections, these critical elements are addressed in turn.
3.0 ELEMENT 1: THE DEFINITION OF FUTURE CLIMATE PARAMETERS

3.1 CLIMATE PARAMETERS

3.1.1 Expected Climate Change in the Sahel

The specific features of CC in West African Sahel have been covered in detail in previous African and Latin American Resilience to Climate Change (ARCC) documents and elsewhere (Baptista et al., 2013; Jalloh et al., 2013). To summarize, few, if any, land areas on the planet present a more difficult challenge in terms of understanding precipitation patterns. Rainfall in the Sahel is driven principally by the annual north-south movements of the Intertropical Convergence Zone (ITCZ) drawing moisture off of the Gulf of Guinea inland (northwards), and subsequently acted upon by the Africa Easterly Jets, and embedded waves, in producing storm events. The movement of moisture northward onto the continent by the ITCZ is further influenced by the sea surface temperatures (SST) of the tropical Atlantic relative to other tropical oceans, particularly the Pacific. Atlantic SSTs are in turn influenced by the Atlantic Meridional Overturning Cell and North Atlantic Oscillation, while Pacific SSTs are influenced by the El Niño-Southern Oscillation and longer decadal cooling-warming cycles (Kosaka and Xie, 2013). Other theories have been proposed involving the possible “dimming” effect from particulate pollution in the northern hemisphere leading to a cooling of the Atlantic SSTs (Giannini et al., 2013). Landward, additional influences exerted by the Azores and Libyan anticyclone circulations are thought to be responsible for observed differences in distributional effects of rainfall in the Eastern and Western Sahel (Lebel and Ali, 2009). Individual storm events, seasonal distribution of precipitation, and decadal trends emerge from the influence of these forces individually, in combination, and sequence, to which anthropogenic CC forcing is being applied.

Given the highly dynamic nature of the West African climate system, with offsetting and reinforcing amplitudes of various short- and long-term, larger- and smaller-scale forces, the ability to model and project future rainfall trends in the sub-region is both complex and limited given current knowledge. Modeling efforts using best practices of employing multiple general circulation models have resulted in a split between projections of increased and decreased precipitation (e.g., Jalloh et al., 2013). The same is not true for temperatures. Here, modeling efforts are unanimous in projecting significant increases, differing only in the rate of increase (e.g.,

ON THE GROUND
At the farm and field levels within the Sahel, farmers’ experience of weather conditions are further modified by micro-variations in soil types; field histories affecting soil organic matter levels; topographical influences on runoff and the concentration of surface flow; the influence of agroforestry associations; microclimes; and annual, local-level variations in the distribution of precipitation in terms of which fields receive what levels of rainfall and when in the agricultural year.
Evaluating the Performance of Agricultural Practices Under Climate Change in the Sahel

2. The impacts for outcomes will likely not deviate far from the following general trends:

- **2025**: slight potential increase in annual precipitation levels reflecting a continuation of the current decadal trend, moderate rise in temperatures (0.5–1°C), and a continued increase in frequency of extreme events (floods, droughts, and heat waves).

- **2050**: no predictable trends in precipitation patterns, significant rise in temperatures (2.5–4.5°C), strong increase in frequency of extreme events (droughts, floods, and heat waves).

3.1.2 Expected Impacts of Warming on Crop Productivity in the Sahel

The impacts for Sahelian agriculture of continued warming trends include:

1. **Evapotranspiration impacts.** Higher temperatures will result in increased rates of moisture loss through potential evapotranspiration, such that unchanged, or even slightly increased precipitation levels, may be more than offset by increased moisture loss through increased evaporative losses. Although the increased plant transpiration associated with higher temperatures may be offset by plant physiological response to increased CO₂ levels in some crops, leading to increased water use efficiency, increased potential evaporation will result in a net reduction of moisture from the system.

2. **Direct impacts of temperature.** Second, increases in nighttime low temperatures effect plant respiration, and have been shown to have a negative effect on yields of key cereal crops (Peng et al., 2004; Lobell and Asner, 2004). Increases in average seasonal daytime maximum temperatures tend to disrupt and accelerate plant physiological development, effectively narrowing the reproductive period, particularly important during the flowering stage. At the extreme, high temperatures can cause heat-induced sterility. Increases in seasonal high temperatures have been correlated with reduced cotton yields in Mali, especially when occurring during boll development, even though the literature indicates higher temperature tolerances (Traore et al., 2013).

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3 Between the two weather records, there is also significant variance, with one station reporting a −0.4°C change in average seasonal high temperatures, and the other a 0.8°C increase, a range of 1.2°C. Such variance underscores the tension between “adaptive practices” from a research perspective based on averages from broad-based sampling, and the realities as experienced by farmers in site-specific locations.

4 Offsetting physiological responses to CO₂ will only occur in crops that use the C₃ carbon fixation pathway as the mechanism to convert CO₂ in photosynthesis, such as rice, soybeans, peanut, and cotton. This does not include corn, millet, and sorghum (C₄ crops).
3. **Unused rainfall.** Third, warmer air carries more moisture, resulting in more frequent large storm events. Recent research has detected the emergence of such trends within the Sahel (Lebel and Ali, 2013), with models predicting further increases in the future (e.g., IPCC/AR5, 2013). In addition to problems caused by inundation, flooding, and increased soil erosion, the dominant soil types in the Sahel, prone to crusting, have relatively low infiltration rates, already surpassed in 50 percent of storm events (Sivakumar, 1989). An increased frequency in heavy rainfall will consequently lead to more of the annual rainfall being lost to run off. Within a more moisture-laden system, a risk also exists of more annual rainfall occurring outside of periods of plant production, although this has not yet been documented in the literature.

4. **Heat wave impacts.** Forth is the increased likelihood of more frequent heat waves, with once-in-20-years events occurring as frequently as once every 2 years (IPCC, 2012). The timing of extreme heat events in relation to stages of crop development is particularly important; at stages such as flowering, there is a risk of heat-induced sterility.

### 3.1.3 The Importance of Intra-Seasonal Rainfall Variation

The analysis of climate data in the manner outlined in the companion ARCC paper in this subseries, An Approach to Conducting Phenological Screening, would net important information on changes in the intra-seasonal distributional patterns of rainfall in the Sahel, as well as information on changes to daytime and nighttime temperatures, and changes in the frequency of extreme events. An understanding of intra-seasonal trends is critical not only for screening the phenology of major crops against CC impacts, but also the assessment of agricultural practices that are the subject of this paper.

The reality of CC is that weather stressors will likely occur simultaneously and in succession in differing combinations. The potential exists for increased frequency of extreme rainfall events within an overall drying trend, a lengthening of the rainy season with increased discontinuity of rain events within, increased rate of soil organic matter decomposition within systems generating less biomass due to decreased rainfall, as well as other potential interactions. To incorporate the impact of multiple stressors of CC in a way that is meaningful to agricultural adaptation programming, a shift in perspective is required from considering only annual averages, to looking more closely at intra-seasonal distribution effects and the occurrence of extreme events.

Understanding and including the intra-seasonal characteristics of the Sahel's climate in assessing the impact of future CC on agriculture is critical as annual averages may mask critical deficits in rainfall, among other influences. Consider the following two cases: one where 600 mm of annual rainfall is more-or-less evenly distributed in small-to-moderate storm events over the course of the growing season; the other characterized by frequent large rainfall events, with 20 percent of the total precipitation lost in runoff, another 25 percent loss occurring either before or after the main growing season, and a further 5 percent lost through increased evapotranspiration. The result in the second case is that half of the annual rainfall is unavailable to crops, even though the annual total is unchanged. While hypothetical, these trends in weather patterns are being documented and will likely continue to accentuate their influence as CC impacts continue to manifest themselves. Lebel and Ali (2009) found an increased frequency of large rainfall events in the Western Sahel associated with that region’s recent rebound in precipitation levels following the sustained downturn in rainfall during the 1970–1990 period. Areas of the Sahel have also exhibited significant shifts in seasonal distribution of rainfall, with a notable decrease in the August peak (Lebel and Ali, 2009), corresponding to the grain-filling stage for the major cereal crops. The continuation of these trends (increased frequency of large rainfall events, shifts in seasonal distribution of rainfall), along with increased temperatures, have the potential to undermine any positive impact of an increase in annual rainfall averages. Such changes would increase the importance of effective moisture retention practices, already critical to many farmers in the Sahel.
3.2 GEOGRAPHIC PARAMETERS

Defined by annual precipitation levels, it has become common practice to refer to the Sahel as a unified whole. However, it would be a mistake to do so in the context of an assessment of CC adaptive practices. As previously noted, significant differences exist in the emergent precipitation patterns in western and eastern Sahel.\(^5\) In terms of agriculture, the northern Sahel (250–400 mm/year) and southern Sahel (400–600 mm/year), including the sub-Saharan zone (600–750 mm), offer significantly different opportunities and challenges and warrant separate consideration.

3.3 SETTING THE PERIOD OF ANALYSIS

For analytic purposes, two time periods need to be considered: one representing the near-term period (e.g., 2025) and the other a longer-term view (e.g., 2050). Although somewhat arbitrary in nature, a 2025 period reflects a reasonably near-term reference point useful in making programmatic decisions involving technology promotion, whereas the longer-time period is valuable in helping to anticipate more significant investment needs and opportunities. The focus in this paper on assessing adaptive practices, when combined with high levels of uncertainty in future climate regimes, innovation rates, and other variables, argue strongly for use of a near-term climate projection.\(^6\)

3.4 STEP-BY-STEP: DEFINITION OF FUTURE CLIMATE PARAMETERS

In general, the choice of approaches used in developing a future climate scenario must be made in consideration of the intended use of the projections. However, the availability and access to representative weather data is itself a constraining factor in the assessment. Data availability will need to be determined prior to setting the final output targets in terms of what features can be realistically analyzed. Similarly, the required level of effort cannot be determined until a decision is reached on the level of analysis that is possible.

In an companion ARCC paper in this subseries, An Approach to Conducting Phenological Screening, arguments (along a discussion of the steps involved) are offered for generating an agriculturally relevant future climate profile (for 2025) suitable to support crop phenological screening procedures. A summary of these steps are presented here, yet readers are directed to that paper for a full review of the issues. The steps for generating a future climate profile for crop variety assessment over the near term (2025) that focuses on intra-annual variation are listed below.

3.4.1 Defining the Area of Analysis

- Select degrees of latitude that bound the countries of Senegal, Mali, Burkina, and Niger, and include the southern parts of Mauritania, with possible inclusion of western Chad and Northern Cameroon through which the 250–750 mm isohyet band passes based on data from the agreed-upon climate period (1980–2010).

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\(^5\) East and west of 0° longitude.

\(^6\) It is important to note, however, that investments concerning longer-term research issues and large infrastructure investments should use longer-term climatic projections in their analysis. Crop breeding efforts, for example, needed to develop varieties tolerant of significantly higher temperature regimes, will take decades to generate useful outputs. Such programs should be initiated now, so that results will be available when expected conditions (i.e., temperature increase) materialize. Similarly, large, national-scale irrigation investment strategies targeting long-term food security and enhanced CC resiliency, should be initiated in the near-term in order the meet anticipated future domestic demands and CC stressors, as well as to capitalize on export opportunities. These issues, however, are not taken up in the present paper.
3.4.2 Selection of Weather Stations

- Select those stations providing the best geographic coverage of the target zone as defined above.
  - Establish a geographic decision rule (xx number of km between stations), and/or use expert judgment to include stations that fall outside the zone as defined above, but which provide data for areas that by latitude or longitude are under-represented in the sample.

- Select stations with minimum required data measurements (precipitation and daily min/max temperature) and continuity of records covering the time period of the analysis (1950–2012).
  - Establish a decision rule for minimum continuity of records for accepting/rejecting stations.

- Pool station data for analysis to account for the programmatic needs, observed climatological difference between East and West Sahel, and key agricultural difference between the northern and southern parts of the Sahelian zone.
  - Country-wise pooling (including portions of neighboring countries) would accommodate the differences between the eastern and western Sahel, within which separation between the northern Sahel (<400 mm) and the southern and sub-Sahel zones (>400–750 mm) can be carried out. The availability and distribution of station data will strongly influence final pooling decisions in order to preserve statistical robustness of the analysis.
Once targeting and pooling decisions have been completed, weather records within each of the pooled groups will need to be queried to identify and project a climate scenario for the 2025 season. The 2025 scenario would constitute the base for carrying out the assessment of adaptive practices. Weather attributes used in generating the 2025 season should be expressed in physical terms, covering issues such as the following:

- Determination of agronomically useful annual rainfall and moisture availability through inclusion of changes in evapotranspiration rates resulting from higher temperatures, and elimination of out-of-season and excessive rainfall events;
- Frequency of intra-seasonal drought (and drought timing) and high-volume rainfall events; and
- Average daily seasonal maximum/minimum temperatures and frequency and timing of extreme heat events.

Due to the investments required in constructing a useful future climate scenario, if a crop phenological screening is also being undertaken, the decision on what approach to take should be made based on the needs of both the crop phenological assessment and the adaptation assessment of non-crop based practices.
4.0 ELEMENT 2: DEFINING ADAPTATION OBJECTIVES

The underlying adaptation objectives determine the specific practices to be assessed. They should be defined in relation to expected future climate conditions. The selection of the Sahelian climatic zone constitutes a certain degree of initial targeting. Yet, as noted, there are significant differences among the northern, southern, eastern, and western portions of this zone; additional specification of objectives may be necessary to determine target practices. An example definition of practices to consider might be:

- New management practices in areas of the western Sahel receiving 400–750 mm of average annual rainfall that increase moisture infiltration and retention in response to the anticipated slight increase in precipitation levels, higher potential evapotranspiration rates associated with a rise in temperatures of 0.5–1.0 °C, and protect soil and crop resources from the likely increased frequency of extreme events (floods, droughts, heat waves) by 2025.

Beyond such climate-based definitions, limitations of time and money will require choices to be made in terms of which adaptive practices are subjected to what types of assessment. A simple process commonly used to guide the initial prioritization of research efforts may aid the prioritization and targeting of assessment efforts on CC adaptation practices. Factors traditionally considered include:

- Physical extent of the production system(s) targeted;
- Percentage of the target system(s) at risk;
- Likelihood of risk being realized;
- Impact to productivity if risk(s) is/are realized; and
- Percentage of potential loss amenable to mediation.

4.1 IDENTIFICATION OF PRACTICES

Once the underlying adaptation objectives are determined and the general boundaries of the assessment are set, the specific practices to be assessed need to be identified. There are four potential sources of adaptive practices:

1. What is currently available within the country/sub-region, including both formally extended adaptive measures being offered through public, private, or project-based interventions, and farmers’ own indigenous responses;
2. What is being extended elsewhere, outside of local context, within the region, and globally;
3. Historically, what practices have been used by farmers living under similar conditions of a hotter/wetter/drier climate; and
4. What adaptive practices are currently in the development pipeline at the national and international research centers.
For the purposes of this paper, the first and last are the most urgent. The second is effectively a broader application of the first; the third an entirely separate line inquiry that is valuable, but not essential. In addition to those technologies and adaptive measures being offered by formal development programs, it is critical that attention also be directed towards identifying the adaptive adjustments made by farmers themselves. Unlike the calendars of multi-year research and development project cycles, farmers must, and have already begun to, respond to changing condition in real-time. The major lesson from the observed changes to farming systems in the Sahel starting in the 1970s is that farmer innovation was the undisputed principal source of adaptive practices. This is true both of indigenous responses and those identified, refined, and later promoted by development organizations (e.g., rocklines, zai holes, parc améliore, stress tolerant varieties, etc.) (e.g., Simpson, 1999). Ignoring this fact when considering adaptive options to current/future CC would constitute a major oversight and would likely miss the bulk of adaptive responses that farmers ultimately implement.

Information collection from sources 1) and 4) are discussed in more detail below.

An indicative list of some of the better known practices in the Sahel follows. They are arranged here with regards to their major perceived contributions.

**Moisture Capture:**
- Contour plowing;
- Tied-ridges;
- *Aménagement en Courbes de Niveau (ACN)*;
- Zai holes (varying diameter, depth, density/ha);
- Rocklines (simple stone-lines, *Fonds de l'eau et de l'équipement rural (FEER)*, *pierres dressées avec sous-solage (PDS)*);
- Earthen bunds;
- Half-moon catchments;
- Vegetative strips; and
- Living fences.

**Supplemental Water Supply:**
- *Goute-a-goute* (garden- and field-level);
- Pumping technologies;
- Check dams;
- *Bas fonds* development (e.g., *Diagnostic Rapide Pré-Aménagement (DIARPA)*);
- Floodplain development; and
- Irrigation system investment.

**Soil Fertility Enhancement:**
- Compost/manure applications;
• Crop residue management;
• Fallow;
• Intercropping;
• Rotations;
• System of Rice Intensification (SRI);
• Conservation agriculture/conservation farming; and
• Agroforestry (various systems, including Farmer Managed Natural Regeneration [FMNR]).

4.2  **STEP-BY-STEP: IDENTIFYING ADAPTIVE PRACTICES**

4.2.1  **Currently Available Adaptations**

The major formal supply-side providers of adaptive practices include: governmental research-extension systems; international research centers; projects (multi-lateral, bi-lateral, nongovernmental organization [NGO]); and formally organized producer groups and private companies engaged in buying/selling agricultural inputs, services, and products. The ability to conduct a virtual review of adaptation options is limited at best. Research programs of international research centers are somewhat amenable to remote review, depending on published papers and written records of the research undertaken (often lagging behind by several years), those of national programs less so. Very poor records, or none at all, exist for the others.

**Extended Practices:** To assess what is currently being offered through formal programs, an on-the-ground effort is needed to collect the relevant data on what technologies are being promoted, as well as those efforts that are “on the shelf” and “in the pipeline.” As background to the fieldwork, an internet search and literature review should be initiated. Use of an organizational survey for collecting information from field programs, and the creation of a technology database into which both field information and that from the literature review can be entered is recommended. The data collected and database should be structured so that “adaptation profiles” can be easily generated for each identified practice, containing the information needed to assess the technology under future climate regimes. One option would be to adapt a survey tool structure that was designed under a previous USAID Rural Agricultural Income and Sustainable Environment Plus Program (RAISE Plus) procurement (see Annex A for an example of a survey tool), and to populate the database with information from relevant organizations and programs in the four target countries (Senegal, Mali, Burkina Faso, and Niger). The database structure would need to be created, allowing queries to facilitate the matching of adaptive practices with specific features of the 2025 climate scenario.

If carried out concurrently, a minimum of two-to-three weeks of field time by two-person in-country teams would be required to collect the data from major NGOs and projects. The teams would need to undergo an initial training and guided practice prior to their data collection efforts (two days required per country). Adaptation of the data collection instrument and database structure will require approximately two-to-three weeks of technical input each prior to carrying out the field activities. Creation of a database structure and procedure manuals would require four weeks of effort. Preparation of training materials will require an additional three days.

**Farmer Adjustments:** Methodologically, the techniques for identifying farmer adaptations involve three basic elements: depicting farming practices at some point in the past, describing current farming practices, and identifying the changes that have taken place (Simpson, 1995). The addition of exploring
the reasons why farmers have undertaken the observed changes, what challenges they currently perceive, and consequently the adaptations they are attempting to introduce, as well as the sources of ideas for the adjustments, and any barriers they have experienced in adopting promoted practices (see Screening and Prioritizing, below), complete the picture. A blending of gender-based, focus group, and key informant interviews is recommended.

The greatest challenge will be in establishing an appropriate sampling frame for surveying local adaptive responses that are both broad enough to net a reasonable indication of what farmers are doing, yet manageable within the timeframe and financial scope of the project. Conducting village-level interviews is time consuming; while rapid appraisal techniques can be used, care must be given to select a combination of methods capable of generating the level of detail required. Among other factors to consider will be the co-location of interview sites in proximity (geographically and in terms of general climate conditions) to weather stations used in generating the future climate profile. In general terms, the less time available for the fieldwork, the more experienced the persons engaged will need to be. The use of Masters (preferably Doctoral) candidates is another option, although will require a longer time-frame for carrying out the work.

A minimum of six-to-eight weeks of effort, per country (concurrent), would be required to collect and synthesize interview data. Due to seasonal migration for off-farm employment, common in the Sahel, the fieldwork is best conducted during the agricultural season, through the end of the harvest period and shortly thereafter.

4.2.2 Adaptations in the Research Pipeline

Using internal resources and funding from bi- and multi-lateral development agencies and other sources, a significant level of financial resources are begin allocated for CC related research (e.g., the Climate Change, Agriculture and Food Security [CCAFS] Challenge Programme of the Consultative Group on International Agricultural Research [CGIAR] is operating under a 100 million United States Dollars (USD) budget in its first five-year funding cycle). To capture information on what these research programs are currently working on, contact with the relevant national and international research centers during the survey of other outreach programs would be the most efficient option. Alternatively, a separate series of interviews could be undertaken—this would be advised if the individuals contracted to carry out the organizational surveys are young and less experienced.

To cover the four countries and relevant international research centers within sub-region, a minimum of two-to-three weeks of field time would be required.

While ideally a survey of research being undertaken by private companies would also be included, experience shows that the proprietary nature of such investments makes access to detailed information on private sector research efforts very difficult.

Screening for farmer needs. Due to the direct and indirect costs of assessing individual adaptive practices, a decision may be required to prioritize which technologies will be selected for further screening. In making this decision, it is most important to assess farmers’ interests and needs, as well as the underlying rational for their preferences. Using farmer input to narrow the list of technologies to be subjected to various screening efforts early in the assessment process greatly improves the likelihood of identifying technologies that will ultimately be adopted on a significant scale, as well as suggesting ways in which technology choices might be modified and refined to better fit farmers’ needs and conditions. The involvement of farmers in option selection also improves the likelihood that selected technologies will include those with general development benefits and serve as no-regret options.
The assessment of farmer interests is best carried out at the country level, using a common framework to capture potential benefits of economies of scale across the four countries. Use of a combination of gender-disaggregated farmer focus groups and key informant interviews (e.g., locally identified “innovators”) offers the best alternative. The collection of additional information on farmer asset levels will also be important. While the creation of farm household typologies have not been successfully used as an outreach tool in targeting technical options to different household types, this type of information is critical for being able to identify the size of the populations potentially reached as well as those likely not impacted, and the reasons why, and thus should also be included resources and time permitting.

The inclusion of group and individual interviews addressing farmers’ perception of the practices being offered to them and their adaptation objectives is most easily addressed through inclusion of these lines of inquiry in the assessment of farmers’ current adaptation efforts (discussed above). Additional time required would be a half-day per study site.
5.0 ELEMENT 3: DEFINING ASSESSMENT METHODS

While the focus of this paper is on assessing the technical viability of practices, it is worth reviewing the larger set of factors that influence the potential uptake and use of individual practices. Methods available to assess adaptive practices can be placed under the following categories. Each reflects a different perspective:

- **Technical**: biophysical/agronomic perspective (e.g., phenological screening, crop modeling, runoff/erosion modeling, ecosystem process modeling, controlled experimentation, and *in situ* validation);
- **Financial**: farm manager’s perspective (e.g., whole or partial farm analysis);
- **Economic**: investment perspective (e.g., benefit-cost analysis of investment options);
- **Environmental**: conservation perspective (e.g., environmental impact assessment, hydrologic and watershed modeling);
- **Social**: target group perspective (e.g., participatory appraisal and planning methodologies);
- **Equity**: agency or government perspective (e.g., gender analysis); and
- **Policy**: policy agreement and coherence (e.g., policy analysis matrix).

With the ultimate goal of identifying effective adaptation practices that have the potential of being widely adopted by farmers, the assessment process must eventually be widened beyond technical considerations alone. At a minimum, adaptive practices will need to be screened from three perspectives:

- **Technical**: does the practice respond to and generate the type of outcomes required in response to anticipated physical changes in the climate?
- **Financial**: does the practice provide financial benefits or, at a minimum, not make those involved worse off vis-à-vis what would have happened in the absence of, or in comparison with alternative, interventions?
- **Social**: is the practice desired by and actionable by the intended beneficiaries?

Issues related to the larger context, such as equity, environment, and economic perspectives, as well as governmental policy, generally reflect agency and national concerns. These must also be addressed before investment decisions are made. However, the effort needed to carry out this second level of analysis is called for only after an initial screening of the essential aspects adaptive practices indicated above.
5.1 TECHNICAL ASSESSMENT

Untangling the web of *in situ* crop-environment interactions in the Sahel presents a challenge that is inherently complex, and more so when subjecting these relations to anticipated future CC impacts. At the field level, the interaction between limiting factors is particularly challenging (see Box 5.1). Understanding the overall crop-environment system and internal responses, however, is critical to being able to assess the impact of individual adaptive options on crop performance. Technical assessments can be carried out at three levels: (bio)physical components of the production environment, crop response, and farm profitability. On the whole, the specialized technical content of these different domains (physical, biophysical, crop-specific, and system modeling frameworks) demands the dedicated attention of appropriate experts. A general overview of these approaches follows; the commissioning of detailed papers outlying specific procedures for conducting assessments of different classes of adaptive practices is highly recommended.

5.1.1 Assessing Complex Impacts on Physical and Biophysical Components

Primary components of the production environment include soil, water, temperature, and sunlight. Water (i.e., rainfall) and temperature are directly affected by CC. CC also impacts other components indirectly through influences on system processes, such as: increased potential evapotranspiration, acceleration of organic matter decomposition, and increased potential of rainfall loss through runoff, among others. The ability to assess the efficacy of different adaptive practices to mediate CC effects on system properties and processes depends on the existence of necessary data, formulas, and/or models. In most, if not all, cases, a combination of tools and inputs will be required. For example, it may be possible to use the comprehensive CENTURY soil model to assess the efficacy of organic manure application recommendations and conservation agriculture practices in building soil organic matter content (SOM) under future climate scenarios (temperature and rainfall) if the soil type, soil amount, and composition of organic matter going into the soil system can be quantified. Other areas, however, will likely require substantial effort to assess individual adaptive practices. Rainfall runoff models, for example, can generate estimations of likely runoff, given rainfall amounts/intensity, slope, surface type, and catchment area, and can be used to estimate changes in runoff given data on likely changes in precipitation patterns under future climate conditions. However, the ability to use these models to assess the efficacy of changes in surface type affecting rainfall infiltration and the introduction of various

LIMITING FACTOR INTERACTIONS

Plant genetic response to elevated temperatures is amplified by soil moisture levels and secondly by overall plant health status. Plant health in turn is related to soil fertility status, which in the Sahel in strongly influenced by soil organic matter content (SOM). SOM levels in turn affect rainfall infiltration and soil moisture retention, and so on. Only limited adaptation can be achieved by targeting any single feature in the plant-environment system. Changing varieties to those more tolerant to higher temperatures and suited to current environmental conditions provides advantage until the status of the environment becomes limiting. Employing moisture-harvesting techniques to capture more of the available rainfall may offer improvement in crop responses to higher temperatures related to soil moisture constraints, but not soil fertility status. Likewise, the outcome of building soil organic matter content, which retains more soil moisture and nutrients, will be sub-optimal without changes in crop varieties more tolerant to higher temperatures, and will be increasingly difficult to achieve as higher temperatures accelerate soil microbial activity and the breakdown of SOM.
adaptive management practices (e.g., contour plowing vs. rocklines vs. vegetation barriers) is unclear. The ability to assess that impact of adaptive practices on other environmental parameters and processes (e.g., surface temperatures and ground wind speed effecting evapotranspiration) in an accurate and efficient manner appears even more challenging.

5.1.2 Modeling Crop Responses

Elevating attention to assessing crop genetic responses to the production environment, the picture is clearer. Due to long-term efforts by breeders and agronomists to develop and assess crop yield performance, a number of well-established procedures and model exist. A survey involving crop model users conducted by the CGIAR CCAFS program identified over 122 crop models (Rivington and Koo, n.d.). Crop models fall into one of two categories: statistical models or process-based models. Process or mechanistic crop models use algorithms and extensive data inputs to generate approximations of plant physiological responses to environmental factors. These models require field-level data and, with some exceptions, tend to focus on the major crops and dominant conditions of temperate zones. In cases where weather data are missing or incomplete, or when future weather conditions are to be tested, as in CC scenarios, other models are used to generate or gap-fill key weather data inputs. In the assessment of tropical production systems, individual models are commonly used to generate proxy responses for other crops for which models do not exist, where the researchers do not have experience in using them, are missing crucial data inputs, or model incompatibilities exist.

Statistical models, in contrast, use extensive empirical datasets of crop yields under different environmental conditions as the basis for predicting crop response to target conditions based on key environmental parameters. Assembling the database used in statistical crop models requires a great deal of effort, and in most cases, the extensive use of controlled trials to establish a grid pattern of varying moisture and soil fertility regimes. When used in predicting future crop response to CC, research shows that statistical models perform better at larger spatial scales, corresponding to the greater accuracy of larger-scale climate models (Lobell and Burke, 2010). It is generally acknowledged that at the extreme range of environmental conditions, often those being tested under CC scenarios, the accuracy of current models (whether process-based or statistical) often breaks down and/or are not able to respond to more than one factor (e.g., extreme heat, drought). Part of this reflects the state of science, part the original intended purposes for which the models were constructed and the availability of data that support them. Improvements continue to be made. When using crop models to project crop responses to CC, best practice, as with using multiple global circulation models (GCMs) to generate future climate scenarios, is to average across output from several models.

At the cropping system level, useful in assessing the impact of changes in management practices that potentially affect the production of multiple crops produced within a system (e.g., changes in field-level soil fertility or water capture enhancing technologies) fewer choices exist. The erosion productivity impact calculator (EPIC) and decision support system for agrotechnology transfer (DSSAT) models appears to the most comprehensive and most used in carrying out system level assessments. The modular nature of the revised DSSAT model (Jones et al., 2003) is particularly attractive through the opportunity it offers for serving as a future platform for conducting CC-related assessments of management practices. The effort required to parameterize the model fully is significant and is not amenable to conducting one-off technology assessments.

5.2 FARM PROFITABILITY

The acquisition and operational costs of employing any new adaptive technology must be profitable from a farmers’ perspective. If practices are technically responsive but financially unprofitable, there is little basis in believing that they will be taken up en masse by resources-poor farmers across the sub-region.
Loss reduction under CC, while important, for farmers near, at, or below the poverty line, represents a continuation of poverty, and is not sustainable under deteriorating environmental conditions. Assessment of the financial benefits of adopting alternative adaptation measures attempts to take the farm managers’ perspective in assessing whether or not a change in productive practices is profitable or not. The standard tools in conducting this type of assessment is the use of whole- and partial-farm budgeting procedures, and can also include the additional use of linear programming to optimize resource allocation. When potential changes involve the entire farming system, or demand the re-allocation of resources that affect the entire farm or multiple farm enterprises, whole-farm analysis is warranted. Where changes affect only one farm enterprise (crop or field), partial-farm budgeting covering that specific enterprise is sufficient. The procedures for carrying out whole- and partial-farm budgeting are covered in the standard text by J. Price Gittenger (1982). The data requirements for carrying out whole-farm modeling are substantial, and should not be underestimated. Partial-farm budgeting, where applicable, represents a less-demanding and preferable choice. To the extent that it can be incorporated, it is highly recommended that a gender-disaggregated approach be used in conducting any financial assessment.

5.3 SOCIAL/BEHAVIORAL ASSESSMENT

Beyond the assessment of technical responsiveness of adaptive practices, and their financial viability, the assessment of farmers’ objective, preferences, and capabilities in making use of alternative practices is a critical aspect in assessing potential benefits of adaptive practices. Many, if not most, of the experiences in the misguided promotion of agricultural technologies that were not taken up by farmers could have been avoided had farmers been involved in determining what technologies would be offered. The use of participatory approaches, rhetoric aside, is still highly uneven within research and development organizations. That farmers ultimately choose what technologies they do or do not adopt is undeniable, yet turning the choice of which technologies to refine and extend over to farmers early in the development process is not a widely practiced model. For purposes of assessing adaptive practice options, using gender-disaggregated focus group consultations within targeted production environments and key informant interviews are preferred methods. A wealth of participatory methods and manuals are available for direct, or adapted, application. From a research perspective, the reasons why farmers dislike or are unable to use particular options can be valuable input in technology refinement and the development of future adaptive practices and tools.

5.4 ANALYSIS OF THE LARGER CONTEXT

Separate from the technical soundness, financial attractiveness, and acceptability of an adaptive practice, another important set of considerations in conducting an adaptation analysis are the potential influence of forces that reside outside the immediate focus on CC impacts—those forces that reside above the field, farm, watershed/agroecological zone, and country levels, yet which may have a profound influence on the ultimate ability of adaptive response to deliver their intended benefits. Whether as part of, or in conjunction with, an adaptation analysis, adaptive responses should be subjected to a thorough scrutiny for weaknesses and threats related to forces from the larger context, essentially engaging the “weaknesses” and “threat” assessment components of a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. Attention should also be given to achieving multiple-wins and no-regret outcomes (“strengths” and “opportunities” elements of a SWOT analysis). Inter-sectoral issues, supportive services, policies, and future price-related concerns should all be considered.

For example, take a hypothetical case of “hard” investments involving construction of an extensive network of community-level water control structures to provide irrigation water in response to decreased rainfall. Depending on design features, such structures may be exposed to future increases in energy prices (concrete and transportation costs are highly sensitive to changes in oil prices). From a
climate change perspective, investments in greater water control may not be needed until sometime in the future, whereas changes to energy prices in the intervening period may make the proposed investments unattractive from an investment standpoint at a later date, and outright unaffordable given competing demands for scarce resources elsewhere in the economy at the time when investments ultimately are needed. A context assessment may identify the benefit in making such investments sooner, thereby achieving “no regret” development outcomes, rather than responding at a later period based purely on a CC-related perspective.

5.5 **STEP-BY-STEP: DEFINING ASSESSMENT METHODS TO ASSESS SPECIFIC PRACTICES**

5.5.1 Technical Responsiveness

After identifying which adaptive practices are being promoted across the study area and soliciting farmers’ input on their experiences with these technologies, adaptations of their own, and their general adaptation challenges and objectives, selected technologies need to be subjected to screening for their ability to respond to the projected attributes of the 2025 climate scenario. As indicated earlier, the technical assessment of agricultural adaptations involves both the study of crop responses and the manipulation of the production environment. The phenological screening of key crops against potential CC impacts is the focus of the accompanying ARCC paper in this subseries, An Approach to Conducting Phenological Screening, and will not be covered further here.

The agronomic literature contains a rich yet disparate body of empirical information on the performance of various management options. The farming system research era in particular generated a substantive body of literature on the biophysical attributes of different agronomic practices (e.g., effects on surface temperatures, wind speeds, moisture retention, shading effects, etc.). Nevertheless, in contrast to assessing genetic resources, the assessment of adaptive manipulations of the production environment offers a far more difficult challenge. Outside of engineering principles used in structure design (e.g., water control structures, dams, and irrigation systems), few agricultural interventions have been subjected to detailed scrutiny in terms of identifying thresholds or failure points. For example, it is questionable whether models used in calculating rainfall runoff and infiltration can be used to assess and compare different practices of moisture capture through use of physical and vegetative barriers on different soil types and slope classes, and their potential failure point under extreme rainfall events.

Options in the face of these constraints include:

1. Assessing only those types of technologies for which ready-made screening tools can be found;
2. Engaging technical experts to conduct one-off assessments using “expert opinion”; or
3. Commissioning technical experts to prepare adaptation-specific assessment procedures that could be applied in a variety of contexts.

The last option, while more time consuming, has the advantage of being able to be used repeatedly as needs arise (country-based or regional), as the product could be used to address more generic questions, such as: **what is the relationship among rainfall event intensity/volume, barrier height, slope, soil surface texture, and distance between barriers that would allow existing infiltration enhancing technologies to be assessed against future climate scenarios of increased high rainfall events?**

Areas that might be addressed include: enhanced water infiltration technologies (and their vulnerability to heavy rainfall events), surface temperature abatement (including wind and solar radiation effects), and soil fertility status changes. The appropriate experts should be able to identify, modify, and develop
assessment procedures as well as screen the identified technologies (or a prioritize sub-set) within a six-to-ten-week period.

Again, gaps in knowledge in the existence of assessment techniques and models indicate areas where USAID should consider supporting additional methodological development. Such longer-term investments are warranted, as CC challenges will continue to manifest going forward.

5.5.2 Farm Profitability

Farmer-screened technologies that pass the relevant technical adaptiveness assessment should be subjected to a basic financial assessment. In carrying out financial analysis the options are to undertake partial- and whole-farm budgeting, the appropriate technique determined by the nature of the adaptive practice. Outside of wholesale production system changes, e.g., replacement of rain-fed with irrigated farming systems, partial-farm budgeting will likely be sufficient in most instances. The time required and resulting accuracy of budgeting exercises depend largely on the complexity of the technology/change to be analyzed and the availability and accuracy of farm-level data. With less complex changes, and where accurate data is readily available, partial-farm budgets can be completed by a skilled analyst in a matter of hours, and days for whole-farm budgets. For more complex changes and systems, involving multiple agroecological zones and/or household classes, the analysis can take weeks. If farm-level data must be collected, completion of the analysis slows considerably, ultimately matching the rate of data acquisition. Anticipated regular use of whole-farm and partial-budget procedures suggest a need for development of a standard framework, so that different analysts can efficiently produce comparable products.

5.5.3 Investment Appraisal

At some point, consideration must be given as to how adaptive practices will be made available to farmers, including support services, training, credit, and other elements necessary for their successful application. To assess the economic benefits of proceeding with the investment, a benefit-cost analysis (BCA) is called for. For agricultural projects, BCAs build off whole- or partial-farm budgets reflecting sub-groups of the target population(s), and apply all of the relevant investment costs required to deliver the necessary services. Outside of major investments by the World Bank and the Millennium Challenge Corporation (MCC), the use of BCA techniques has fallen out of favor. This is largely due to the level of effort required in carrying out detail assessments. As a result, few bi-laterally funded projects have any realistic notion of their potential benefit-cost outputs prior to investment. The targets set tend to arbitrary and reporting often involves assumptions and data that are incomplete, flawed, or suspect. The return to use of more rigorous project appraisal techniques is strongly recommended. The time required to complete a full BCA is significant and can span several months for especially large projects and/or if primary data must be collected.

In special cases, other assessment techniques offer more appropriate approaches for assessing alternative investment options. In instances where a specific development target is known, cost-effectiveness analysis (CEA) can be used to identify least-cost options for achieving targeted outcomes. In cases where decision-makers are confronted with multiple interests, and where not all the costs and benefits can be quantified in monetary terms, multi-criteria analysis (MCA) can be used. Because agricultural CC adaptation presents a number of “yes/no” decision points, e.g., the need to respond to anticipated CC stressors, it will be important to conduct investment-level assessments, regardless of technique (BCA, CEA, or MCA), after initial screenings have taken place.
6.0 SEQUENCING THE ASSESSMENT SCREENING

As outlined in the preceding sections, the complexity of assessing adaptive practices across the Sahel, and the appropriate sequencing of steps, lend themselves to depiction through illustration. The figure below outlines the general flow of stages, indicating the recommended pathway. Action boxes (small) and arrows highlighted in red depict key decision points where specific choices need to be made. Due to the large number of variables, and their inter-relation, consideration of options is best approached by a sequential consideration of each step in the flow path.

Key: Phase I (red, orange, yellow); Phase II (green, blue)
7.0 SOURCES


ANNEX A. SAMPLE QUESTIONS FROM A DATA COLLECTION TEMPLATE
Sample questions from a data collection template related to crop usage:

<table>
<thead>
<tr>
<th>1. CROPS Target Groups</th>
<th>2. Main CROPS Ag/NRM Methodologies</th>
<th>3. Major CROPS Ag/NRM Operational Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ AIDS Affected Households</td>
<td>□ Community-Based Natural Resource Management</td>
<td>Circle type of organization and write organization name in space provided.</td>
</tr>
<tr>
<td>□ Disabled/Blind</td>
<td>□ Community-Based Seed Systems</td>
<td>Definitions:</td>
</tr>
<tr>
<td>□ Elderly</td>
<td>□ Food For Work</td>
<td>IO = international organization,</td>
</tr>
<tr>
<td>□ Fisher Folks</td>
<td>□ Farmer Field Schools</td>
<td>GO = governmental organization,</td>
</tr>
<tr>
<td>□ Refugees</td>
<td>□ Farmer Participatory Research/Farmer-led Extension</td>
<td>NGO = non-governmental organization,</td>
</tr>
<tr>
<td>□ Women/Female Headed HH</td>
<td>□ Indigenous Knowledge Systems</td>
<td>MA = member association (e.g. Coops, Farmer</td>
</tr>
<tr>
<td>□ Rural Poor Farmers</td>
<td>□ Participatory Plant Breeding</td>
<td>Organizations, Village Associations, and so on).</td>
</tr>
<tr>
<td>□ Other (Specify)</td>
<td>□ Participatory Varietal Selection</td>
<td></td>
</tr>
<tr>
<td>______________________</td>
<td>□ Participatory Rural Appraisal</td>
<td></td>
</tr>
<tr>
<td>______________________</td>
<td>□ Other (specify) ____________________</td>
<td>1. __________________________ circle one: IO, GO, NGO, MA</td>
</tr>
<tr>
<td>______________________</td>
<td></td>
<td>2. __________________________ circle one: IO, GO, NGO, MA</td>
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<td>3. __________________________ circle one: IO, GO, NGO, MA</td>
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<td>4. __________________________ circle one: IO, GO, NGO, MA</td>
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<td>5. __________________________ circle one: IO, GO, NGO, MA</td>
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<td>______________________</td>
<td></td>
<td>6. __________________________ circle one: IO, GO, NGO, MA</td>
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<tr>
<td>4. CROPS Activity</td>
<td>5. CROPS Species or Sub-activity</td>
<td></td>
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<tr>
<td>----------------------------------</td>
<td>---------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>□ Food Crop Production</td>
<td>□ Cereals, □ Vegetables, □ Roots / Tubers, □ Fruits,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Other (specify) ______________________</td>
<td></td>
</tr>
<tr>
<td>□ Cash Crop Production (domestic market)</td>
<td>□ Cereals, □ Vegetables, □ Roots / Tubers, □ Fruits, □ Cotton, □ Peanuts, □ Sesame,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Other (specify) ______________________</td>
<td></td>
</tr>
<tr>
<td>□ Export Marketing</td>
<td>□ Cereals, □ Vegetables, □ Roots / Tubers, □ Fruits, □ Cotton, □ Peanuts, □ Sesame,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Other (specify) ______________________</td>
<td></td>
</tr>
<tr>
<td>□ Irrigation Systems</td>
<td>□ Infrastructure Construction, □ Rehabilitation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Other (specify) ______________________</td>
<td></td>
</tr>
<tr>
<td>□ Organic Agriculture</td>
<td>□ Cereals, □ Vegetables, □ Roots / Tubers, □ Fruits, □ Cotton, □ Peanuts, □ Sesame,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Other (specify) ______________________</td>
<td></td>
</tr>
<tr>
<td>□ Integrated Pest Management</td>
<td>□ Cereals, □ Vegetables, □ Roots / Tubers, □ Fruits, □ Cotton, □ Peanuts, □ Sesame,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Other (specify) ______________________</td>
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</tr>
<tr>
<td>□ Erosion Control</td>
<td>Technology Types: □ contour plowing, □ rock lines,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ terraces, □ vetiver grass, □ Other (Specify) ___________________</td>
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</tr>
<tr>
<td>□ Soil Fertility Management</td>
<td>Technology Types: □ compost, □ cover crops,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ legume intercropping/rotations, □ manure,</td>
<td></td>
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<tr>
<td></td>
<td>□ Other (Specify) ______________________</td>
<td></td>
</tr>
<tr>
<td>□ Seed Multiplication / Dissemination</td>
<td>□ Cereals, □ Vegetables, □ Roots / Tubers, □ Fruits, □ Cotton, □ Peanuts, □ Sesame,</td>
<td></td>
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<tr>
<td></td>
<td>□ Other (specify) ______________________</td>
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</tr>
<tr>
<td>□ Mechanization</td>
<td>Type: □ animal traction, □ tractors/rice multiculture,</td>
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<tr>
<td></td>
<td>□ harvest, □ post-harvest,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Other (Specify) ______________________</td>
<td></td>
</tr>
<tr>
<td>□ Value Added Processing</td>
<td>Products(1) ______________________________</td>
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