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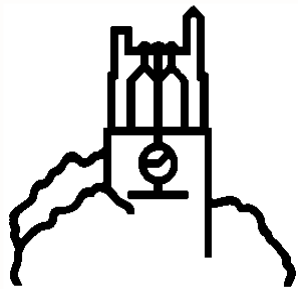
MSU International Development Working Paper

Pathways to Improved Profitability and Sustainability of Cotton Cultivation at Farm Level in Africa: An Approach to Addressing Critical Knowledge Gaps

by

Valerie Kelly, Duncan Boughton, and Benjamin Magen



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PATHWAYS TO IMPROVED PROFITABILITY AND SUSTAINABILITY OF COTTON CULTIVATION AT FARM LEVEL IN AFRICA: AN APPROACH TO ADDRESSING CRITICAL KNOWLEDGE GAPS

by

Valerie Kelly, Duncan Boughton, and Benjamin Magen

February 2011

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EXECUTIVE SUMMARY

Context and Objectives

In 2009, the World Bank published a comparative study of cotton sector reforms[1] , based on detailed case studies carried out during 2007/08 in nine of Africa's main cotton producing countries. The purpose of the study was to draw practical insights from the diversity of experiences in institutional reforms of cotton sectors and to better understand the strengths and weaknesses of the different types of sectors operating in Africa, the likely effects of specific types of policy change, and the possible ways forward.

One chapter of this World Bank study focused on cotton yields and returns, looking first at international comparisons of lint yields per hectare and then at comparisons of performance indicators among different types of farms in selected countries. Two conclusions emerged from this work that motivated the research proposed in this paper:

- Cotton yields in Africa lag behind those in other countries; and
- Good performance in terms of cotton productivity and profitability seems to be limited to a relatively small subset of all cotton farmers.

The finding that only a small proportion of cotton farmers make profits is a serious concern, with important implications for cotton development strategies in countries where poverty reduction is a top priority. However, the data underlying the study's farm-level analyses were collected using a Participatory Rapid Appraisal (PRA) approach that provided descriptive information on a limited, non-random sample of farmers. While some broad insights on differences in farm characteristics and the profitability of cotton production for farmers producing large, medium, small and very small amounts of cotton were obtained from the PRA results, researchers agreed that there was a need to better quantify cotton profitability at farm level. In addition to identifying the factors affecting profitability there is also a need to identify, characterize, quantify, and understand the behavior and dynamics of different cotton farm groups in order to develop appropriate policy recommendations and support programs to help farmers – or different categories of farmers – benefit more from cotton cultivation.

This paper develops a concept note for additional research that would address the perceived weaknesses of the earlier work. The underlying hypothesis of the proposed study is that technology research, farmer training, and policy and institutional reforms to improve cotton sector productivity and incomes tend to be designed for *typical* or *model* farmers. This often fails to take into account the diversity among cotton farmers and what this diversity implies for cotton sector development in general and the ability of the cotton sector to contribute to poverty reduction in particular. The proposed research is expected to contribute to aggregate growth in cotton productivity and incomes through the design of more targeted support interventions based on a better understanding of the strategies, capacities, and constraints of the different types of cotton farmers.

Methods

In designing the research program described in this document, the following steps were taken:

[1] Organization and Performance of Cotton Sectors in SSA: Learning from Reform Experience, Tschirley D., Poulton C., Labaste P., 2009

- Identification of the specific research objectives and questions to be addressed;
- Articulation of a conceptual framework to guide the research;
- Review of the literature to:
    - Summarize current thinking on *best bet* farm-level cotton production technologies and practices and what is known about their relevance to different types of farms;
    - Look for answers to the research questions being posed; and
    - Learn about the design of programs to address similar questions in the past;
- Identification of existing data bases and ongoing research that could be used to answer some of the research questions;
- Development of a methodological approach to be taken in coordinating this multi-country research; and
- Development of a list of country studies capable of contributing to the overall study.

Highlights of the Research Proposal

The paper proposes a research framework that combines a production frontier and an agricultural systems approach. This combination forces one to remember that the technical factors set limits on the opportunity set that is available to farmers while the wide variety of human factors taken into account through systems research influence the incentives that shape how the farmer responds to that technical opportunity set.

The research proposed aims to address the following questions:

- What are the current levels of income and returns from cotton by farm types?
- What are the main factors affecting profitability and returns by farm types?
- What are the different strategies of cotton farmers with respect to:
    - The place of cotton in the overall farm enterprise
    - Level of intensification
    - Quality goals
    - Choice of marketing channels?
- How do these different strategy choices relate to a farmer's resource endowments and access to services?
- How have farmers' production and marketing strategies for cotton vs. other crops changed over time and for what reasons?
- In a given cotton production system, what is the combination of cotton production and marketing strategies most likely to increase farmers' overall income and productivity and ensure the sustainability of the farm enterprise?
- Is there a minimum resource endowment and level of services required for a farmer to profitably pursue cotton production?
- What technologies and farming practices are most likely to raise cotton income for each type of farmer?
- What technologies and farming practices are most likely to raise cotton yields and aggregate cotton production for each type of farmer?
- What types of programs and policies are needed to support farmers wanting to (1) move closer to the existing production frontier, (2) pursue alternative niche markets, (3) adopt new technologies, or (4) exit cotton production?

The paper includes a review of the literature on cotton production technologies, marketing options available to African farmers, and the current state of research on cotton farm typologies. The review of technologies touches on the following types of cotton technologies:

- Pest management;
- Land, soil, and water management;
- Varietal improvement, weed management; and
- Mechanization

The review concludes that Bt cotton represents one of the best technical options for increasing productivity and incomes, but notes that many of the soil, water, and land management practices described in the literature have the potential to improve cotton yields and returns to labor by approximately the same percentages as the introduction of Bt cotton—both types of technologies generate yield increases ranging from 20% to 50%.

Marketing options reviewed included aiming for quality premiums, creating and promoting an African label, producing for the organic markets, and producing for the fair trade markets. Most analysts agree that both organic and fair trade markets are growing but represent such a small share of the overall cotton market that they are unlikely to provide solutions for the vast majority of African cotton farmers. Regaining its former reputation for high quality cotton seems like an option likely to have broader impacts.

Two major types of farm typologies of relevance to African cotton farmers were identified:

- Simple ones based on productive assets (e.g., landholding size, level of mechanization) and used primarily for extension, monitoring, and evaluation purposes, but occasionally by researchers and policy analysts; and
- More complex ones developed by researchers to understand the dynamic evolution of cotton farms over time, farmer strategies and life cycles, and the factors that shape each group's responses to environmental and institutional changes.

Research Proposed

A country case study approach is proposed to (1) facilitate comparisons across the different types of cotton sectors identified in the comparative study of 2009, (2) provide insights about the determinants of productivity differences among farmers in different types of cotton sectors, and (3) provide information that can be used to make recommendations for productivity improvements at both the country and the Africa regional levels.

At a minimum, each country study should:

- cover the principal or most important zones and cotton farmers in the country;
- develop a typology of cotton farms – or identify and validate an existing one - that differentiates farmers by yields, aggregate cotton production, and/or returns to labor;
- quantify the relative share of farmers in the cotton zone falling into each category of the typology and their geographic distribution;
- collect data in order to establish farm budgets; and
- carry out an analysis of the farm budgets for each of the farm types identified, taking into account their likely future trajectory if no changes are made in basic cotton sector parameters such as input/output prices, technologies available, access to markets, etc.

Based on the literature review to date, it is proposed that each typology take into account the relevance of the following minimum set of farm characteristics to ensure some ability to compare typologies across countries:

- Agroecology;
- Access to land (quantity owned vs. rented in; nature of rights to land owned);
- Land use patterns (area cultivated, rented out, continuous cultivation vs. fallows, importance of permanent vs. annual crops, land improvement investments);
- Demographics (family size, composition, education, age/gender of household head)
- Ownership of or access to animal traction equipment;
- Ownership of livestock and its role in overall farm strategy;
- General characteristics of the input package used and how inputs are accessed (organic and inorganic fertilizers, types of seed, use of pesticides/herbicides, etc.);
- Access to and use of extension for both cotton and other activities;
- Membership of farmer association or cooperative for cotton or agribusiness activities;
- Access to and use of credit for both cotton and other activities;
- Role of cotton production in the overall farm strategy; and
- Role of non-farm income in the overall household strategy.

Data on these farm characteristics would need to be combined with data on farm performance to develop the typologies and get an understanding of factors differentiating farms in terms of income and productivity. This means that for each country study a *core* data set for a random sample of farmers will be collected that includes yield and cost of production for cotton and other crops that compete with cotton for land and labor. In addition, information will be collected on household assets and non-crop sources of income. To be sure that the typologies take into account dynamic processes, qualitative information will have to be collected about farmers' strategies and key changes in their farm enterprise over time as well as information about major changes over time in the natural resource base and policy environment in which the production system is operating. In addition to these minimum requirements listed above, each country study could include the possibility to carry out the following activities:

- A research-action component that monitors the implementation of a specific intervention to improve farm productivity and incomes, with the objective of documenting how different farm types identified in the typology respond to that intervention and evaluating the usefulness of the typology for predicting farmer response.
- A quantitative business model approach that uses relatively simple mathematical whole farm models to simulate the response of different farm types to changes in selected parameters related to cotton production.

The inclusion of one or both of these elements will ensure that the development of the farm typologies is more than a theoretical exercise and provide an opportunity for national collaborators to experience the practical application of the typologies. The action-research component will provide those developing the typologies with an opportunity to assess the typology's usefulness for applied research and to make modifications in the initial typology if necessary.

Options under consideration for choice of countries and specific case studies are drawn from the literature review and discussions with knowledgeable individuals in each country. The options are summarized in the table below:

Sector type	Country	Possible topic
National Monopoly transitioning to local monopolies	Mali	Role of farm typology in explaining IPM/SF adoption and performance
Local monopoly	Burkina	Use of farm typologies by producer organizations to improve the effectiveness of their support services; need to assess implications of widespread adoption of Bt cotton for choice of topic and collaborators.
Competitive	Tanzania	Undetermined.
Concentrated	Zambia	Role of farm typology in explaining adoption and performance of selected technologies or practices
Hybrid	Benin	Performance of farmer advisory services and the contribution of farm typologies to the performance.

To harmonize data collection and analysis across countries the paper proposes that each study collect:

- quantitative data on core variables such as yield, cost of production, key crop management indicators (time of planting, time of first weeding, yield loss events) for cotton and crops competing with cotton for land and labor, and on household assets and non-crop sources of income, and
- qualitative core data on farmers strategies, views of constraints to increasing productivity and incomes, potential benefits and inconveniences of innovations being studies, what differences they perceive in adoption and impacts across different types of farmers and why, etc.

A major shortcoming of the PRA methods used in the past was the non-representative nature of the samples and the very small number of farmers providing the information. For the proposed study, sample sizes should be large enough to obtain statistically significant differences across typology groups for the key classification variables and the key performance variables of interest (yields per hectare, aggregate cotton production, and returns to labor).
The core data should be used to validate the typologies and then develop typical crop budgets for each farm group identified by the typology and consider the implications for the theoretical trajectories of each farm type should there be no major changes in technologies, markets, and institutions. They will also serve to establish where different groups of farmers are in relation to the production frontier and supply curve and what characteristics identify them.

Intermediate outputs at the country level could include:

- A paper describing the typology and presenting the differential productivity results by farm type; each study would need to include some analysis of the role played by the overall cotton sector institutional structure (following on the earlier WB study) and develop a set of qualitative/hypothetical business model trajectories for each type of farm identified (end of year one);

- A set of outreach activities that would include country-level workshops during the first and second years,
- A paper identifying and designing an action-research activity and/or a simulation modeling activity (end of year one);
- An interim report on the action-research and/or simulation model (end of year two);
- A final report on the action-research and/or simulation modeling (end of year three); and

Cross-country outputs of the proposed research would include:

- study plan detailing choice of case study countries and zones, common methodology and timeline;
- a synthesis paper drawing together the results from the first year of work on typologies and development of farm business model hypotheses for all the country studies (middle of year two);
- a cross-country meeting of researchers and other stakeholders during the third year, and a major outreach event toward the end of the fourth year;
- a synthesis report capturing the major findings of the study, including a comparative analysis of the country results and a set of recommendations/proposals for the design of future policies and programs that aim at improving the profitability of cotton cultivation for small African farmers and raising rural incomes.

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BOX

1. PRA Methodology 3

ACRONYMS AND ABBREVIATIONS

ASR	Agrarian Systems Research
CDO	Cotton Development Organization, Uganda
CIRAD	*Centre de Coopération Internationale Agronomique pour le Développement* (Center for International Agronomic Cooperation for Development)
CMDT	*Compagnie Malienne pour le Développement des Textiles* (Malian Company for the Development of Textiles)
DDPC	*Département de Développement de la Production Cotonnière*
ESA	Eastern and Southern Africa
FSR	Farming Systems Research
EU	European Union
FCFA	*Franc du Communauté Financière d'Afrique*
GM	Genetically Modified
GMO	Genetically Modified Organism
ICABR	International Consortium on Agricultural Biotechnology Research
IER	*Institut d'Economie Rurale du Mali* (Rural Economy Institute)
IFPRI	International Food Policy Research Institute
INERA	*Institut de l'Environnement et de Recherches Agricoles* (Institute for the Environment and Agricultural Research)
IPC	*Interprofession du Coton au Mali* (Cotton Interprofession of Mali)
IPM	Integrated Pest Management
IRC	*Institut des Régions Chaudes* (Institute for Hot Regions)
IREEP	*Institut de Recherche Empirique en Economie Politique* (Institute of Empirical Research and Political Economy)
M&E	Monitoring and Evaluation
MSU	Michigan State University
NGO	Nongovernmental Organization
PRA	Participatory Rural Appraisal
SOC	Soil Organic Carbon
SOCOMA	*Société Cotonnière de Gourma, Burkina Faso* (Cotton Company of Gourma)
SOFITEX	*Société Burkinabé de Fibres et Textile* (Burkina Company of Fiber and Textile)
U of M	University of Maryland
UNPCB	*Union Nationale des Producteurs de Coton du Burkina Faso* (National Union of Burkina Faso Cotton Producers)
USAID	United States Agency for International Development
WACIP	West African Cotton Improvement Program
WB	World Bank
WCA	West and Central Africa

1. BACKGROUND

1.1. Comparative Study of Cotton Sector Performance in Sub-Saharan Africa

The World Bank recently published a comparative study of cotton sector reforms[2] , based on detailed case studies carried out during 2007/08 in nine of Africa's main cotton producing countries: Benin, Burkina Faso, Cameroon, and Mali in West and Central Africa (WCA); and Mozambique, Tanzania, Uganda, Zambia, and Zimbabwe in Eastern and Southern Africa (ESA).

The purpose of the study was to draw practical insights from the diversity of experiences in institutional reforms of cotton sectors and to better understand the strengths and weaknesses of the different types of sectors operating in Africa, the likely effects of specific types of policy change, and the possible ways forward. The ultimate goal is to help policy makers ground their decisions in a solid understanding of the key strengths and weaknesses of their cotton sectors. The study developed a typology of cotton sectors based largely on differences in the level of competition versus coordination in the conduct of ginning activities and compared performance on a range of performance indicators across the different types of sectors.

The sector typology included four basic models, plus two hybrid cases:

- Non-market based national monopolies: Mali, Cameroon;
- Non-market based local monopolies: Burkina Faso and Mozambique;
- Market-based concentrated systems with a few actors: Zambia and Zimbabwe;
- Market-based competitive systems with many actors: Tanzania; and
- Hybrids: Benin and Uganda.

1.2. Cotton Productivity and Profitability

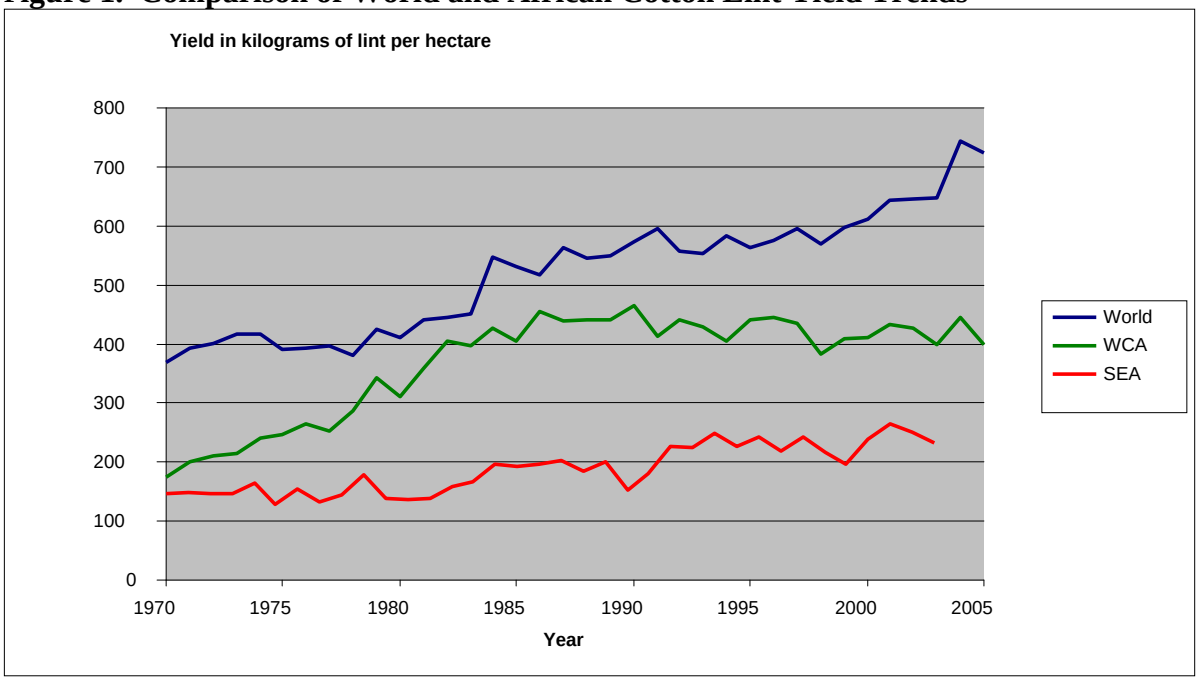
Chapter 10 of the World Bank study focused on cotton yields and returns, looking first at international comparisons of lint yields per hectare and then at comparisons of performance indicators among different types of farms in selected countries (Poulton, Labaste, and Boughton (2009). The performance indicators used were seed cotton yields, costs of production, and returns to labor. The findings are summarized in the next paragraphs as they motivate the research proposed in this paper.

1.2.1. International Yield Comparisons Show Africa Falling Behind

The comparison of world and African lint yield trends shown in Figure 1 is sobering, as the world trend line reflects the fact that the production frontier has been moving out in many countries, driven by the introduction of new technologies such as genetically modified (GM) cotton.

[2] Organization and Performance of Cotton Sectors in SSA: Learning from Reform Experience, Tschirley D., Poulton C., Labaste P., 2009

Figure 1. Comparison of World and African Cotton Lint Yield Trends



Source: Tschirley, Poulton, and Labaste (2009).
Note: The world trend line includes both irrigated and rainfed cotton.

In comparing African cotton yields (tons of lint/ha) to the world average, Figure 1 shows that the recent stagnation in yield growth in Africa contrasts sharply with rapid yield growth shown for the world in general. The increasing trend in the world yield has been apparent since the early 1980s, but appears to have increased during the 2000s, which corresponds to the widespread adoption of Bt cotton in several countries[3] .

The ESA trend has been very slow but exhibits relatively steady yield gains (from a very low base) since the early 1990s while the WCA trend has been a fairly constant decline (from a relatively high base) since the late 1980s.

The driving force behind the WCA and ESA yield differences is credited to the greater willingness and ability of the WCA monopoly systems to invest in varietal development, input supply and credit, quality extension services, and logistical support. The authors also noted yield differences between the concentrated and competitive systems in ESA. The more concentrated systems have better yields, reflecting the greater ability of the concentrated systems to supply inputs on credit because they were able to protect their investments (i.e., with fewer actors there is less risk of farmers avoiding credit repayment by selling output to other firms). The report notes the important role played in this case by "the lagged impact of past performance" referring to major investments made in WCA and in Zimbabwe well before 2000. These investments are most likely responsible for the inter-country yield differences apparent today.

This suggests that the African challenge is two-pronged: (1) as recommended by Poulton, Labaste, and Boughton (2009), a large number of underperforming but capable farmers must move closer to the existing production frontier (while those unable to do so exit cotton production entirely) and (2) farmers with good productivity using currently available

[3] Bt cotton was introduced commercially in 1996 in the U.S., Australia, and Mexico; in 1997, in China and South Africa, and in 2002 in India; by 2007, 70% or more of the cotton produced in these countries was Bt cotton, with the exception of Mexico where Bt cotton represents about half of cotton produced (Tripp 2009) .

technologies must move to a higher production frontier. Without such a two-pronged approach, African countries will likely fall further behind their competitors, as has been happening during the two cropping seasons that have passed since the research reported by Poulton, Labaste, and Boughton (2009).

1.2.2. High Variability in Performance across Farms Raises Concerns

Although the yield and returns differences across sector typologies were relatively easy to identify and explain, the team found that within each sector there was extremely high variability in outcomes across farmers operating in the same production environment. Although this is not an unusual finding for Africa, understanding the reasons for the differences and how to reduce them remains a challenge. Data for the farm-level analyses came from the cotton companies or research institutions and through village level interviews in seven of the nine case study countries using Participatory Rural Appraisal (PRA) methods, which were the only ones available given the short length of the field visits by the study team (see Box 1).

Box 1. PRA Methodology

Using a single criterion—aggregate quantity of seed cotton produced per farm—researchers asked focus group participants to classify farms in their village into three or four groups ranging from the largest producers of cotton, to medium, small, and very small. The focus group participants then provided general descriptive information concerning farmers (land owned/cultivated, household demography, productive assets, etc.) and developed indicative cotton crop budgets for each group. This data enabled the team to assess yields and returns to labor by group.

Descriptive information about the different groups of farms suggests that farmers who produced the largest quantities of cotton tended to have more land, more labor, more animal traction equipment, and use more inputs. Despite higher levels of input use, this top group had lower costs of production than their neighbors. Farmers who obtained lower yields and produced lower absolute levels of cotton generally had more limited access to production assets, particularly household labor, which is often hired out by farms in groups 3 and 4 at critical dates in the cropping calendar, thus delaying work on household fields and lowering yields.

Differences in yields and returns to labor were much smaller in WCA than in ESA when comparing farmers producing the largest quantities of cotton to those producing smaller amounts. This result is attributed to the relative success of the WCA state monopolies in providing most cotton farmers with inputs and access to animal traction equipment whereas only the largest producers have access to inputs and equipment in ESA.

Recognizing the limitations of the Participatory Rural Appraisal techniques used to collect this information, the report was relatively circumspect in its recommendations for improving African cotton yields and returns. While the conclusion that: “An important lesson from this analysis is that assisting more farmers to move into groups 1 and 2 is critical for sector competitiveness…and for poverty reduction” (Poulton, Labaste, and Boughton 2009) is correct, the means by which to achieve that goal are far from evident. Specific recommendations to improve extension advice and access to inputs, to facilitate asset accumulation (especially animal traction), and to pay farmers higher prices— are all recommendations for improving yields and returns that have been standard currency for decades in Africa. Despite past efforts to implement such recommendations, the majority of African cotton farmers still perform well below the agronomic potential of the crop.

1.3. Need for a Better Knowledge of the Returns of Cotton Cultivation at Farm Level

Although the PRA results provided some insights on farm-level productivity and returns to farmers, the inherent limitations to the PRA surveys and perceived lack of recent cross-sectional and longitudinal studies of cotton yields and returns in Africa warrant a more in-depth analysis of the causes of variation in returns of cotton cultivation and cotton performance at farm level. Researchers involved agreed that there was a need to better quantify cotton profitability at farm level, identify the factors affecting profitability, and identify, characterize, quantify, and understand the behavior and dynamics of different cotton farm groups. This is necessary to develop appropriate policy recommendations and support programs to help farmers - or different categories of farmers - benefit more from cotton cultivation, or allow them in some cases to switch to more profitable crops and diversify their cropping systems.

In response to this perceived need, the World Bank has provided funding for the development of a concept note for a research program that would contribute to improvements in the knowledge of farm-level cotton yields, returns, and profitability. The objective of the research would be to characterize the primary farm types, depending on sector/country context, and their strategies, behaviors, and responses to interventions designed to support productivity and income growth such as technology research, farmer training, and policy design.

The underlying hypothesis of the proposed research is that aggregate productivity growth and incomes could be significantly enhanced if there were a better understanding of the strategies, capacities, and constraints of the different types of cotton farmers as this knowledge would permit the design of more targeted support interventions. For example, it would be very useful to know, for each major category of cotton farm, the main structural constraints they face, how they react to incentives, and what potential exists for progress. It will also be useful to identify the set of services and assets required for a household to be able to raise incomes and build assets over time through cotton production.

The research proposal developed in this paper aims to address these challenges through the application of cotton farm typologies to the quantification of cotton farm-level profitability and the design of performance enhancing research, capacity-building, and policy interventions.

2. OBJECTIVES

The paper describes a research program that will:

(1) add to the knowledge on the current returns of cotton cultivation to farmers in SSA, and on factors affecting these returns;

(2) improve the understanding of the diversity of farm-level responses to recent changes in the cotton sector;

(3) improve the understanding of the factors that contribute to the sharp differences in performance observed among farmers operating in similar agroecological and institutional environments; and

(4) examine the extent to which this improved knowledge by major type of farm can contribute to more effective interventions to improve farm-level performance by
- moving farmers closer to existing production frontiers (by reducing costs and increasing returns through farmer training programs or policy interventions for example), or
- moving out the frontier through the introduction of improved technologies.

This research is expected to be relevant and useful for decision-makers and stakeholders in the cotton sectors. Therefore, making sure that local partners can make use of the results of the research for their cotton policies and programs is also an important objective of this work.

The approach of the proposed farm-level study is similar to that of the 2009 sector-level study. Whereas the latter classified cotton sectors into broad categories based on their organizational and institutional structure (often a result of historical experience or geographical differences), the proposed study will examine the extent to which using cotton farm typologies can improve the understanding of performance differences and provide insights to identifying the types of programs and policies needed to improve performance for each group at the farm level.

Farm performance will be viewed primarily through the same lens used in the comparative study— by measuring seed cotton yields and returns to farm labor used in cotton production. Recognizing that aggregate production at the farm level can be a more important determinant of overall cotton sector performance than yields per hectare; this indicator has been added to the list as well. The focus of this research will be cotton productivity and incomes, with other farm and non-farm activities examined to the extent that they complement, compete with, or provide a potential alternative to cotton.(e.g., migration, off-farm employment, or shift to horticultural crops for example).

In the current context of generalized crisis in African cotton sectors, and growing indications that diversification into other farm and non-farm activities will be critical to the future of the cotton sectors in many countries, setting appropriate boundaries on how far the research goes beyond cotton in terms of data collection and analysis will be difficult.

The underlying hypothesis of the proposed study is that technology research, farmer training, and policy and institutional reforms to improve cotton sector productivity and incomes tend to be designed for *typical* or *model* farmers. This often fails to take into account the diversity among cotton farmers and what this diversity implies for cotton sector development in general and the ability of the cotton sector to contribute to poverty reduction in particular.

Even in countries where cotton farm typologies are used, they tend to be static in nature (failing to take into account farmers' strategies, for example), narrowly defined (often based only on ownership of productive assets) and there is only weak evidence that the existing typologies are correlated with yields and returns to labor (e.g., Mali's *Compagnie Malienne des Textiles (*CMDT) typology). The proposed research will address this gap in improving the understanding of the relevance of farm typologies and their relationship to farm performance.

The research will look at the structure, strategies, and constraints of the main types of farm households identified and assess what this implies for their capacity to adopt productivity enhancing technologies and practices or to respond to specific types of incentives and support programs. In some cases, the farmer's objective is not to increase cotton productivity but to maximize returns from different activities and minimize costs of production and labor, while reserving time and resources for social obligations, religious ceremonies, etc. Productivity and incomes can be improved significantly, but the ways to do that will vary significantly depending on local factors. The typologies of cotton farms will take into account these factors, as well as others.

The research is expected to differentiate between: (1) farm types that possess the minimum set of assets to pursue strategies to improve cotton yield and income performance (e.g., appropriate type and quantity of land, equipment, labor), and are able to access a minimum set of supporting services needed to profitably produce cotton (e.g., roads, credit, extension), and (2) farm types that do not meet these minimum criteria.

This second category will need to be further differentiated according to whether the provision of additional public or other collective goods and services can enable them to achieve cotton profitability or whether alternative farm or non-farm enterprises would be more appropriate. Armed with a better understanding of the factors underlying variation in cotton profitability at farm level, it should be easier to design policies and programs to encourage groups of cotton producers to improve their productivity and incomes or develop alternative income sources.

A clear understanding of these distinctions and a willingness to act on them through policy and farm support programs could contribute to the reversal of negative cotton productivity and farm income trends in Africa. Without more attention to these differences, underperforming farmers will likely continue to produce cotton, resulting in lower average yields and aggregate levels of production. A better understanding of farm typologies and productivity links can also contribute to a parallel effort to assist the better performing farmers push out the production frontier so that the competitiveness of African cotton vis-à-vis the rest of the world is being addressed from the bottom up and the top down.

In some regions, cotton may be the only significant source of income, and therefore the only way for farmers to obtain agricultural inputs. Hence, governments may decide to support cotton production in some areas in order to keep them out of extreme poverty. In these situations, given the dependency of cotton production on government support, it may be difficult to assess which farmers have *adequate resources* to produce cotton competitively.

As with the earlier study by Tschirley, Poulton, and Labaste (2009) the proposed research will build on a set of country case studies that identifies similarities and differences across cotton sector structure and types of cotton farms and how these may influence cotton productivity and incomes. Each country study will focus on differences across farms within that country and by type of cotton sector organization. A synthesis of all the country studies will consolidate the findings, draw out general lessons, and address the role that cotton sector organization plays in shaping differential production and income impacts across farm types.

3. APPROACH USED TO DESIGN THE RESEARCH PROGRAM

In designing the research program described in this document, the following steps were taken:

- Identification of the specific research objectives and questions to be addressed;
- Articulation of a conceptual framework to guide the research;
- Review of the literature to:
  - Summarize current thinking on *best bet* farm-level cotton production technologies and practices and what is known about their relevance to different types of farms;
  - Look for answers to the research questions being posed; and
  - Learn about the design of programs to address similar questions in the past;
- Identification of existing data bases and ongoing research that could be used to answer some of the research questions;
- Development of a methodological approach to be taken in coordinating this multi-country research; and
- Development of a list of country studies capable of contributing to the overall study.

The rest of this paper is organized to briefly summarize the main findings at each step of the process outlined above and describe the proposed research methods.

4. RESEARCH QUESTIONS

The research questions are presented in two sections: (1) those that have already been addressed largely through the literature review conducted while developing this concept note, and (2) those to be addressed through the conduct of additional country case studies at farm level.

A review of the agronomic and socio-economic literature on currently available cotton production technologies and farming practices was conducted to provide general information on the state of the art with respect to where the production frontiers are and which socio-economic factors affect farmers' production decisions. A review of documentation on cotton farm typologies was conducted in an effort to understand the strengths, weaknesses and relevance of existing typologies so that the proposed case studies can benefit from what is already available in each country. The specific research questions addressed through the literature review were the following:

- What are the main parameters influencing profitability of cotton production?
- What does available agronomic and socio-economic research conclude concerning the most promising types of technologies[4], farming practices, and marketing strategies for improving incomes and raising cotton productivity in Africa?
    - What are the best bet technologies and practices, and marketing strategies?[5]
    - What is their potential for increasing yields and farm incomes?
    - What are the characteristics of farms most likely to succeed with these technologies, practices and marketing strategies, and the characteristics of those most likely to fail or be uninterested?
- What are the existing typologies of relevance to African cotton production zones?
    - What are the most commonly used criteria for categorizing African cotton farmers (e.g., agroecology, size, productive assets, performance indicators, etc.)?
    - To what extent do the criteria differ by cotton sector and country?
    - To what extent are dynamic and static factors combined in the typology?
    - What methods were used to develop these typologies?
    - How have these typologies been used?

Drawing on the literature review, tentative answers to these questions are provided in section 5.

The key research questions that will be addressed through the country case studies include the following:

- What are the current levels of income and returns from cotton according to different farm types?

- What are the main factors affecting profitability and returns, distinguishing between those specific to the cotton sector (e.g. price, yield, quality) and those not specific to

[4] We use the term "technology" here in a very broad sense, summarizing what is known about major categories of cotton technologies (pest management, mechanization, soil conservation and fertility, etc.).

[5] The term "best bet" is drawn from the literature on participatory technology research and implies that different types of farmers have been asked to assess the technology from their personal perspective and provided feedback to researchers.

the cotton sector (e.g., competition for resources, especially labor, from other more remunerative crops, other economic opportunities)?

- What are the different strategies of cotton farmers with respect to:
    - The place of cotton in the overall farm enterprise (key source of income, one of many, trying to exit cotton, etc.)?
    - Level of intensification (preferences for more vs. less intensive technologies and farming practices)?
    - Quality goals (aiming for quality premiums, happy with prices for lower quality)?
    - Choice of marketing channels (conventional, fair trade, organic, etc.)?
- How do these different strategy choices relate to a farmer's resource endowments (land, labor, capital, mechanization, management skills) and to a farmer's access to services (inputs, credit, extension, non-government organization's programs)?

- How have farmers' production and marketing strategies for cotton vs. other crops changed over time and for what reasons?

- In a given cotton production system, what is the combination of cotton production and marketing strategies most likely to increase farmers' overall income and productivity and ensure the sustainability of the farm enterprise?

- Is there a minimum resource endowment and level of services required for a farmer to profitably pursue cotton production (i.e., are there some types of farms that should not engage in cotton production)?

- What percent of farmers in the cotton zone fall into each of the above categories?

- What technologies and farming practices are most likely to raise cotton income for each type of farmer, and to what extent are they consistent with those that raise yields?

- What technologies and farming practices are most likely to raise cotton yields and aggregate cotton production for each type of farmer (based on strategies, resource base, and access to services)?

- What types of programs and policies (farm management advice, improved access to credit, demonstration plots, targeted subsidies, etc.) are needed to support farmers wanting to (1) move closer to the existing production frontier, (2) pursue alternative niche markets, (3) adopt new technologies, or (4) exit cotton production?

5. CONCEPTUAL FRAMEWORK

To answer the set of questions above, it will be useful to draw on two related conceptual approaches to understanding agricultural productivity and farm incomes:

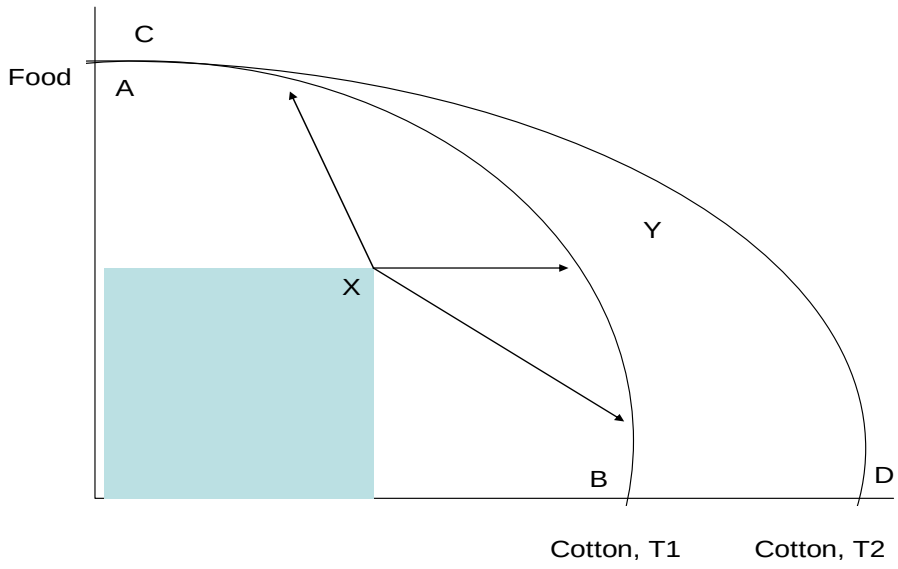
- Production frontiers and supply curves; and
- Agricultural Systems Research.

5.1. Production Frontiers and Supply Curves

The production frontier concept is illustrated in Figure 2.

The situation illustrated by the curve A-B is that of a farmer with a fixed set of inputs and available technologies that can be applied to the production of either cotton or food staples. Curve A-B represents the different combinations of cotton and food crops that the farmer can obtain by using available resources efficiently (i.e., maximizing output). If the farmer is producing at any point inside the curve (e.g., point X), he is not achieving the maximum output possible with his resources. Identification and removal of the constraints that prevent the farmer from reaching the production frontier could move him from point "X" to curve A-B. Given the assumed level of resources and technology, it is not possible for the farmer to produce outside the curve (e.g., point Y); to aspire to produce at a level higher than that shown by curve A-B (e.g., curve C-D), the farmer would need to acquire more resources or have access to a superior technology which gets more output without using more resources. The concept of the production frontier is generally flexible and could be applied to some of the newer resource allocation choices offered to farmers by putting organic cotton and conventional cotton on the axes rather than cotton and food.

Figure 2. Cotton and Food Production Possibilities Frontier



The hypothesis is that many African cotton farmers are in the situation represented by point "X", but the reasons for this failure to produce on the production frontier are not clear. Do they have strategies that do not aim for economic efficiency in the technical sense (e.g., risk aversion)? Have they simply not mastered the use of the available technologies? The distance from "X" to a position on the frontier is similar to what is often called a *yield gap* by scientists when comparing yields obtained on farmers' fields to those obtained on research stations. However, in many cases the yield gap is due to different resource endowments (e.g., better soils, more labor) that actually put the research station on a different frontier. During the past two decades, researchers have been experimenting with different approaches to reducing yield gaps, including participatory research that allows farmers to identify best bet technologies addressing both their resource constraints and their production and income objectives. For example, *mother and baby* research protocols combine more complex and rigorous tests of technology performance (mother) with more easily managed tests of components (the baby) that are selected and implemented by farmers.

Another hypothesis related to the concept of production frontiers is that African cotton farmers who are currently on the frontier A-B (or even at point "X") could move to a higher level of productivity and incomes (C-D) if a more productive or less costly technology became available. An example of how this might happen is currently playing out in Burkina Faso with the introduction of Bt cotton. The farmer's ability to actually move from A-B to C-D is contingent not only on researchers' finding a more productive technology but also on extension messages helping farmers to adopt the technology, and support programs that ensure access to inputs, credit, farm management training, etc.

Another way of viewing the production frontier is in terms of the supply curve. New technology can shift the technology frontier out, resulting in lower average unit costs for a given level of output, which in turn shifts out the supply curve and improves competitiveness. Similarly, moving farmers from a point inside the frontier to a point closer to it (through more effective use of existing technology) lowers average unit costs and moves them closer to the potential supply curve.

Using this framework forces one to keep in mind the distinction between the two types of productivity increases, but it also raises a question that is difficult to answer: In Africa, what should be the relative importance of efforts to move farmers closer to the existing frontier versus moving the frontier out? From the perspective of the future competitiveness of African cotton sectors vis à vis those in other countries (particularly China and India), there is a strong argument for a focus on moving the frontier out, as that is what has happened recently in countries that have shifted to Bt cotton production. Africa's failure to push the frontier out (whether it be through Bt cotton or other major innovations) could jeopardize its ability to compete with those who have already done so. From the perspective of improving the average level of, and reducing variability in, productivity and incomes within countries so that cotton can serve to pull farmers out of poverty, moving farmers up to the current frontier may be an easier and more appropriate approach.

5.2. Systems Research: Farming and Agrarian

While the economic concept of a production frontier and supply curve help to understand the relationship between farm-level productivity and sector competitiveness, they do not provide specific information needed to help farmers move toward the production frontier or shift out their supply curve. They also do not offer much help in understanding some of the opportunities for increasing farm incomes through the pursuit of alternative marketing

channels (e.g., fair trade cotton). Both Farming Systems Research (FSR) and Agrarian Systems Research (ASR) have been used extensively in Africa since the 1980s (the former primarily in Anglophone countries and the latter in francophone countries) to address these more complex issues.

Both approaches take into account:

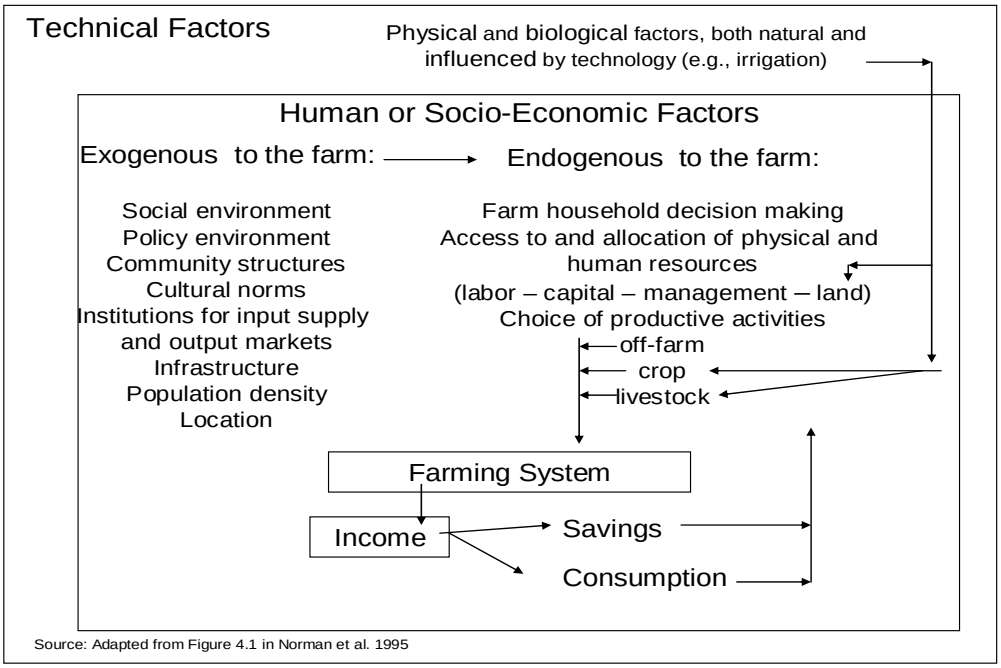
- on-farm production conditions,
- a systems approach to understanding the complexities of the environment in which farmers operate,
- conceptualization of the farm as a complex system of many farm and non-farm production and consumption activities,
- an analysis of producers' practices,
- development of recommendation domains or farm typologies to group farmers with relatively homogeneous characteristics into meaningful categories for research and action,
- the participation of producers in the process of developing technologies, programs, and policies to improve farm performance, and
- the need to ensure a social and political environment conducive to innovation.

Where the approaches differ is in the relative weight given to different types of analysis and the nature of the problems being addressed. FSR can be classified as *technology-centric* in that the goal is to produce or encourage adoption of highly productive technologies and farming practices; the research is usually conducted at the level of the farming or production system and contains a strong research-action component that involves on-farm testing of proposed solutions. ASR tends to be more *typology-centric* in that its point of departure is understanding farm dynamics and using that understanding to develop farm typologies of relevance for the design of programs and policies to improve farm productivity in general. ASR gives more importance to an initial identification and diagnosis at the level of the agrarian system (i.e., the broader system within which different production systems operate), to the strengthening of producer organizations, as well as to policy issues. While ASR can be applied in a research-action context, this is not an essential component.

Both approaches provide excellent frameworks for understanding farmers' strategies and decisions and the wide array of physical, technical, endogenous, and exogenous factors that shape those strategies and decisions. The frameworks were developed in response to criticisms that the money invested in agricultural technology research was not producing tangible results because of low adoption by farmers and a realization that more attention needed to be given to socio-cultural, political, and economic factors influencing adoption. The systems research approach is multi-disciplinary (agricultural and social scientists working together) and looks at the farm enterprise from a much more holistic perspective than technology research had done in the past.

Figure 3 illustrates the general concepts and relationships that are used to guide agricultural systems research. The figure shows that farm incomes are shaped by two broad categories of factors: technical and human. The technical factors are both physical (e.g., soils) and biological (e.g., seeds); they reflect what is present in the natural environment as well as adaptations introduced through technology development (e.g., irrigation, fertilization). Technical factors tend to put limits on the types and potential of agricultural activities in which a farmer in a particular environment can engage. Human and sociological factors cover everything else. Some human factors are exogenous and out of the control of the farmer (e.g., roads, markets, prices) while others are endogenous and shaped by the strategies and actions

Figure 3. Schematic Presentation of Holistic Systems Research Approach



of the farmer (e.g., mix of household income generating activities, capital investments). Over time, there have been many variants of the systems approach used in agricultural research, with each iteration tending to widen the circle of factors taken into account.

5.3. Combining the Two Frameworks

The combination of a production frontier framework and an agricultural systems framework forces one to remember that the technical factors (including technologies) set limits on the opportunity set that is available to farmers while the wide variety of human factors (exogenous and endogenous to the farm) influence the incentives that shape how the farmer responds to that opportunity set. Whether one puts the initial emphasis on the technology (the static production frontier framework and the more dynamic FSR framework) or on the typology (the dynamic ASR framework), there is a need to match technologies to farmers' production and strategies, resource endowments, and the variety of exogenous factors that shape production and marketing outcomes. A matrix illustrating these typology/technology relationships for the case of cotton farmers in Mali is presented in Section 6.3. below.

The next chapter provides a synthesis of recent literature on farm-level performance of cotton with an emphasis on production technology. At the end of the review, we illustrate the operational value of looking at choice and potential adoption of technology through the lens of farm typologies.

6. SYNTHESIS OF LITERATURE REVIEW FINDINGS

An extensive literature review was carried out to identify recent research results dealing with both the technical and the socio-economic factors affecting farm-level cotton performance and the extent to which farm typologies have been used in efforts to promote increases in cotton yields and returns to labor. The discussion is divided into three sections. The first section focuses on the technical literature, illustrating what the current thinking is on the potential for technology to improve cotton productivity and performance and how that potential might differ by farm type.

The second section reviews current thinking on the potential contribution of marketing innovations that might improve farm incomes (e.g., moving to organic or fair trade cotton or aiming for the high quality market, for example). The third section looks at the issue of farm typologies, identifying the typologies of relevance already developed and how they are used.

6.1. Promising Technologies and Practices

Any research proposing to understand better options available for improving cotton farmers' incomes needs to take stock of what is known about the technologies and practices now available, which types of farmers are using them, and what is known about the constraints to expanding the adoption of the technologies that exhibit good potential for increasing yields and/or returns to labor.

In the chapter on cotton research in the comparative study of 2009, Boughton and Poulton note that "A first step toward defining the role of research in improving yields will be to understand the causes of low productivity in specific agroecologies and farm types to determine the mix of investments necessary." The fact that many African farmers are achieving yields far short of the existing frontier suggests a need for substantial socio-economic research to understand the reasons for the yield gaps and find solutions, many of which will not be technical ones.

The review of the technical literature was not limited to research in Africa, but efforts were made to cover whatever was available on African cotton productivity. The discussion that follows is organized by five broad categories of productivity enhancing interventions: pest management, soil/land management, varietal improvement, weed control, and mechanization. It summarizes the findings concerning yield and income increasing potential and the factors influencing the adoption and successful use of the technologies and practices.

6.1.1. Pest Management

Among the pest management practices and technologies, Bt cotton appears to have the most potential for increasing yields while also decreasing costs and improving profits. Worldwide, Bt cotton now represents 50% of cultivated cotton area and 60% of production (Kabwe 2009). Yield increases when comparing Bt cotton to traditional pest management practices are in the 30-65% range (Gouse et al. 2005, Bennett et al. 2004; Vitale et al. 2006 and 2008). Yield increases tend to be higher for smallholders who did not have the resources to apply adequate amounts of pesticides prior to the adoption of Bt cotton (Gouse, Pray, and Schimmelpfenning 2004). Several studies have found increased net profits for smallholders having adopted Bt cotton (Falck-Zepeda, Horna, and Smale 2007 and Vitale et al. 2006 and 2008 conclude from pre-adoption confined trials that increased profits are likely). However,

other results have been more nuanced: positive net impacts were predicted in Mozambique through a simulation model only if health benefits were quantified and producers received prices for their cotton that were comparable to other prices received in the region (Pitoro et al. 2009). Bt cotton is an interesting case when viewed in the production frontier framework: it simultaneously shifts the production frontier out and forces farmers to operate closer to it because of heavy up front input costs that convert to losses if the crop is not managed adequately. Hence, this technology has a significant *leverage* potential on cotton productivity for the farmers who are able to absorb the risk and implement good crop management practices.

Despite the promise of Bt cotton and very positive results in China and India, there is a variety of factors likely to slow down the spread of the technology in Africa and the adoption by resource-poor farmers. Institutional arrangements can pose serious problems. In South Africa (Makhathini Flats), for example, a monopsony ginner introduced Bt cotton. However, when a competitor entered the market it became impossible to use crops for loan collateral and the system fell apart (Gouse et al. 2005). Liberalized ginning sectors risk mixing different types of seeds, which can result in difficulties when preparing differentiated supplies of conventional and Bt planting seeds for the following season. Weak seed production and input delivery systems throughout the continent will make it difficult to deal with the added demands of Bt cotton (Eicher, Maredia, and Sithole-Niang 2006; Hofs and Berti 2006; Hillocks 2005). Many cotton extension and credit programs now favor better off smallholders (e.g., Mozambique), reducing the likelihood that resource-poor farmers would benefit (Boughton et al. 2007). Bt cotton will be beyond the reach of poor cotton farmers unless credit is available; this creates more of a challenge for the ESA African cotton sectors that provide little credit to farmers but may be easier to address by the WCA cotton sectors that have well-established credit programs.

Bt cotton is also a very knowledge-intensive technology requiring a major extension effort with farmers. Experience in South Africa (Bennett et al. 2004) and more recently in Burkina Faso (personal communication with several cotton sector actors in Burkina) has shown that farmers have incorrectly discontinued the use of pesticides that should have been continued along with Bt cotton, bringing about serious yield declines. Poor crop management practices, pervasive in African agriculture, severely compromise benefits from Bt cotton (Eicher, Maredia, and Sithole-Niang 2006; Hillocks 2005). The complex property rights issues surrounding Bt cotton seeds are difficult to explain and police (Hillocks 2005). The initial steps that must be taken to introduce Bt cotton in a country that has no existing biotechnology regulatory framework can take 5 to 10 years. This will prevent Bt cotton from being adopted in the short-run for many of the African cotton sectors that are now teetering on the brink of dissolution due to declining productivity and profits.

A recent review of worldwide experiences with Bt cotton (Tripp 2009) provides four very detailed case studies (China, India, Columbia, and South Africa) on Bt cotton adoption. It includes a discussion of the various institutional, contracting, and regulatory issues raised by its introduction and its impacts on different actors (e.g., resource poor farmers, commercial farmers, seed companies, ginners) and provides a comprehensive resource for decision makers working on this complex topic. The book's summary conclusion concerning the Bt cotton experience in South Africa was the following:

Research has clearly shown that the Bt cotton technology works and that both large-scale and smallholder farmers can benefit, especially in seasons with high bollworm pressure. The fact that South Africa has a functioning regulatory framework for GMOs made it possible for cotton farmers to benefit from advance in biotechnology. Even though cotton production has

decreased significantly over the past decade (due in large part to low relative prices), the market share of GM varieties has not decreased, despite the availability of conventional varieties. In fact, farmers have indicated that if it had not been for these technological advances the decline in the cotton sector would have been much more dramatic. (Tripp 2009)

Tripp goes on to note, however, that

…no technology (GM or otherwise) can resolve the fundamental institutional challenges of smallholders and agriculture in Africa…the wider story of cotton in South Africa emphasizes that while all agricultural systems require adequate investment and appropriate technologies, their viability is determined by the policies and institutions that facilitate sustainable and profitable production.

The alternatives to Bt cotton, currently employed by most of Africa's cotton farmers, are traditional pesticide use or some version of Integrated Pest Management practices (IPM). While the evidence of alternative approaches to pest management such as IPM practices is positive in terms of reduction in pesticide use levels and costs, yield increases and cost savings tend to be small—100-200 kg/ha with a 40-50% reduction in pesticide levels generating a $20/ha reduction in costs (Silvie et al. 2001; Nibouche et al. 1998). However, the cost savings from reduced pesticide use are frequently reduced by increased labor demand.

6.1.2. Land, Soil, and Water Management

There are many methods that have been developed for conserving and improving soil and water resources. Although much of the research has focused on systems that combine both improved tillage and fertilization practices, we review individually four groups of practices that are most frequently mentioned in the literature: improved fallows, reduced tillage and conservation farming (it is difficult to separate the two concepts), ridge tillage, and organic fertilizers. This is followed by a discussion of efforts to measure the combined impact of IPM and improved soil fertility management practices.

Improved fallows using agroforestry methods have improved the soil organic carbon (SOC) of soils, contributing to better yields in many African countries (Vagen, Lal, and Singh 2005). Fallows in Zambia and Kenya, using fast growing, nitrogen-fixing leguminous trees have improved soil moisture capacity. However, adoption in Kenya, as measured by the share of farmers, dropped from 22% to 14% when funds for improved fallow extension programs were cut (Haggblade et al. 2010). Much of the research on improved fallows has focused on maize and non-cotton crops, but there are examples of farmers successfully using it with cotton (Ajayi 2007). Constraints to adoption include inadequate plot size, insecure land tenure, and labor shortages (Ajayi 2007). Bush fires and animal browsing can also destroy the trees planted for fallows, discouraging adoption.

Minimum tillage methods have been researched worldwide. Some initial results of minimum tillage in Cameroon suggest reduced soil runoff, from 15 – 25 tons/ha under conventional tillage to just 3-5 tons/ha under minimum tillage (Roose and Barthes 2001). Conservation tillage, which involves plowing before planting, with a no-till with mulch method used after planting, has been introduced in Mozambique, Malawi, Ghana and other countries. It has shown high yield gains in maize, and is spreading to cotton areas with the promise of reducing labor costs while decreasing soil erosion and increasing fertility (Ito, Matsumoto, and Quinones 2007). In Burkina Faso's maize-cotton rotations, farmers have

used minimum tillage with organic compost and mineral fertilizer (Ouattara et al. 2006). In Benin, farmers in different areas use organic fertilizers mixed with mineral fertilizers in differing proportions, often combining this with ridging and mounding (Saidou et al. 2004). Conservation farming in Zambia results in yield increases ranging from 25% to 50%. Econometric analysis separating the impact of the tillage method from other practices indicates average yield increases of 1650 kg/ha, of which 750 kg/ha could be attributed to tillage methods alone (Haggblade et al. 2010; Tschirley, Zulu, and Shaffer 2004). Zambian farmers using conservation farming methods increased returns to land and labor by roughly 50% over conventional tillage and were able to expand cultivated area by moving roughly 30 days of labor out of the peak season into the dry season (Haggblade and Plerhoples 2010). Conservation tillage is generally well suited to small-scale farmers, with the technology spreading rapidly (Ito, Matsumoto, and Quinones 2007). In Mali, small-scale farmers are more likely to use no-till practices, while wealthy farmers, who have better access to land, animal traction equipment, and fertilizers, have largely abandoned it. Interestingly, comparisons of soil quality between small-scale and larger farmers in Mali showed little difference, leading to the hypothesis that no-till methods were able to maintain soil quality as well as heavy tillage and input intensive practices (Mosely 2005). Considerations for promotion and targeting of conservation farming and other reduced tillage approaches include labor availability and agroecological factors. Minimum tillage generally implies additional labor for land preparation during the off season; it can reduce total labor costs but it also requires labor at a time when rural households might need to seek cash through migration or non-farm activities. The success of conservation farming techniques varies depending on the soil, weather and rainfall (Haggblade et al. 2010). This was illustrated in Zimbabwe by the improvement of results from reduced tillage on clay soils compared to those on sandy soils (Chivenge et al. 2007).

Ridge tillage (*Aménagement en courbes de niveau* or ACN) involves building closely spaced, permanent terraces across a field to enhance water management. There is persuasive evidence from testing that this method increases SOC, and usually produces yield gains in cotton, groundnut, maize, and other crops, ranging from 30% to 50%, with particularly good results on sandy soils (Doumbia et al. 2009). This range of yield gains is comparable to those reported above for Bt cotton, suggesting that there are technology options to increase cotton yields without switching to biotechnology. The ACN fields showed a 66.6% increase in mean water infiltration rates on test sites in Mali and Niger (Kablan et al. 2008). This method is also fairly inexpensive, leading to large profits for farmers (Gigou et al. 2006). Constraints to adoption include lack of animal traction equipment (used to speed up the construction of ridges), and lack of improved means of marking the contours. At present, only soil and water conservation technicians have the equipment and skills needed for this task (Kablan et al. 2008). The lack of available technicians means that in some areas the demand for this technology has not been satisfied (Gigou et al. 2006). While the technology is easy and inexpensive, farmer cannot implement it without a transfer of skills and equipment needed for contour marking or an increase in the number of available technicians.

Organic fertilizers (animal manure, crop residues, and green manure) have been promoted as essential complements to inorganic fertilizers because of their capacity to build SOC (Roose and Barthes 2001; Bationo et al. 2007; Saidou et al. 2004). Inorganic fertilizers are also promoted as complements to organic fertilizers because the nutrients from inorganic fertilizers can help offset nutrient-weak organic fertilizers (Palm, Myers, and Nandwa 1997). The main difficulties related to the use of manure as organic fertilizer are that most farmers have too few animals to produce it themselves, and that there are very high costs involved with the transport of large amounts of material for fertilization (Ajayi et al. 2007). Recent ASR in Mali found a strong correlation between cotton yields per hectare, returns to labor,

and livestock ownership facilitating the use of organic fertilizers. Evidence suggests that farmers with access to manure through ownership of large herds and an ability to purchase inorganic fertilizers were able to pursue a strategy of continuous cultivation for a cotton/maize rotation rather than having to introduce fallows every four years, as did farmers with limited access to manure and inorganic fertilizers. Returns to labor for the former were approximately double those of the latter (Dufumier 2005). In some cases, there are socio-cultural taboos against its use (e.g., the use of cow dung in some parts of Benin) (Saidou et al. 2004). The use of plant residues has also been constrained in West Africa because of a generally low level of biomass production and quality, as well as competing uses for the material (Bationo et al. 2007, Palm, Myers, and Nandwa 1997). Though a proper mix of organic and mineral elements can significantly reduce fertilizer costs, there is not an easily determined ideal mix of the two, and rapidly changing prices for inorganic fertilizers complicate the task. Extension recommendations and farmers choices need to take into account other practices used (fallowing or specialized tilling methods), access to inorganic fertilizers and input credit, and the nature of farmers' land, labor, and livestock resources.

Combining improved pest and soil fertility management practices shows promise for increasing yields in several countries of West Africa and reducing the incidence of pests. Data from a training and half-hectare demonstration plot program to promote these practices in Mali during the 2008/09 cropping season show an average yield gain of 34% (1644 vs. 1229 kg/ha) over the demonstration farmer's same season yields on other cotton fields, and a reduction of insect infestations of 14% (CMDT 2009). These are average results for 200 demonstration plots across the seven cotton production areas in Mali. Unfortunately, there is no information about cost or income impacts, and the farmers selected to conduct the demonstrations were those who were already considered to be among the best cotton farmers (average seed cotton yields for the previous three seasons were greater than one ton). In the training and the conduct of the demonstrations, a single set of practices was recommended across all farmers and zones—reinforcing the observation made by Poulton, Labaste, and Boughton (2009) that there is a need to pay more attention to inter-farm differences and the role they might play in technology adoption and impacts. Test programs similar to the Malian one have been carried out in Burkina Faso and Benin by the West African Cotton Improvement Program, which supported the Mali program.

6.1.3. Varietal Improvement

Other than Bt cotton discussed above, the literature review did not unearth a large number of recent studies on cotton breeding or improved varieties being introduced in Africa. This is perhaps due to reduced investment by governments and cotton companies in varietal research, which was mentioned in Tschirley, Poulton, and Labaste (2009), and to the fact that the cotton companies whose results are rarely published often fund cotton breeding. There has been some discussion of the strengths and weaknesses of participatory approaches to plant breeding in Benin (Lancon et al. 2004), which concluded that it was not possible to establish a link between decentralized breeding results and improved local adoption. Other recent work in Benin has focused on adapting varieties to local conditions, particularly rainfall (Sekloka et al. 2007).

Bt cotton was also covered in the varietal research literature, with a focus on the constraints to its testing and introduction. For example, farmers involved in participatory breeding work in India began to cross Bt cotton with local varieties despite legal restrictions (Lipton 2007). Problems are also foreseen with the introduction of Bt cotton into systems without enforced

varietal zoning, as the lack of varietal zones already makes it difficult to maintain varietal purity (Hillocks 2005; Poulton et al. 2004).

Another issue that needs to be addressed is for whom varieties are being bred. Boughton and Poulton (2009) note the need for variety research to be based on the needs of both farmers and ginners. In Mali, a new cotton variety was introduced with an increased ratio of fiber to seeds. This is a boost for ginners, but farmers have been complaining that the weight of their seed cotton production, on which their cotton earnings depend, is lower with this new variety. As demand for comestible oils increases and cottonseed oil plays a growing role in satisfying local demand in Africa, breeders may also need to consider the oil output as well as the fiber output of their varieties.

6.1.4. Weed Management

Literature on weed management technologies and practices for cotton was also difficult to find. Work in Zimbabwe compared different approaches to weed management, finding that herbicide use both with and without oxen was the least expensive management option for weed control (Mavunganidze et al. 2008). There is also some evidence of herbicide use before planting in conjunction with *no-till* approaches to reduce plowing (e.g., southern Cameroon).

The dearth of published information on this topic probably reflects extremely low use of herbicides in African cotton production and a lack of cotton-specific research on alternative approaches to weed control.

6.1.5. Mechanization

Mechanization of smallholder farms in much of WCA originated with the introduction of animal traction to cotton farmers. This was made possible by the vertically integrated structure of the WCA cotton sectors, which made it possible to provide equipment and input credit to farmers in a production system with a guaranteed market and a closed credit system linked to seed cotton purchasing, which ensured repayment.

We found very little recent literature on cotton mechanization, despite the fact that tractors are now replacing animal traction equipment for some of the better-off farmers in WCA. Despite the lack of *technology* research on the benefits of mechanization, there is compelling evidence that mechanization is a key factor differentiating farmers with high cropping incomes from those with low cropping incomes, but not necessarily differentiating among farmers in terms of yield performance. (Harvard and LeThiec 1999; Bigot and Raymond 1991; Faure 1994). This connection is developed more fully in Section 7 on farm typologies, because ownership of animal traction equipment is a commonly used criterion for creating farm typologies.

6.1.6. Summing up the Cotton Technology Situation

Our review of the recent literature on cotton technologies and farming practices was not meant to be exhaustive but to provide some guidelines concerning 1) currently available technologies that could be used to benefit African farmers currently producing below the production frontier and 2) technologies that might be available in the future to push out the

production frontier. In this review, we made every effort to highlight what is known about the types of farmers most likely to benefit from the different technologies and practices. Most of the literature focuses on pest management and soil, land and water management practices. Although Bt cotton is controversial as an approach to pest management and thus far only being pursued in South Africa and Burkina Faso, we note that the potential to increase yields and reduce costs appears to be substantial IF the many hurdles mentioned in the literature can be overcome. Given the constraints to widespread promotion of Bt cotton in Africa in the near term, it is encouraging to note that many of the soil, water, and land management practices described in the literature have the potential to improve cotton yields and returns to labor by approximately the same percentages as the introduction of Bt cotton—both types of technologies generally generate yield increases ranging from 20% to 50%. Soil and water management practices, however, also have the capacity to significantly increase cereal yields when cereals are grown in rotation with cotton, thereby responding to farmers food security concerns as well as their cash income concerns. The bottom line for the study at hand, however, is not the potential productivity of the available technologies and practices, but the need to understand why many of the seemingly promising technologies that have been available for a very long time have experienced only limited levels of adoption and often, those having adopted them are not realizing the anticipated potential. In brief, what are the constraints to, and opportunities for, realizing the full potential of currently available technologies and practices and how do they differ by farm type?

6.2. Marketing Options

While improving the technical efficiency of African cotton farmers is critical if incomes are to increase and African cotton sectors are to remain competitive in world markets, there has been both discussion and on-the-ground experiences with improving cotton incomes by making changes in marketing strategies. Among the key options under discussion are: quality improvements that would bring price premiums, creating and promoting an African label, producing for the organic markets, and producing for the fair trade markets. None of these options can be framed as exclusively a *farm-level* decision variable because most African farmers do not have a large choice in terms of who purchases their seed cotton. In addition, the decisions about which markets are targeted are dependent on the choices of the ginning companies and/or the availability of NGO supported projects promoting organic and fair trade markets. For farmers who are faced with a choice of outlets, however, it is useful to review the current thinking concerning the different marketing options.

There is general agreement that the quality of African cotton, once ranked among the best in the world, has declined in the recent past due primarily to polypropylene contamination from the bags used at harvest time. Estur, Poulton, and Tschirley (2009) note that because of its long fiber and hand picking, African cotton could obtain a premium of up to 10 cents/pound on international markets, but contamination with foreign matter has been a constraint in recent years. To overcome contamination problems, ginners need to control their supply chain and farmers need to be encouraged to produce good quality fiber through the appropriate use of quality pricing mechanisms by seed cotton buyers. Even though all countries offer price differentials for quality, there is a tendency to classify most fiber as top quality due to the difficulties of grading at the time of purchase. While the rest of the world has moved to mechanical testing of cotton quality, most of Africa continues to rely on visual inspection. Also contributing to the problem is the undetectable nature of polypropylene contamination (not detectable until the contaminated fiber is incorporated into textiles and dyed). While the long-term prospects for African cotton sectors regaining their quality

reputation are good, major institutional reforms will need to be put into place before the price incentives necessary to encourage on-farm management changes are evident. In 2004, Senegal, one of the smallest cotton sectors in Africa, introduced a successful initiative to reduce polypropylene contamination at three levels—farm harvest procedures, bailing materials, and during truck transport. The result was that in 2007, Senegalese cotton ranked second in the world (after Israel) for control of polypropylene contamination.

To date, fair trade and organic cotton marketing opportunities have been dependent on support from NGOs who provide substantial subsidies to participating farmers. Two cases in point are the supply of cotton harvest bags to farmers free of charge during the above-mentioned campaign to reduce polypropylene contamination in Senegal and the supply of cotton bags by the USAID-funded West African Cotton Improvement Program (WACIP) to assist Burkinabé farmers to meet the demands of an organic cotton market they were supplying. The extent to which these markets will provide significant opportunities for cotton farmers to increase incomes is still being debated. Most analysts agree that both market outlets are growing but represent such a very small share of the overall cotton market that they are unlikely to provide solutions for the vast majority of African cotton farmers (points made in draft WACIP reports on the topic). François Traoré (former President of the WCA regional cotton producers' union) has expressed his concern that these niche markets do not offer the types of opportunities needed to bring the WCA cotton sectors out of their current crisis. This concern comes from the first hand experience of having had to use the funds of the conventional cotton producers in Burkina to pay the organic producers because they had not yet (in March 2009) marketed the entirety of their organic production from 2007/08 (Traoré 2009). One unsuccessful result should not eliminate all hope for these markets to develop, but it should be a call for a more thorough analysis of the real opportunities and their implication for different types of African cotton farmers.

6.3. Farm Typologies

Much of the literature reviewed above provided relatively very little guidance on the willingness and/or ability of different types of farmers to successfully adopt particular technologies or target different markets. By contrast, there are many examples of cotton researchers in the social sciences and agricultural support services developing farm typologies with the objective of gaining a better understanding of key factors that differentiate farmers. These typologies have been used to facilitate the introduction of new technologies (including new crops), to understand why some farmers are not producing at or near the production frontier, and to provide general farm management training and marketing advice. The latter use is an area of growing importance as cotton sector reforms push farmers increasingly into more unpredictable and complex production and marketing situations (e.g., increasing choices among types of cotton to grow (conventional or organic) and types of markets to target (conventional or fair trade). Growing complexity with respect to both marketing and technologies (e.g., the regulatory issues associated with the introduction of GMOs) raises the question as to whether typologies that divide African farmers into different types of *business models* could provide a useful framework for the design of future cotton sector strategies, research programs, extension activities, and policies.

Our review of the literature suggests that there are two types of typologies of relevance to African cotton farmers:

Simple ones based on productive assets and used primarily for extension, monitoring, and evaluation purposes, but occasionally by researchers and policy analysts; and

More complex ones developed by researchers to understand the dynamic evolution of cotton farms over time, farmer strategies and life cycles, and the factors that shape each group's responses to environmental and institutional changes; these more complex typologies are used to design and target farm management training and marketing advice and for broader cotton sector strategy and policy assessments.

The complexity of these dynamic typologies suggests that they could be adapted to a *business model* approach that would help with understanding farmers' strategic choices and improving on the productivity and income performance. Table 1 summarizes what can be documented concerning the typologies used for extension, monitoring, and evaluation in the nine countries covered by the comparative study.

The table has many blank boxes and some with incomplete information because it is difficult to find published information on these typologies. The present state of knowledge on existing typologies seems to suggest that countries in WCA have been more likely to develop and use farm typologies than their counterparts in ESA.

Table 1. Farm Typologies Used by Cotton Sector Actors

Country	Typology description	Sources or Potential Source
Benin	None yet identified	
Burkina Faso	A. No traction equipment B. Lightly equipped (pair of oxen or donkey and a plough) C. Highly equipped (2 pairs of oxen and a full chain of equipment (plough, seeder, weeder, etc.)	Used by INERA in annual monitoring and evaluation studies; reported by Renaudin 2007 and used in EU 2007 diagnostic study (Burkina Faso 2007).
Cameroon	Since 1980, Sodecoton has used a simple typology based on two factors: Whether the farm produces cotton Whether the farm uses animal traction Taking into account different levels of animal traction use, the classification has 6 levels: • Farms not cultivating cotton, using manual techniques, or herbicides and focusing on food production. Mechanical mounding is sometimes observed. • Farms not cultivating cotton but owning at least one full set of animal traction equipment. • Farms cultivating cotton manually or using herbicides. Mechanical *buttage* sometimes observed. • Farms cultivating cotton and owning at least one set of animal traction equipment. • Farms not cultivating cotton and renting animal traction equipment to prepare the soil for	Gergely 2008, Aboubakary 2003.

Country	Typology description	Sources or Potential Source
	cultivation • Farms cultivating cotton and renting animal traction equipment for soil preparation.	
Mali	Annual monitoring and evaluation data are analyzed for 6 geographic zones and 4 farm types, whose definitions remain constant across all zones. The farm type definitions are: A. Farm with 2 animal traction units (animals and plow), plus at least one seeder, one cart and a livestock herd of at least 10 beef cattle, including two pair of oxen trained for traction; B. Farm owning one animal traction unit plus at least 10 cattle, including one pair of oxen for traction; C. Farm owning an incomplete traction unit but knowing how to use animal traction; and D. Farm dependent on manual cultivation with little knowledge on how to use animal traction equipment.	CMDT
Mozambique	No classification used	Personal communication Raul Pitoro
Tanzania	None yet identified	Poulton
Uganda	None yet identified	Baffes
Zambia	None yet identified	Tschirley
Zimbabwe	Smallholders and commercial farmers form two major groups.	Poulton

Table 2 summarizes what can be documented concerning farm typologies used recently by various research projects; some are based on the cotton sector typologies described above but others (Mali, for example) have gone beyond the traditional typologies adding many more dynamic considerations.

Table 2. Farm Typologies Used in General Cotton Sector Research

Country	Typology description and application	Sources or Potential Source
Benin	Nothing found yet	
Burkina Faso	A. No traction equipment B. Lightly equipped (pair of oxen or donkey and a plough) C. Highly equipped (2 pairs of oxen and a full chain of equipment (plough, seeder, weeder, etc.) Found significant differences in net returns to cotton labor per hectare across farm types for 2005/06 (47,000 FCFA, 80,000 FCFA, and 98,000 FCFA	European Union 2007; Renaudin 2007

Country	Typology description and application		Sources or Potential Source
	respectively for A-C); income differences by group are greater if farm size is taken into account. Also significant differences in cotton yields by group, but differences greater for cereals than for cotton. Cereal yields for non-cotton farmers much lower than those for cotton farmers for each group.		
Cameroon	Recent research on direct seeding-mulching practices in two villages in Northern Cameroon suggest that the Sodecoton typology no longer discriminates well among farmers as most produce cotton and use animal traction. The typology that has been developed for the promotion of seeding-mulching practices is based on: Labor sources and availability(family and hired), Farm size and ownership. It is not clear if this typology will eventually replace the older Sodecoton typology or not.		Aboubakary 2003
Mali	Agrarian systems classification dividing cotton producing areas into 3 types of production systems and 6 major types of farms:		Bainville and Dufumier 2007; Dufumier 2005
	Production Systems 1. Continuous cultivation (good access to equipment and animals) 2. Slash/burn (poor access to equipment and animals) 3. Peri-urban permitting diversification into fruits and vegetables	Farm types 1. Large family size, highly equipped, large animal herd 2. Medium family size, well equipped, large number of animals 3. Medium family size, at least one traction team but animals insufficient for soil fertility needs 4. Small family size, manual equipment, no cattle, no cotton 5. Fulani herders (sedentary and transhumant) 6. Sunday farmers (generally hiring labor and using extensive practices)	
Mozambique	Farm size in hectares used to differentiate farmers for various types of farm performance analyses		Personal communication R. Pitoro
Tanzania	Land and livestock as indicators of relative household wealth used to divide farmers within villages to explore impacts of price volatility on		Bargawi (2008)

Country	Typology description and application	Sources or Potential Source
	farmers. No specific typology developed to incorporate cross-village differences, but factors which differentiated 3 villages studied included agroecological (soils, rainfall) and institutional factors (historical role of Ujama, access to highways, and relative importance of cotton vis a vis other crops in the village (which influences willingness of traders to travel to villages)	
Uganda	Male- and female- headed households Geographic/zone differences	Maratou and Baffes (2009) on-going research to understand productivity differences
Zambia	No explicit typology developed but econometric analyses showed (1) significantly higher cotton yields for farms with male heads, better access to ploughs and livestock, a larger family size and a larger share of males in the family and (2) a negative correlation between farm size in hectares and yield (interpreted as extensive production being more profitable for those with good land access)	Brambilla and Porto 2006, using time series Zambian Central Statistic Office Post-Harvest data for 1997-2002
Zimbabwe	Nothing yet identified	

The review is not exhaustive (because information about these typologies is not often available in easily accessible publications), but it does highlight some commonalities. In most countries, cotton is grown in a number of different agroecological environments, so agroecology is often an important criterion used in differentiating cotton farmers. At the household level, asset types and levels (animal traction equipment, livestock, vehicles, housing, and furniture, for example) are frequently used for grouping farmers.

The general observation is that *wealthier* farmers are more likely to use the most up-to-date and productive technologies, more likely to have access to input credit, and more likely to have more land and family labor. Although there is a need to clarify the link, the wealthier families often appear to be the original settlers of a village and therefore the families able to control access to land (e.g., the case of Mali). This tendency of the wealthier to do better with more productive technologies has been enforced by many extension service programs that have relied on *model farmer* approaches, which can encourage the development of an elite class of farmers benefitting from more regular and intensive extension service support. Wealthier farmers tend to have the highest levels of cotton production, but not necessarily the highest yields as there is sometimes a negative correlation between farm size in hectares and yields, with land-abundant farmers getting better overall returns to labor though extensive rather than intensive practices.

The assets most commonly used to differentiate cotton farmers in terms of productive capacity are ownership of animal traction equipment and livestock (the latter for both traction

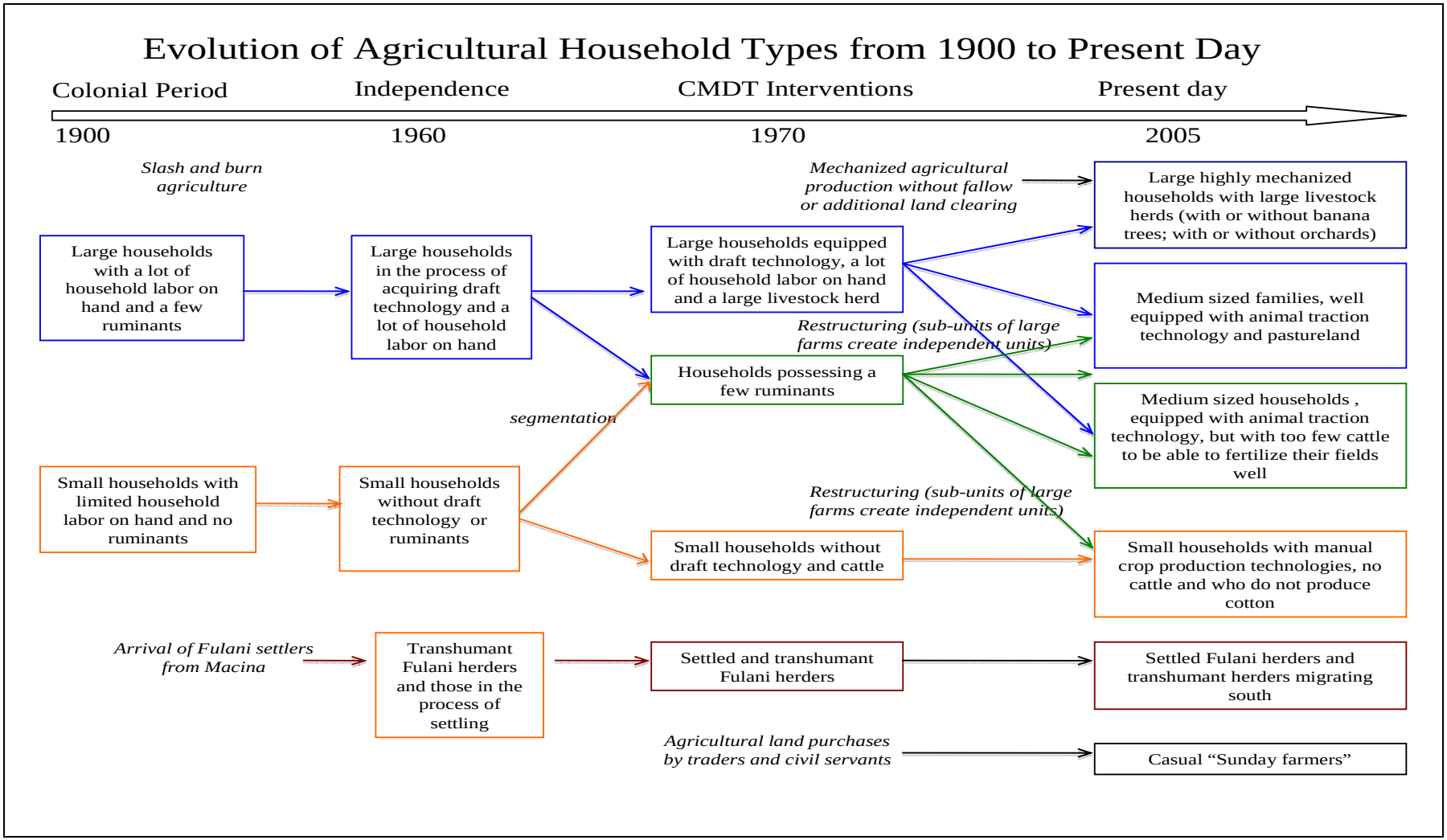
and soil fertility). Family size is also important in many cases. In most African cotton systems, ownership of animal traction equipment or tractors is positively correlated with land holdings and other indicators of wealth (type of housing, food security, etc.). The highly coordinated cotton systems of WCA recognized early the important contribution that animal traction could make to farm productivity and incomes in general, and developed institutions to strongly support its expansion to the vast majority of farmers (unlike ESA, where animal traction use remains limited). Early recognition of this productivity-animal traction link explains why farm typologies in Mali and Burkina have been based on equipment for decades.

Mali's official farm typology was developed in the 1980s and has since had few modifications except the recent addition of farmers with motorized equipment to the "A" category. Interestingly, a 2005 study in eleven villages representing three different cotton sector agrarian systems confirmed the importance of access to animal traction equipment in differentiating among farmers in all of the study sites more than 20 years after the initial classification was created (Bainville and Dufumier 2007). Figure 4 presents a summary of the key elements of the *dynamic* typology which incorporates more information about the evolutionary path (colonial period to present) of different categories of farms and then terminates in 2005 with a set of 6 major farm types, which take a wider range of factors into account than the official CMDT typology. The extent to which this more complex typology can be used as a tool that makes a substantial contribution to the design of cotton sector policies, technology research, and farmer training remains an open question. The typology has been taken into account in the design and implementation of programs to provide farm management training (*conseil à l'exploitation*) in the Malian cotton zone. However, in a review of experiences in the use of the *conseil agricole* approach, Harvard, Coulibaly, and Dugué (2006) warned against heavy-handed pre-grouping of farmers by typologies for the purposes of *conseil agricole*:

Mais attention, de ne pas enfermer le conseil dans le carcan des typologies, mais laisser la possibilité aux agriculteurs de se regrouper, de s'organiser pour le conseil sur des critères qui leurs sont propres. L'utilisation des typologies peut se faire à postériori pour voir dans quels types se trouvent les exploitations volontaires pour le conseil. Dans le cas du volontariat, il est important de savoir quels sont les exploitants qui participent aux activités de conseil, à quels types ou quelles catégories ils appartiennent, de voir aussi si certains types d'exploitations sont exclus. Ceci peut permettre de réajuster la démarche et les outils mis en œuvre.[6]

[6] Roughly translated, this paragraph calls for allowing farmers to form their own groups for training purposes and developing typologies based on the voluntarily formed groups, with particular attention to noting what types of farmers joined the different groups and which types were totally absent. Training materials and methods can then be adjusted in response to the nature of the groups formed.

Figure 4. Example of a Dynamic Cotton Farm Typology for Mali



Source: Translated and adapted from Bainville and Dufumier 2007.

Table 3. Illustrative Typology-technology Matrix for Mali

Farm Typology Menu (Select relevant characteristics from dropdown menus)	Cotton Technology Menu	Enabling Conditions Required for Technology Use	Technology choices	
			Inappropriate	Promising
Primary farm type (select 1 of 6)	**Pest management**			
	Pesticides	No interest in organic production	x	
Large size family extremely well equipped, very large herd	IPM (specify type)	Adequate labor force		x
Medium size family well equipped for animal traction	Bt cotton	Better than average crop management skills		
Medium size family with animal traction equipment	Organic cotton	Ability to follow rules (e.g., no conflicting ag activities)		x
Small family with manual equipment only	**Soil and water conservation**			
Fulanli livestock herders	Improved fallows	Adequate land and animals		x
"Sunday" Farmers	No-till & conservation farming	Good mgt skills; adequate labor supply		
Secondary characteristics of relevance (select up to 3 of 13)	Ridge tillage	Agents to mark contours		
	Soil fertility			
Access to bottom lands	Organic fertilizers	Ownership of animals; proximity to pasture		
Non-intensive cultivation of bottom lands (e.g., tree crops)	Compost pits	Access to water		x
Own or have acces to pasture land	Stabling of animals	Ownership of animals; resources for fencing		x
No access to bottom lands	Collect and transport	Donkey and cart		x
Intensive cultivation of bottom lands (high labor need)	Inorganic fertilizers	Access to credit; reliable supply chain		
Not enough animals to adequately fertilizer own crop land	Organic and inorganic	All of the above		
Manure available for collection; lack transport	**Variety choice**			
Manure collection difficult (far from grazing areas)	Conventional	Good supply source		x
Rely heavily on hired labor	Bt cotton	Better than average crop management skills		
Livestock sedentary	Other (specify)			
Livestock transhumant	**Weed control**			
No cotton production at present	Manual	Adequate labor force		
No Cattle	Animal traction	Adequate labor and equipment		
Cotton Strategy Menu (select up to 3 of 7)	Manual and traction	Adequate labor and equipment		x
	Chemicals	Access to credit/no interest in organic	x	
Maintain cotton but diversify to diminish reliance on cotton	**Land preparation**			
Switch to higher value cotton (organic, fair trade)	Manual	Adequate labor force or ability to hire		
Maintain current level and intensity of cotton production	Animal traction	Ownership or ability to rent		x
Maintain current area but intensify cotton production	Tractor	Ownership or cash resources to pay		
Move entirely out of cotton as soon as possible	**Livestock**			
Rely on cotton production to get inputs but not for income	Transhumant			x
Other ??	Fattening	Stabling areas; ability to purchase feed		x

Note: To illustrate the matrix, we have selected the farm types, secondary characteristics, and cotton strategies shown in italics in the first column at the left. The "x" in the two columns at the right provide advice on inappropriate and promising technology choices given the farm typololgy selected.

Source: Designed by authors drawing on Bainville and Dufumier (2007) and technology literature review.

In line with suggestions in Section 5.3 above that improvements in productivity and incomes will require methods permitting one to link particular farm typologies to appropriate cotton production technologies and farming practices, Table 3 uses one category of the Bainville-Dufumier typology plus information on intra-category differences to illustrate how this might be made operational. The list of technologies in the table is a bit generic, but the table serves to illustrate the challenges of keeping both the socio-economic factors that are highlighted in the typologies and the technical factors highlighted in the list of technologies in view as one tries to find appropriate leverage points and actions for improving cotton incomes and productivity. Information in the *enabling conditions* column refers primarily to farm characteristics, but further development of the matrix would require that it also take into account the policy and institutional environment.

No examples have been found of typologies being based on indicators of performance such as yields or returns to labor. Similarly no examples are available of cotton farmer typologies having been developed or confirmed using quantitative methods such as correspondence or cluster analysis, although several countries (e.g., Mali, Zambia, Mozambique) appear to have databases that could be used in this manner[7].

This brief review of cotton farm typologies used in Africa illustrates that some attention has already been paid to understanding performance differences among farmers using farm typologies—more so in WCA than in ESA. The static nature of the typologies used by cotton sector actors calls into question their potential usefulness in understanding the constraints to increased cotton productivity. In addition, there is a noticeable gap in the literature reviewed: the absence of documented evidence reporting the use of the more dynamic typologies to introduce programs and policies that have successfully increased cotton yields and returns to labor.

An important issue, not covered in the literature reviewed, is how well the existing farm typologies group together farmers with similar yields and returns to labor. Concern over these two performance indicators drives the proposed research, so this question is of significant interest. Apparently, the long-used typology in Mali is only weakly correlated to yields, with the correlation being significant primarily in years with good climatic conditions; during bad years everyone does poorly (Belières personal communication 2009). A number of studies have shown that ownership of animal traction equipment, a major component of several cotton farm typologies, tends to be correlated with income but not necessarily with cotton yields (Harvard and Le Thec 1999, Bigot and Raymond 1991; Faure 1994; Faure and Djagani 1989). While typologies developed for the irrigated rice system in Mali, using factor analysis methods, show significant differences in average yields by group, the standard deviations for each group are large (32-49% of the mean), suggesting that each group contains a wide range of different levels of productivity performance (Kébé et al. 2005). Variability of results is expected to be even larger for cotton than for rice, given that rice is irrigated and cotton is rainfed.

If within each group of farmers in a given typology, we find wide variability in yields and returns to labor, the typology may need to be further subdivided. This additional step will

[7] We did find one study regarding irrigated rice production zone in the Office du Niger of Mali, where an analysis of 20 variables using factor analysis methods largely confirmed the typology already in place, which was based on farm size, and level of water control. The analysis did, however, also indicate that the level of importance of rice cultivation (whether it was a principal or secondary activity - many farmers have other full-time employment and hire labor on their farms) was an important distinguishing characteristic (Kébé et al. 2005).

allow us to understand what is causing the variable performance reflected in these two performance indicators and what that might imply about the types of policies and investments needed to improve cotton farm incomes and productivity. An illustration of the types of further disaggregation likely to be necessary is illustrated by the *secondary characteristics of relevance* section shown in the left column of Table 3.

7. DATA BASES AND ONGOING RESEARCH OF RELEVANCE

The authors of this paper believe that any effort to use cotton farm typologies should not be done in isolation but as one component of a broader study that is focused on solving a practical farm income or productivity question of interest to cotton sector actors. The Uganda study presently under way is an example of this approach. An initial problem of men achieving better income and productivity outcomes than women was selected as the farm type problem. A particular productivity problem related to pest management was identified as a vehicle for testing how men vs. women household heads responded to two different interventions for improving pesticide management. A detailed set of data is being collected on 500 cotton farmers to analyze how men and women respond to the different *treatment* options and to develop farm typologies that go beyond the simple division of farms into groups based on the gender of the household head.

In an effort to ensure that the research proposed builds on existing data bases and ongoing research efforts, Table 4 presents a summary of what has been learned about relevant data and research in each country of interest and how these existing research programs might contribute to addressing the research questions under consideration. The results are summarized in the following paragraphs, which are presented by country, listed in alphabetical order. For each country, there is a description of each type of database and on-going research of relevance/or research program identified to date.

Table 4. Data Bases and On-going Research of Relevance

Country	Type of data base and/or research
Benin	*Evaluation of farmer advisory services.* CIRAD, in collaboration with IREEP (Institut de recherché empirique en économie politique) has a study planned for 2010-2012 to evaluate the impact of the Farm Advisory Services "*conseil aux exploitations*" program in Benin. The plan is to interview 500 farmers (400 in the cotton zone), with two interviews at an interval of 2 years. Data will include farm structure and technical and economic performance. Details will be elaborated in 2010. Research will be conducted in conjunction with a PhD thesis. Many of our hypotheses about how to improve farm incomes and productivity require improving our ability to provide farmers with new sets of the farm management skills needed to function in liberalized market situations. Therefore, any information from this study on how results differ across different groups of farmers and the extent to which farm typologies employed by the program have improved results would be relevant to the questions we are asking in the proposed research.
	Databases. We have not yet ascertained whether there are any data bases maintained by Benin's cotton companies or the national agricultural research program, and which would be relevant to our research
Burkina	*SOFITEX M&E Data*. The service for the Développement de la Production Cotonnière (DDPC) of SOFITEX, Burkina's largest cotton company, maintains a monitoring and evaluation unit that conducts annual surveys. This service monitors the operational aspects of the agricultural season (area planted each 10 days, input supply, rainfall, pest problems, measurement of production and yields. The Direction of Inputs of SOFITEX undertakes input monitoring while the commercial service monitors the production. Changes to better integrate the monitoring tasks of these two units are currently studied (information from G. Faure, CIRAD, Trip Report to Burkina Faso, February 14, 2008).

Country	Type of data base and/or research
Burkina	*SOFITEX Multi-level cotton sector survey.* The DDPC service also has a survey collecting data at four levels (village, producer groups, household, and plot) for their evaluation needs. The survey is conducted by 17 permanent interviewers who cover 17 different types of villages, collecting several types of data (demography, infrastructure, number of producer groups, etc.). For the producer groups, data on the number of member households, infrastructure, cotton production, credit are collected. In addition there is a permanent sample of 30 households per village, covering topics such as family structure, education, labor force, assets (equipment, animals, land) and a full inventory of cultivated plots with a subsample of the cotton plots followed in detail each year (production practices used, dates of key production tasks, input use, total production and yields). More limited data are also collected on some non-cotton plots. The 17 villages were selected to reflect differences in rainfall, the timing of the introduction of cotton cultivation, the relative importance of cotton production, and ethnicity. Persons responsible for the program believe the data are under-utilized because there are only two analysts available. Data that are not considered confidential by SOFITEX, particularly those coming from the annual surveys of cotton producers and producer associations) should be of interest to other actors in the sector and be used to help identify constraints and find solutions. Presently, there is no institutional mechanism for sharing this database. (Information provided by G. Faure, CIRAD, Trip Report to Burkina Faso, February 14, 2008).
Burkina	*The INERA cotton program* carries out several different types of research and support for cotton sector professionals in the area of genetics, entomology, agronomy, and agricultural economics. Three researchers intervene in the area of agricultural economics. The cotton program has been monitoring a group of 9 villages (5 in the SOFITEX zone, and 2 each in the SOCOMA and FASO COTON zones) for two years. This monitoring focuses on agricultural production practices, decision making, and technical innovations. Also covered is farm income as a function of changes in crop and input prices. There is also complementary work underway associated with the introduction of organic and Bt cotton (information provided by G. Faure, CIRAD, Trip Report to Burkina Faso, February 14, 2008).
Burkina	*Study of agrarian system dynamics in cotton zones (« Etude des dynamiques des systèmes agraires en zones cotonnières »).* The Institut des Régions Chaudes (IRC) and the Union National des Producteurs de Coton du Burkina Faso, having recognized that the policies in place during the past 20 years have contributed to a sharp differentiation of farms in the cotton zones without any parallel effort to develop policies and programs that are also differentiated by farm type, are partnering on an agrarian systems study to help UNPCB better understand the impact of its various activities and adapt its interventions to the prevailing situation in different production zones and for different types of farmers. The study has training and research components. The research objectives are to understand how farms operate under different agroecological and socio-economic circumstances and develop a typology of production systems. The training component involves a team of one French student and one Burkinabé student collecting the data together for each production system and writing independent theses on the topic. Theses were to be defended in October 2009, so some of the results of this study may be available.
Cameroon	*Testing and introduction of seeding-mulching practices*. The development of farm typologies in connection with this action-research program may be of relevance, but the research was conducted in only two villages so is limited in geographic scope. See Aboubakary for more information.

Country	Type of data base and/or research
Mali	*CMDT annual monitoring and evaluation data*. This is a multi-year panel that started in the early 1990s with some replacement of sample households over time. It includes very detailed data on technical determinants of yields for both cotton and cereals. It can be analyzed using the CMDT typology or used to explore the creation of alternative typologies. The total sample (about 3,000 farms per year) is large, but would be reduced to about 750 farms if we wanted to use the subset that has detailed input/output data and that was continuously in the panel). The data set lacks information on crop marketing, food security, and other sources of income. It appears to be an excellent source of data for analysis of the technical determinants of yields and crop income.
Mali	IER/CIRAD/MSU RuralStruc includes full input/output and income data collected using a single-visit survey covering the 2006/07 season. It contains some information on the evolutionary path of the farm (when and how land was settled, changes in access to land), household population, income by gender, and perceived impacts of structural adjustment on farm performance, food security, and general well being). Data are currently being collected by MSU/IER on the same sample for 2008/09 and 2009/10 to create a short panel. Data set could be used to develop typologies using some type of cluster analysis and for multivariate analyses to determine the relative importance of different factors influencing productivity and incomes. The survey covers approximately 250 farms in each of 4 zones: the cotton zone, irrigated rice zone, a zone of heavy international outmigration, and a zone of traditional millet, providing an opportunity to compare cotton systems with other major agricultural production systems in Mali.
Mali	Agrarian System research conducted by Dufumier (2005) provides *dynamic* typologies for the cotton sector that could be used as a base rather than trying to create new typologies. A shortcoming of the work for our purposes, however, is the lack of information on what share of farming population is represented by each group in the typology and what the future development paths might look like for each group. Some type of random sampling approach would be needed to address the first issue and simulation modeling of business alternatives to address the second.
Mali	WACIP-funded IPM/Soil management training program for 25,000 farmers implemented by CMDT in 2008/09 and 2009/10 could be used as a basis for a case study measuring the impacts (levels of adoption, yield and income impacts, etc.); there appear to be no plans to conduct an impact study (see description of demonstration plot part of the program in Section 6.1.2)
Mozambique	There is no information about available databases. An annual agricultural survey is conducted, but it includes only a small sample of cotton farmers (approximately 7% of 5500 households in the sample grow cotton).
Tanzania	*Databases*. No information available. *Potential for a country case study*. Colin Poulton thinks there may be some scope for collaborative research given the Tanzania Cotton Board's current interest in improving cotton productivity and SOAS's past work in Tanzania.
Uganda	Ongoing research-action work by John Baffes et al. is looking at differential adoption and productivity results by gender related to the introduction of improved farming practices. The study covers 500 cotton growers in 4 regions who will be interviewed twice (before and after the project interventions). The sample was random but design ensured selection of adequate numbers of household heads of each gender. Survey data will be used to develop a farm typology. Two *intervention treatments* were tested: one pesticide training and the other training and pesticides provided for free. The sample selection was random

Country	Type of data base and/or research
	but later adjusted following discussions with ginners and CDO (ginners were involved in the treatment). Work is being conducted collaboratively by WB and U. of Maryland. Ginners are among the local partners. Laoura Maratou (U of M) has prepared a presentation on two *themes*: (i) survey structure, process, problems encountered, etc. (the inclusion of this theme was motivated by likely questions similar to the ones you asked) and (ii) preliminary findings from the first survey. Total budget for this work is approximately $250,000 (to illustrate what it might take to do a case study with measurable quantitative results).
Zambia	Nationally representative Central Statistics Office annual survey of over 3000 farms has been used in the past to examine cotton farmer behavior and productivity (see work by Brambilla). The data set is longitudinal (but not a panel) covering 1997-2002. More information on details is needed to determine its usefulness. There appears to have been no effort to develop farm typologies using these data.
Zambia	Potential for a country case study. MSU (Tschirley) has had preliminary discussions with Dunavant about their interest in joining forces to look at issues of productivity determinants with respect to different technologies and practices they are currently testing and promoting.
Zimbabwe	Nothing found

The above summary of research programs is still a work in progress. More data sets and ongoing research will probably be identified as the details of country case studies are worked out and access is thus made possible to some of the more promising data sets to verify their potential for addressing the research questions of interest.

Information available thus far suggests that there is some potential to build on existing databases and research in Benin, Burkina Faso, Mali, Zambia, and Tanzania. Work in Uganda is already underway and will be available to supplement case studies developed under this proposal.

At present it looks like countries fall into two distinct groups: those with a history of using farm typologies (Mali and Burkina) and those that do not (Tanzania, Zambia, and perhaps Benin). It is also noteworthy, that countries with a history of using farm typologies for research and monitoring and evaluation are the ones that have benefited in the recent past from additional ASR that has provided information of relevance for updating and expanding the traditional typologies. Given this uneven playing field for farm-level typology work, the design of the studies in each country will, by necessity, have to give different levels of attention to first indentifying the relevant typology versus applied research using the typologies to solve specific problems. For example, in Mali (and perhaps Burkina) it may be possible to start immediately with a research-action activity along the lines of what has been done in Uganda to test how different types of farmers respond to the same sets of interventions. In Tanzania and Zambia, however, the research design will need to include a significant *typology* component if we are to obtain comparable information from each country on farm typologies.

8. OVERVIEW OF PROPOSED MULTI-COUNTRY RESEARCH PLAN

As already mentioned, a country case study approach is proposed for answering the research questions listed in Section 4. The case study approach is a logical extension of the initial work done by Poulton, Labaste, and Boughton (2009), where the data were collected using similar (but not identical) research methods that are adapted to the situation in the study countries. The country study approach (1) facilitates comparisons across the different types of cotton sectors identified in the comparative study of 2009, (2) provides insights about the determinants of productivity differences among farmers in different types of cotton sectors, and (3) provides information that can be used to make recommendations for productivity improvements at both the country and the Africa regional levels.

8.1. Basic Components of Each Country Study

At a minimum, each country study should:

- cover the principal or most important zones and cotton farmers in the country;
- develop a typology of cotton farms – or identify and validate an existing one - that differentiates farmers by yields, aggregate cotton production, and/or returns to labor;
- adapt typologies to the specific needs of the cotton sectors in each country;
- quantify the relative share of farmers in the cotton zone falling into each category of the typology and their geographic distribution;
- collect data in order to establish farm budgets; and
- carry out an analysis of the farm budgets for each of the farm types identified (business models), taking into account their likely future trajectory if no changes are made in basic cotton sector parameters such as input/output prices, technologies available, access to markets, etc.

Based on the literature review to date, it is proposed that each typology take into account the relevance of the following minimum set of farm characteristics to ensure some ability to compare typologies across countries:

- Agroecology;
- Access to land (quantity owned vs. rented in; nature of rights to land owned);
- Land use patterns (area cultivated, rented out, continuous cultivation vs. fallows, importance of permanent vs. annual crops, land improvement investments);
- Demographics (family size, composition, education, age/gender of household head)
- Ownership of or access to animal traction equipment;
- Ownership of livestock and its role in overall farm strategy;
- General characteristics of the input package used and how inputs are accessed (organic and inorganic fertilizers, types of seed, use of pesticides/herbicides, etc.);
- Access to and use of extension for both cotton and other activities;
- Membership of farmer association or cooperative for cotton or agribusiness activities;
- Access to and use of credit for both cotton and other activities;
- Role of cotton production in the overall farm strategy; and
- Role of non-farm income in the overall household strategy.

Data on these farm characteristics would need to be combined with data on farm performance to develop the typologies and get an understanding of factors differentiating farms in terms of

income and productivity. This means that for each country study a *core* data set for a random sample of farmers will be collected that includes yield, cost of production, for cotton and crops that compete with cotton for land and labor. In addition, information will be collected on household assets and non-crop sources of income. To be sure that the typologies take into account dynamic processes, qualitative information will have to be collected about farmers' strategies and key changes in their farm enterprise over time as well as information about major changes over time in the natural resource base and policy environment in which the production system is operating. Some of this information can be collected using a combination of FSR and ASR rapid appraisal techniques, while other elements will need to come from farm survey work.

In addition to these minimum requirements listed above, each country study could include the possibility to carry out the following activities:

- A research-action component that monitors the implementation of a specific intervention to improve farm productivity and incomes, with the objective of documenting how different farm types identified in the typology respond to that intervention and evaluating the usefulness of the typology for predicting farmer response.
- A quantitative business model approach that uses relatively simple mathematical whole farm models to simulate the response of different farm types to changes in selected parameters related to cotton production.

The inclusion of one or both of these elements will ensure that the development of the farm typologies is more than a theoretical exercise and provide an opportunity for national collaborators to experience the practical application of the typologies. The action-research component will provide those developing the typologies with an opportunity to assess the typology's usefulness for applied research and to make modifications in the initial typology if necessary. The Uganda study described in Section 7 provides an example of the type of research-action component we have in mind. The choice of the intervention will depend on the choice of national partners and their priorities—it can be a technical intervention and/or an institutional or policy change. By including a research-action component, we make the research more dynamic while also making it potentially more interesting to partners who are concerned about what can be done concretely to improve farm performance and the competitiveness of African farmers vis a vis producers elsewhere in the world. The objective would be to develop a sound understanding of the differential impacts of the innovation on the profitability of cotton for different farm types. The advantage of having a flexible study that grafts onto country technology diffusion, marketing, or institutional reform efforts is that we can undertake both the static and dynamic analysis of the productivity of different types of farmers. To conduct this type of dynamic analysis we would need to collect the core data described above, and develop the farm typologies but in comparable areas with and without diffusion of the technology, practice, or institutional reform of interest. Farmers in the two areas being compared would need to fall into the same general typologies.

Developing quantitative business models is advisable because there is always skepticism about the usefulness of policy inferences based solely on qualitative approaches, which is more akin to hypothesis development than to hypothesis testing. The approach is analogous to the initial cotton sector typology work reported in comparative study of 2009: the team developed their typology, developed a set of hypotheses about how performance would differ across cotton sector types, and then collected data to test their hypotheses. The challenge at the farm level is that a quantitative approach can be costly and time consuming to develop

from scratch. Therefore, the feasibility of doing this will depend on resources available as well as on our ability to link up with local institutions that have already developed basic models that could be easily adapted to the purposes of this research.

8.2. Selecting Countries and Action-research Themes

Recommendations about how many and which countries to include in the study are based on the desire to ensure that this work contributes to insights about farm-level productivity and income for each of the different cotton sector types operating in Africa while also taking advantage of the opportunities available for linking to ongoing research or existing databases (see Section 7). Although it is not expected that the institutional arrangements represented by the different cotton sector typologies would play an important role in explaining productivity differences among farmers (every country exhibits this diversity), including a variety of cotton sector types in the overall study will allow exploration of existing relationships between the type of sector and the factors that explain differences in cotton productivity and income.

The review of databases and recent work on productivity and farm typologies suggests that there are opportunities to link the proposed research to ongoing activities in several countries covered by the comparative study of 2009 study. Partnering with local institutions already addressing farm-level productivity and income issues should speed up the research process and enhance the chances of applying the results from the typology work to specific problems. All these considerations lead to propose the mix of candidate country studies listed in Table 5. Suggestions about possible topics and partners are very preliminary because local partners have not yet been consulted and more thinking needs to go into the precise focus of each country study to ensure complementarities across countries.

If resources are not adequate for five studies, priority should be given to the four non-hybrid systems. Although Mali is theoretically in a transition from a national monopoly to a local monopoly, the pace of the reform is slow and we believe the system is distinct enough from the Burkina Faso case to maintain both countries on the list of proposed studies. Should the CMDT be privatized before the study begins, the national partners in Mali would likely be a combination of the IPC and IER.

Taking an approach of linking country studies to ongoing research efforts means that we are likely to have substantially variability in themes and methods across countries, thus some preliminary agreement is required on the broad characteristics of the study design that would apply to all countries. Suggested characteristics include:

Time frame: Country studies that cover only the minimum set of components should require approximately one year to implement. Those that will include either the action-research component and/or the simulation component will need approximately three years. The first year would focus on typology validation/development (collection and analysis of relevant data) and the design of the action-research component. Year two and three would focus on the implementation of the action-research and development of the mathematical models. In the case of dynamic studies of with and without populations, a second year of field data collection after the *intervention* is recommended to confirm the results of the first year and to permit the use of more sophisticated panel techniques for looking at the farm-specific effects on adoption and yields, but it is not taken into account in the planning below.

Table 5. Options under Consideration for Country Studies

Sector type	Country	Possible topic	National partners	International partners
National Monopoly transitioning to local monopolies	Mali	Role of farm typology in explaining IPM/SF adoption and performance	CMDT/IER and perhaps IPC	MSU
Local monopoly	Burkina	Use of farm typologies by producer organizations to improve the effectiveness of their support services; need to assess implications of widespread adoption of Bt cotton for choice of topic and collaborators.	UNPCB/INERA	CIRAD
Competitive	Tanzania			SOAS/Poulton
Concentrated	Zambia	Role of farm typology in explaining adoption and performance of selected technologies or practices	Dunavant	MSU
Hybrid	Benin	Performance of farmer advisory services and the contribution of farm typologies to the performance.	IREEP	CIRAD

Methods for determining the typology to be used: There are several options for identifying or developing typologies and the choice will depend to some extent on the state of typology development in each country. A typology can be developed using existing typologies (but modifying as necessary to accommodate the specific productivity/income issue of inquiry and dynamic concerns) or creating new typologies through some combination of analysis of existing data (cluster or correspondence analysis), FSR or ASR rapid appraisals, or ex-post analysis of the survey data collected as part of the project. In selecting methods and sampling procedures for developing the typologies, it will be important to keep in mind the objective of being able to draw quantitative inferences from the typologies in terms of what share of cotton farmers fall into different categories and what the geographic distribution of different categories is.

Data collection: Each study would collect

- quantitative data on core variables such as yield, cost of production, key crop management indicators (time of planting, time of first weeding, yield loss events) for cotton and crops competing with cotton for land and labor, and on household assets and non-crop sources of income, and
- qualitative core data on farmers strategies, views of constraints to increasing productivity and incomes, potential benefits and inconveniences of innovations being studies, what differences they perceive in adoption and impacts across different types of farmers and why, etc.

In countries where it is possible to do a dynamic analysis comparing sites with and without the promotion of a particular innovation, the above mentioned data must be collected in comparable areas with and without diffusion of a particular innovation.

Sample sizes: A major shortcoming of the PRA methods used for the analyses presented by Poulton, Labaste, and Boughton (2009) was the non-representative nature of their samples and the very small number of farmers providing the information. For this more in-depth study, sample sizes should be large enough to permit us to establish statistically significant differences across groups for the key classification variables and the key performance variables of interest (yields per hectare, aggregate cotton production, and returns to labor).

In the case of with and without analyses, samples will need to be large enough to provide statistically significant results on the productivity differences across groups with and without diffusion as well as across the groups in the farm typology. The exact sample sizes will need to be worked out for each study, but given the variability associated with farm-level production data in Africa, a sample of at least 60 and preferably 100 farmers for each major farm group of interest would seem a reasonable ball-park estimate. The total sample size will be the multiplicative sum of the number of agroecological zones covered, the number of farm types, and the number of technologies diffused (with and without comparison), and a minimum 10% attrition factor for a two-year panel. Thus, in a country with one principle agroecological zone, three farm types, and one technology the sample size would range from a minimum of about 400 (60 x 1 x 3 x 2 x 1.1) to a more comfortable 660 (100 x 1 x 3 x 2 x 1.1). Note that inclusion of a second agroecological zone with the same number of farm types and an action research approach would double the country study sample requirement.

Data analysis: The core data should be used to validate the typologies and then develop typical crop budgets for each farm group identified by the typology and consider the implications for the theoretical trajectories of each farm type should there be no major changes in technologies, markets, and institutions. They will also serve to establish where different groups of farmers are in relation to the production frontier and supply curve and what characteristics identify them.

For the simulation work, linear programming models or less complex simulation methods could be used to evaluate the potential impact of different innovations or exogenous shocks (e.g., changes in input/output prices, improved credit availability and terms, negative climatic events) on different types of farmers. In countries where analytical skills are weak in these areas, the data analysis should include funding for a training component.

For the with/without studies, there are several analytical methods that can be used to address attribution problems when trying to determine if a particular innovation is truly responsible for differences observed in before/after and with/without comparative studies. Methods of potential relevance that have been used for similar analyses include propensity score matching (see Nkonya et al. 2008, for example), double differencing (Omilola 2009, for example) and regression discontinuity designs (see www.socialresearchmethods.net/kb/quasird.htm for example). Maredia (2009) provides a good overview of the topic.

Outputs of this research would include:

- study plan detailing choice of case study countries and zones, common methodology and timeline;
- detailed country case studies for the selected countries; and

- one synthesis report capturing the major findings of the study, including a comparative analysis of the country results and a set of recommendations/proposals for the design of future policies and programs that aim at improving the profitability of cotton cultivation for small African farmers and raising rural incomes.

Intermediate outputs could include:

- A paper describing the typology and presenting the differential productivity results by farm type; each study would need to include some analysis of the role played by the overall cotton sector institutional structure (following on the earlier WB study) and develop a set of qualitative/hypothetical business model trajectories for each type of farm identified (end of year one);
- A paper identifying and designing an action-research activity and/or a simulation modeling activity (end of year one);
- A synthesis paper drawing together the results from the first year of work on typologies and development of farm business model hypotheses for all the country studies (middle of year two);
- An interim report on the action-research and/or simulation model (end of year two);
- A final report on the action-research and/or simulation modeling (end of year three); and
- A set of outreach activities that would include country-level workshops during the first and second years, a cross-country meeting of researchers and other stakeholders during the third year, and a major outreach event toward the end of the fourth year.

These intermediate outputs could be initially presented at annual cross-country workshops and then revised based on feedback.

9. NEXT STEPS

Once there is an agreement on the framework and broad outline of the work to be done as described in this document, decisions will have to be made on which country studies to undertake, who the implementing partners in the country will be, what the key technology or institutional issues of relevance will be in each country, and how each study will be designed. To that end, proposals presented in Table 5 can serve as a basis to prioritize the list of countries and topics. Detailed terms of reference will be developed for the country case studies in coherence with the proposed common analytical framework.

A high level of coordination will be needed to ensure comparability of results across countries. It is therefore recommended that one institution be identified to take the lead in the development of guidelines for the overall study and arrange a workshop for selected countries and partners to develop detailed methods and country work plans. Proposals would need to include information about the participating institutions, the personnel who would be available to work on the project, the counterparts and partners at country level, the country-specific aspects of the study and a budget. It is anticipated that this initial stage would take three to four months to complete.

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