AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Opportunities and Investment Strategies to Improve Food Security and Reduce Poverty in Mali through the Diffusion of Improved Agricultural Technologies

Jeremy Foltz, PhD
University of Wisconsin-Madison
jdfoltz@wisc.edu

For

USAID-Mali AEG group

This Draft June 16, 2010

Opportunities and Investment Strategies
to Improve Food Security and Reduce Poverty in Mali
through the Diffusion of Improved Agricultural Technologies

Executive Summary

This document reviews the potential agricultural technologies that exist or can feasibly be produced to help promote poverty reduction and food security in Mali in the next 5 to 10 years. Overall there are a plethora of good technologies either available, in the pipeline, or feasible with a small amount of research effort. In many cases succeeding in poverty reduction and increasing food security will not be about choosing the exact right technology, but about helping farmers access and know about a panoply of available technologies from which they can choose the right one to maximize their future potential.

Mali has seen significant agricultural growth in the last 20 years, with increases both in areas cultivated and yields in almost all sectors and large increases in livestock production. The next decade could be a key moment when the country turns the corner from self-sufficiency toward a producer of quality food for its people and major agricultural exporter to the region and internationally or one in which it slides back toward subsistence production. The generation, adaptation, adoption, and diffusion of new agricultural technologies will be a key ingredient in determining which of these two directions becomes a reality.

A number of forces external to the agricultural sector are likely to have a significant effect on the ability of the agricultural sector to grow in the next decade. The Malian economy is likely to continue growing at a reasonably fast pace (3-5%) with new mineral and oil discoveries as well as a likely future up-tick in remittances pushing the economy forward. This mineral export led growth will likely produce increased competition with agriculture for labor and combined with international migration and an increased emphasis on schooling for children, will produce labor shortages and higher labor costs in rural areas. That said, persistently high levels of population growth will continue to demand agricultural production. If economic growth continues as predicted, wealthier urban populations will start demanding higher quality and higher protein foods, fish and livestock products, for which Mali has great as yet mostly untapped potential.

The predictions for climate change are for increased volatility of weather patterns although they are unclear on whether that means less or more rain on average. Since Malian farmers are already well versed in how to deal with a stochastic environment this may not affect Malian agriculture as much as it would other places in the world. Climate change, however, will likely make it harder for farmers to specialize in types of production or crops, which is often a result of adopting modern techniques. We should expect climate change to push Malian farmers to keep their diversified risk-reducing portfolio of activities, making technological change based on intercropping and multiple production processes more attractive whereas mono-cultures and specialization will become more difficult. This may also increase demand by farmers for soil and water

conservation (SWC) technologies, although this effect may be mitigated by labor shortages.

With the continuation of road building and airport and airline service improvements, Mali is likely to have improved access to the world economy at lower costs than currently available, which can help open up export markets. But it will still be a high cost place for all types of transport. We expect world commodity prices to stay reasonably high for most commodities produced by Mali (corn, wheat, sorghum, rice) with a smaller likely rebound in cotton due primarily to a stronger dollar. Meanwhile input costs especially fertilizer are likely to maintain their current relatively high levels.

Mali will continue to have imperfectly operating land, credit, labor, and insurance markets. Innovations in some of these markets, especially credit markets have the potential to help foster new technology adoption, but we are not optimistic on this front. Further there seems very little likelihood of an agricultural insurance scheme having any positive effect on poor rural producers.

1. The Needs of Malian Agriculture

Agriculture provides two related benefits to the people of Mali. First and foremost it provides rural and peri-urban people with their own livelihood in terms of partial (or full) self-sufficiency and security in food. Second it provides a source of income to farmers, traders, and a source of foreign exchange for the government. The choice of new technologies should take into account these dual roles (food security and poverty alleviation) and provide new technologies that address one or both of these concerns.

We divide potential technologies along these lines into those that can improve agricultural production intended to provide food security, self-sufficient livelihoods, and those that can provide significant income benefits. Malian farmers readily make these distinctions in their own choice of technology (planting one variety of sorghum as a cash crop and another as a subsistence crop), so are likely to appreciate and adopt new technologies based on how they respond to one or both of these needs.

Before reviewing the most promising technologies it is worth noting that there are a great deal of promising technologies to increase Malian agricultural production, profitability, and sustainablility. It would be a mistake to take too narrow a view and choose only one or two as the best, because while each of these is individually promising the uncertainties associated with each one are high. It is likely that promoting a diversity of technologies for a range of farmer needs and capabilities as well as varying ecological niches will have the greatest impact on food security and poverty throughout the country.

2. Food Security: More productive, robust, and safer self-sufficiency production.

In improving the individual food security of Malian farmers there are three promising strategies both of which inject improved technologies into production systems farmers already know and use. The first is to improve the genetic material used in production of crops and livestock. The second is to intensify the intercropping that farmers already engage in for risk reduction by making it more productive as a food and income source. Third is to improve cultivation techniques to conserve soil and water.

I terms of genetic improvement, three areas stand out: improved millet/sorghum varieties, improved fonio varieties, better livestock genetics. With 73% of Mali's cereal land planted in sorghum and millet and that land producing 51% of Mali's cereal output and much of that land likely to continue to be in low input risk averse agriculture, technologies that improve that land's productivity without changing practices have great adoption and diffusion characteristics. Promising technologies here, in terms of both farmer acceptance and overall effect on food security for the poor, are ICRISAT millet and sorghum varieties with better genetics that can increase yields 20% for open pollinated (OPV) and 30% for hybrid varieties without farmers changing their agronomic practices. A potential 10-15% increase in cereal production nationally is possible with this technology.

Fonio is a highly valued crop for its low labor needs, early season production, drought resistance, and women are its primary producers. Unfortunately fonio yields are low and this has reduced the acreage devoted to fonio despite its evident benefits and high prices in the market. More research is needed to provide women farmers with higher yielding fonio varieties and better agronomic techniques.

Recent livestock research has shown a number of promising genetic improvements that can be used by livestock holders at all scales. These genetic improvements can improve the productivity, weight gain, without significantly changing herder practices or risk profiles. These include improve breeds of cattle, goat, sheep, and crosses of Rhode Island Red chickens with local varieties. This last one has the potential to greatly improve backyard chicken raising; an important income generation activity for women. More effort on getting these genetically improved varieties out into the general livestock population would be useful. There are also significant improvements in feeding practices, forage production, conservation and use that could increase livestock production.

A second important line of intervention is to push intensification of intercropping systems that have long since been developed in Mali. Better planting and fertilization techniques applied to intercropping of millet/sorghum with cowpea/soy/sesame/peanuts can increase farmer yields of both grains and legumes while reducing their risk profiles in terms of both climate and market risk as well as reducing the need to purchase expensive fertilizers. These techniques are well tested and can go directly to pilot extension programs. A second type of intercropping that shows great promise is the addition of fish raising to irrigated rice ponds. Adding fish can produce up to 1.5 tons of fish per hectare and at the same time maintain the same or better rice yields. With the correct control of

water, fish farming in rice fields could be more lucrative than rice farming. Intercropping of fish and rice will require both research and extension efforts.

A third line is to help farmers reduce their risks, through improving their planting, soil conservation, and water retention techniques. Integrated pest management also shows much promise where small changes in farmer practices; e.g., changing planting schedules by a few weeks, can reduce or eliminate pest damages. Most of these improvements require only an investment of time and change of technique from the farmer end, but a lot of investment in extension by the government and partners is necessary to bring the necessary information to farmers. Rather than focus on one or two technologies, this kind of work should provide farmers with a menu of planting, soil, and water conservation and integrated pest management techniques. This portfolio approach is especially important because in many parts of Mali farmers are still rotating their land through fallow periods, which severely reduces the incentives to invest in soil and water conservation techniques.

3. Cash Crops: More productive, less risky, and more lucrative cash crops

Malian farmers need new more productive, less risky, and more lucrative cash crops, in order to improve their incomes and step out of poverty.

A first way to provide this is to improve cash crops that are also consumable within the household such as corn, millet/sorghum, rice, wheat, and fish. Promising technologies include new seed varieties of drought resistant, fertilizer responsive crops such as corn. For women, intensifying their home corn-fields (*champs de case*) with hybrids and fertilizer represents an avenue for more extension work. Better varieties of rice for bas-fond, dry-land, and irrigated areas, which are more disease resistant and fertilizer responsive (e.g., NERICA). Improved rice and wheat farming techniques, such as the SRI (rice) and SBI (wheat) programs, show promise in raising yields through better techniques; but levels of farmer acceptance are still low and need further work. In addition the fertilizer responsive sorghum and millet varieties produced in the INTSORMIL program and used also by Sasakawa Global, show promise as a cash crop version of a subsistence crop.

Along with increased production of cash crops, better training and diffusion of simple methods to store grains could yield great dividends on the marketing end. Currently losses to pests and spoilage are very high for stored grain and simple improvements in storage techniques using existing facilities and equipment could reduce these losses and lower storage risks.

New cash crop potential exists in sesame and soybeans, especially where one can intercrop them with existing subsistence crops such as sorghum and millet. Both of these are likely to be technologies available and beneficial for women farmers. Another new crop with intercropping potential is jatropha-curcas, which can provide farmers with a steady source of income and potential fertilizer from the jatropha press-cake. More

research is needed on testing which crops are best for this intercrop. Women are likely to be involved in collecting and maintaining jatropha and it has a lot of potential around women's garden plots.

Mali is poised for large expansions in dairy production, something that should bring a steady income stream to rural households and women in particular within 20 km of a paved road. Most of the development can be done with the existing cow stock and technologies; key requirements are training, organization, and some minor infusions of technology. Further efforts to help push dairy development include better forage production, selection, and storage as well as improving local milk preservation and conservation techniques.

Increased development of fish farming also shows promise, both as an intercrop with rice and as either the stocking of existing local ponds or of specifically built fish-ponds. Mali has a perfect environment to expand fish farming where water is available. With a potential production of 9 tons/hectare worth 9 million CFA, the returns to fish farming are well above those of other crops, although the investment costs will be prohibitive for all but the most wealthy. Cooperatives may be able to alleviate some of these costs.

In terms of the export crops that compromise the USAID value chains such as onions, mangoes, garlic, potatoes, the biggest need is to start testing international quality versions of the crops grown here. It is not too soon to start testing to see how well the key varieties of these crops that sell internationally would potentially grow in Mali.

4. Labor saving technology

As set out in the introduction, the future of Malian agriculture will be increasingly determined by labor constraints. Herbicide use in Mali has doubled in the last 5 years in part in response to labor constraints and is likely to increase substantially in the future. Herbicide use has very positive spillover effects on women's time and ability to work on their own crops or collect karité nuts. More extension work and agribusiness training is needed, along the lines of USAID's IPM CRSP's work in pesticide literacy and safety, to ensure safe and effective use of herbicides, In addition Mali needs research work testing the safety and long-term consequences of increased herbicide use in a savanna environment.

Increased use of plows, multiculteurs, and tractors will likely also be warranted to face the lack of rural labor supply. Research and extension on the best use of tractors and multiculteurs in Mali in terms of soils, crops, and profitability is warranted. Further expansion of use of multifunctional platforms for grinding, threshing, and other post harvest chores is another area worthy of donor investment, because of the potential benefits in freeing up women's time.

5. **Improving Ecological system services**

Malian rural areas have a symbiotic relationship with their forests, grasslands, and tree-parklands in their fields. Increased mechanization of farming, the use of herbicides, and climate change has the potential for negative effects on the productivity and regeneration of these spaces. Relatively little is known about this and therefore more research is needed into how to maintain and regenerate the productivity of these spaces. Aside from natural regeneration, IER and ICRAF have done some promising research into making more productive, faster growing tree species that have yet to be diffused. In addition there is clearly a larger quantity of karité and other wild fruits that could be collected. Barriers to doing so include women's access to appropriate transport devices, market access, and creation of markets for locally eaten, but rarely sold local fruits.

6. Gender specific technologies

Among the various technologies described above a number are likely to have the largest impact on improving women's income and food security.

All labor saving technology, such as herbicide, is likely to have a gender impact not as much in women directly using it, but in it freeing up women's time for more lucrative activities. For example increased use of herbicide would free up women's time during the key time of year when they collect karité nuts, July-August, potentially engendering an increase in the production of karité butter and better women's incomes. Multi-functional platforms also provide a large labor savings for women, which can help income and food generation.

Improvements in fonio seeds and cultivation techniques would go directly to addressing women's income, especially in the dogon plateau and southwest Mali where fonio is grown extensively. Better fonio cultivars could also extend the reach of fonio cultivation into other areas where it was formerly grown.

More efforts at extending existing techniques for intensifying intercropping of cereals and legumes can also have significant income and food security benefits for women. This could also help women in forage production or provide forage for their own livestock raising activities.

Dairy development is likely to also have strong income and food security benefits for women. In addition moving more productive Rhode Island red and local chicken crosses out to more households is likely to help women's income and food security.

Finally women are the major collectors and beneficiaries of the ecological system services of forests, grasslands, and in the field tree parklands. Efforts to regenerate and make these areas more productive can have significant benefits to women.

7. Key constraints to success

A number of key constraints stand in the way of the effective creation and diffusion of the new technologies sited above. They are: (i) imperfect input, credit, and output markets, (ii) the lack of an effective extension system, (iii) problems in the incentives for researchers in IER and elsewhere to connect to the diffusion of their technologies, (iv) transport problems including poor roads, trucks and high costs and levels of corruption, (v) donor incentives and desire for short-term measurable outcomes rather than more nebulous but potentially more important research outcomes, (vi) high levels of weather and health risk that cannot be easily mitigated by insurance products or credit, (vii) fragmentation of efforts across sectors, value chains, and actors which can lead to a lack of coordination.

(i) Imperfectly operating input, credit, and output markets will continue to be a problem in Mali. Most important of these is the lack of a developed seed market. The private seed sector is a vital cog in the diffusion of new seed varieties and despite some signs of growth it is currently a long way from the ability to provide seeds to farmers who need them. Continued effort in the seed sector by multiple actors is a necessary pre-requisite to the diffusion of most seed varieties in Mali.

Agricultural credit is also not available in Mali at the levels necessary. The access to credit situation is likely to get worse before it gets better with the dissolution of CMDT. Some possibilities of amelioration come from recent efforts to sell farmer cooperative grains under contract with credit given as part of the deal. However, this will still not reach most of those most in need of credit. Creative efforts to find new solutions to the agricultural credit problem are warranted, such as mobile and cellphone banking and commitment savings devices for fertilizer purchase.

A non-competitive fertilizer market also poses challenges to the adoption of fertilizer responsive crops, by often raising the cost of fertilizers and making access a function of connections rather than need. This sector would most likely be helped by the government reducing its interventions, since most of the evidence seems to point to government efforts to subsidize fertilizer as one of the causes of the lack of competition and supply problems. Continued efforts in improvement on the marketing side are also warranted.

(ii) The lack of an effective extension system is one of the key constraints that is currently and will in the future hold Malian agriculture back from its potential. The solution is quite simple, greater monetary investments to hire more personnel. Nothing will substitute for more personnel out in rural areas. If new people are hired, more effort can be made to increase the density of extension agents and more effort needs to be done in better training of agents. There are also not enough female extension agents. Efforts to hire more female agents and place them in rural areas are a necessary condition for the successful diffusion of a number of the gender specific agricultural technologies listed in this report.

(iii) Along with the problems in the extension system, the research system is as disconnected from the extension system as the extension system is disconnected from

farmers. Researchers often lack the incentives to produce easily adopted packages for farmers and if they do there is no help for them to extend them, thus PhD scientists end up doing the extension work. Some revision of the incentives within IER will be necessary to help push technologies out the door.

In addition, while the trained personnel in the Malian research establishment are hard-working and well trained, there need to be many more people in the system. Certain areas are clearly undermanned as for example in socio-economic analysis where there is not a critical mass of well-trained economists.

(iv) Problems in transport and logistics remain key constraints particularly to the production of cash crops and the integration of markets. The Malian government is investing heavily, with donor support, in new transport infrastructure including roads and airport improvements. This should help, but more needs to be done. More effort in reducing corruption on import and export fees and petty corruption on the roads of Mali and neighboring countries is also important.

(v) Most of the key donors who would finance the necessary research tend to have overly short-term thinking in their funding strategies. Often there is a preference for measurable and short-term outcomes rather than a number of the outcomes that the technologies listed above are likely to produce. They will tend to be long-term high value outcomes, but often progress in reaching them will not be measurable in convenient metrics such as number of hectares, seeds, trainings, etc. Success in the creation and diffusion of the technologies in this report hinges on donors who are willing to make long-term investments in people, research laboratories, research projects, extension systems, seed marketing infrastructure, and innovative credit schemes. Short-term goals measuring hectares of new varieties or numbers of fish-ponds will not achieve the goals of poverty reduction and food self-sufficiency.

(vi) Malian farmers face high and not easily mitigated weather and health risks. Financial market insurance schemes (e.g., index insurance) as risk reduction technologies can at best account for one of the risks that farmers face, low rainfall, and current efforts to do so have run into major institutional constraints (imperfect/corrupt regulatory structure, poor collection of weather and yield data) that could delay implementation for decades. This lack of insurance markets and potential climate change means that successful technologies will have to help farmers diversify their risk portfolio rather than specialize it.

(vii) Finally these technologies need efforts across the whole system in order to be successful rather than a fragmentation of efforts across sectors, value chains, and actors.

Opportunities and Investment Strategies
to Improve Food Security and Reduce Poverty in Mali
through the Diffusion of Improved Agricultural Technologies

I. Introduction

This work seeks to provide an analysis of the agricultural technologies available and developable in Mali in the next 5-10 years. It takes as its organizing theme technologies that will have impacts on both food security and poverty reduction. These goals are both complementary and in contradiction to each other, depending on the technology in question. If food security were the sole choice criteria one might choose technologies that maximized food production, while not necessarily having an effect on poverty and perhaps worsening the distribution of income. In contrast many important and high quality interventions to address poverty will have no effect on food production.

The premise of this document on where to intervene is based on spreading benefits to the largest number of people rather than focusing on maximizing food production. That is poverty and distributional issues will be paramount, with the work on those going through improvements in food security. Enabling bottom two thirds (asset poor farmers) to reduce their deficit may have a bigger impact on rural food and nutrition security than enabling most endowed third to increase their surplus. We strive in this document to find technologies that can address both at the same time and can have impacts across a distribution of farmers and rural people.

There is a further goal of promoting gender targeting with as many of the technologies as possible. In particular the document focuses where relevant on technologies that can help women, be adopted by women farmers, and/or promote livelihood outcomes beneficial to women.

Agriculture provides two related benefits to the people of Mali. First and foremost it provides rural and peri-urban people with their own livelihood in terms of partial (or full) self-sufficiency and security in food. Second it provides a source of income to farmers, traders, and a source of foreign exchange for the government. The choice of new technologies should take into account these dual roles (food security and poverty alleviation) and provide new technologies that address one or both of these concerns.

We divide potential technologies along these lines into those that can improve agricultural production intended to provide food security, self-sufficient livelihoods, and those that can provide significant income benefits. Malian farmers readily make these distinctions in their own choice of technology (planting one variety of sorghum as a cash crop and another as a subsistence crop), so are likely to appreciate and adopt new technologies based on how they respond to one or both of these needs.

Before reviewing the most promising technologies it is worth noting that there are a great deal of promising technologies to increase Malian agricultural production, profitability,

and sustainablility. It would be a mistake to take too narrow a view and choose only one or two as the best, because while each of these is individually promising the uncertainties associated with each one are high. It is likely that promoting a diversity of technologies for a range of farmer needs and capabilities as well as varying ecological niches will have the greatest impact on food security and poverty throughout the country.

II. Background on Malian production and predicted future state of the agricultural economy

Mali has seen significant agricultural growth in the last 20 years, with increases both in areas cultivated and yields in almost all sectors and large increases in livestock production. The next decade could be a key moment when the country turns the corner from self-sufficiency toward a producer of quality food for its people and major agricultural exporter to the region and internationally or one in which it slides back toward subsistence production. The generation, adaptation, adoption, and diffusion of new agricultural technologies will be a key ingredient in determining which of these two directions becomes a reality.

A number of forces external to the agricultural sector are likely to have a significant effect on the ability of the agricultural sector to grow in the next decade. The Malian economy is likely to continue growing at a reasonably fast pace (3-5%) with new mineral and oil discoveries as well as a likely future up-tick in remittances pushing the economy forward. This mineral export led growth will likely produce increased competition with agriculture for labor and combined with international migration and an increased emphasis on schooling for children, will produce labor shortages and higher labor costs in rural areas. That said, persistently high levels of population growth will continue to demand agricultural production. If economic growth continues as predicted, wealthier urban populations will start demanding higher quality and higher protein foods, fish and livestock products, for which Mali has great as yet mostly untapped potential.

The Malian economy has maintained reasonably robust levels of economic growth even in the face of a global recession and a reduction in tourism due to terrorism fears. Agriculture continues to play a major role in the economy and will likely for the foreseeable future. There are, however, a number of changes on the horizon that may impact the operation, profitability, and prospects for agriculture.

The start of exploitation of new discoveries of bauxite, gold, iron, uranium and oil will likely greatly expand the levels of primary exports from Mali. The diversity in its mineral portfolio suggests the possibility of a less volatile revenue stream than is common from primary commodity exporters. This suggests that Mali will in the near future start experiencing some of the effects of “dutch disease”. The key elements of dutch disease that would affect agriculture are the increasing demand for services, especially in urban areas, and the concomitant increase in rural-urban migration and lack of competitivity of agricultural wages. The net effect will likely be increased labor

shortages in rural areas and agriculture, especially in more marginal zones and especially for young men (15 – 35) who are most likely to migrate. The question is whether Mali can push its economy to be like that of commodity and agricultural exporters such as Canada and Australia, or whether it becomes more like Gabon in which massive urban migration has left agriculture as a minor sector. The former scenario is more likely than the latter, but it will depend to a great degree on government policies as well as the successes of new technologies to keep agriculture competitive as a livelihood.

In addition as the world economy restarts itself there may be an increase in international migration. This can bring both costs such as labor shortages and benefits from added remittances, which can substitute for missing credit markets. Again this suggests future labor shortages, although perhaps with better farmer access to capital.

The increased emphasis among Malian families in education and the extension of schools into many small previously educationally isolated places in all parts of the country has had profound implications for labor use in agriculture. While children still play an important role in agricultural labor, that role is diminishing. This has started a cascade of effects in farming practices such as movements toward using fields closer to home due to the lack of children to scare away birds for days on end. We should expect this trend to continue and for it to impinge especially on farmer interest in and the diffusion of labor-intensive technologies.

a. Commodity price trends

Overall world commodity prices for wheat, maize, sorghum, rice, and cotton are off their recent highs of 2008, but have rebounded to a relatively high level and are projected to stay that way for the rest of the decade. These levels are well above the low commodity prices we saw in the decade up to 2007, which are not likely to return soon. In addition the increased volatility of commodity prices in the last few years is likely to persist into the first half of this decade.

Specifically maize, rice, cotton, and wheat prices are predicted to stay above current levels with perhaps a 10-20% increase by decade's end. Meanwhile groundnut prices are predicted to be up 30% in the first half of the decade and then return to the current level by 2020. Beef prices are expected to rise 50% over the decade, while chicken prices will be up 10-20%. Prices for fertilizers are mostly predicted to stay high, with DAP and TSP prices predicted to go up 33%, rock phosphate will decline in price 20%. Meanwhile urea's price is predicted to go down in the first half of the decade but return to its current level by 2020.

b. Climate Change predictions for Mali

Predicting the exact rate, nature and magnitude of changes in temperature and rainfall for sub-Saharan Africa is a highly complex scientific undertaking and there currently

remains considerable uncertainty with regard to the final outcome of climate change and its impacts (IPCC, 2007). This is illustrated for regions of sub-Saharan Africa (SSA) in Table 1. The table summarizes the output of 21 General Circulation Models used by IPCC in their latest report to predict the annual changes in temperature and rainfall that might occur by the end of the 21st century. Maximum and minimum predictions of change are given together with the 25, 50 and 75 quartile values from the 21 GCM's.

Whilst all models agree that it will become warmer, the degree of warming predicted is quite variable. However, with regard to the percent changes in rainfall amounts, the uncertainty is considerably greater and in many instances models do not even agree on whether changes in rainfall will be positive or negative. This is especially true for the West African region where different climate models reach starkly different conclusions about future precipitation regimes. Depending upon the model used, it is possible that precipitation might increase during the period by as much as 13%, but it is equally probable that it will fall by 9% with the most likely possibility falling somewhere in between these two (See table below) (Cooper et al., 2008).

While this level of uncertainty poses difficulties for developing plans to adapt to future climate changes, the challenges posed are certainly nothing new for those with experience living and working in West Africa. If anything, a predicted potential swing of 10% in either direction for annual precipitation is *well within* the historic norms for two of the regions' most population zones: the Sahel and Soudanian belts. Farmers in the zones have always faced climatic variability at intra- and inter-annual and decadal time scales on the order of these predicted magnitudes.

Region	Season	Temp. Response (°C)					Precipitation Response (%)				
		Min	25	50	75	Max	Min	25	50	75	Max.
West Africa	DJF	2.3	2.7	3.0	3.5	4.6	-16	-2	6	13	23
	MAM	1.7	2.8	3.5	3.6	4.8	-11	-7	-3	5	11
	JJA	1.5	2.7	3.3	3.7	4.7	-18	-2	2	7	16
	SON	1.9	2.5	3.3	3.7	4.7	-12	0	1	10	15
	Annual	1.8	2.7	3.3	3.6	4.7	-9	-2	2	7	13
East Africa	DJF	2.0	2.6	3.1	3.4	4.2	-3	6	13	16	33
	MAM	1.7	2.7	3.2	3.5	4.5	-9	2	6	9	20
	JJA	1.6	2.7	3.4	3.6	4.7	-18	-2	4	7	16
	SON	1.9	2.6	3.1	3.6	4.3	-10	3	7	13	38
	Annual	1.8	2.5	3.2	3.4	4.3	-3	2	7	11	25
Southern Africa	DJF	1.8	2.7	3.1	3.4	4.7	-6	-3	0	5	10
	MAM	1.7	2.9	3.1	3.8	4.7	-25	-8	0	4	12
	JJA	1.9	3.0	3.4	3.6	4.8	-43	-27	-23	-7	-3
	SON	2.1	3.0	3.7	4.0	5.0	-43	-20	-13	-8	3
	Annual.	1.9	2.9	3.4	3.7	4.8	-12	-9	-4	2	6

Source: IPCC 2007

The diverse climate regimes associated with West African ecosystems are subject to large inter-annual, inter-decadal and multi-decadal variations, particularly with regard to precipitation, making climate change and its impacts on ecosystems water resources and agriculture particularly difficult to predict (Hulme et al., 2001; Nicholson, 2001).

Although sometimes lumped together as the Soudano-Sahel savanna belt, the Soudanian and Sahelian regions are not systematically or directly coupled in terms of annual rainfall fluctuations. In the last two decades, for example, (1990-present) a return to wetter conditions was observed in much of West Africa, but below average rainfall continued almost unabated in the Sahel region, (especially at the northern edges) at least until the early 2000s (Nicholson 2005).

In both the Soudan and Sahel bands, inter-annual variability of the precipitation probably depends on the interaction of the ocean, the vegetation and the atmosphere (Zeng et al., 1999; Nicholson, 2000; Wang and Eltahir, 2000). The global climate models currently used, which are called Atmospheric-Ocean Global Climate Models (AOCGMs), do not simulate vegetation dynamics and/or land cover change which further limits model usefulness and accuracy. While there are a growing number of simulations for the 21st century using AOGCMs, none are able to reproduce the long term evolution of the precipitation (the magnitude of the inter-decadal precipitation variability) over the Sahel during the 20^{th} century (Lau et al., 2006).

For example, in a multi-model study of the 20th century simulations of Sahel drought from the 1970s to1990s, Lau et al. (2006) showed that half of the models are not able to reproduce the drought and that those that do are not able to reproduce its timing and duration. Recently, Neelin et al. (2006) compared the precipitation simulated by 10 different AOGCMs following one of the IPCC's socio-economic scenarios (SRES A2). Although most of these models simulated precipitation increases somewhere in the Sahel with decreases along the Gulf of Guinea, 2 models produced the opposite pattern. Overall, the models showed little agreement in terms of precipitation change in West Africa for the key months of June–July–August, the wet season in the Sahel and Soudano zone (see Neelin et al., 2006, Fig. 8).

Policy makers need reliable predictions about future precipitation regimes. Climate change scenarios combine two major sources of uncertainty—those associated with the bio-physical parameters of global climate models and those based on socio-economic scenarios which are derived from different possible futures of economic development and adoption of new energy technologies. To provide policy makers an idea of how much variation is inherent in the climate models, modelers often select scenarios representing the best and worst case outcomes. Others use “average” climate change models for predicting the most likely outcomes. However, due to the high interannual variability of precipitation associated with the region, the GCM simulated precipitation changes are not necessarily statistically significant (see Ruosteenoja et al., 2003).

In summary, when considering how to make use of the results produced by the current climate change models, policy makers are forced to confront the reality that due to the high levels of uncertainty in the models our ability to predict future climates in West Africa (or even the general direction of these changes) is no better than our ability to predict the rainfall pattern for the next year in the Sahel. As Mortimore and others have long argued, generations of small farmers in Sahelien countries have to a large extent been able to develop their livelihood strategies in ways that enable them to constantly

cope with, and adapt to, an erratic climate and a variety of other (Mortimore and Adams 2001).

As such, the best prescription for broad policy goals for dealing with potential future climate scenarios should be based on the existing objectives of improving farmer abilities to manage diverse livelihood strategies that are already based on coping with high levels of uncertainty in terms of climate. In addition, because it is possible that the climate in the region *may be* subject to dramatic change in the coming decades, efforts should be made to strengthen the ***adaptive capacity*** of small producers. Finally, policy makers and climate modelers will need to combine their efforts and join hands in an effort to develop new concepts for adaptive management plans that address the question of what constitutes a "shift" in the climate regime for the Soudanian or Sahelian zones. Here, a better understanding of the changes that occurred during the past half century might provide the best guidance for the way forward.

The lessons for policy-making on adaptation to climate change are, despite the complexity of the issue, relatively simple--promote general economic development that provide farmers with a range of options rather than a specific climate or drought driven focus on certain crops and water conservation techniques, this will allow greater flexibility for local people to adjust to future changes no matter which direction they take. In short, strengthening general adaptive capacity to cope with climate change variation will, especially in the agricultural sector, be better than devising narrow climate adaptation solutions with uncertain outcomes (Mertz et al 2009: 815).

The question is how can the international and research community respond to the challenges of climate change. The reactions to the droughts of the 1970's through the early 1990's presents an illustration of the possibility of response to changes in climate regimes. After a wet period in the 30 years proceeding 1970, the next 25 years were a much drier regime for the Sahel and Soudanian zones. Research efforts from a combination of international centers (CG system) and IER in Mali were able to produce shorter length varieties to respond to these events, but it took until the late 1980's, nearly 15 years into the new climate regime for these crop varieties to come on line and another 5 for them to be widely diffused.

The experience from that climate event in West Africa suggests some key research needs with respect to climate change are:

1) Regime Change: The ability to know when climate is in a new regime
2) Research: The ability to do research to generate agronomic solutions that will address the new climate regime identified
3) Extension: The ability to inform farmers in a timely manner about new technologies developed in #2.

Addressing #1 requires better long-term data on the weather in Mali and better models and predictions from those models. Much of that work will likely come from outside the country in international efforts to improve climate change predictions, but some effort

should be devoted to training Malian scientists to be part of these efforts. It is worth noting that insurance products cannot mitigate climate regime change, because they are based on predictions from past climate regimes. Thus any risk management scheme will need to identify this regime change and help farmers have a production system that is adaptive to it.

Addressing #2 requires continued support for a robust local research system exemplified by IER and IPR, as well as continued support to the CG centers, ICRISAT, CIMMYT, WARDA, AVRDC, ICRAF, etc. working on crops relevant to Mali. Better biotechnology laboratories, especially those capable of doing marker assisted selection, are a key input into speeding up the research process to produce solutions to climate regime change. The current number of trained scientists and laboratory capabilities in Mali is not sufficient.

Addressing #3 requires more investment in extension services than are currently being made in Mali. As highlighted elsewhere in this document, there exists a lack of personnel, a lack of training, and too few female extension agents.

c. Summary of Effects external to the agricultural sector

In summary we expect commodity and input prices to remain high for the next decade and for there to be an increasing shortage of labor, especially of young men, in rural areas. In order for agriculture in Mali to remain competitive in that kind of environment it will need to become more productive and become an agriculture that can be done by and is profitable for an increasingly female dominated rural labor force. This implies increased use of labor saving technologies and development of more value added production. To respond to climate change farmers will need help with new technologies to deal with increased risk and volatility in the climate. The research system will need better early warning systems and better research capabilities, trained scientists and equipped biotechnology laboratories, to address the potential new climate regimes.

III. New Technologies

Technological change in cropping systems typically has five components in the semiarid zone: (i) increasing water availability, (ii) improving soil fertility, (iii) developing new cultivars to take advantage of these improvements, (iv) increasing the profitability of farmers' activities, and (v) decreasing the volatility of income. For livestock and fish farming the interventions usually come in the form of better management, intensification of feeding, and better genetics for livestock.

a. Field Crops

In most of the cereals produced in Mali, sorghum, millet, maize, rice, wheat, there exists improved more fertilizer responsive seeds that have the potential to double or triple existing yields. Some of these technologies require inputs of fertilizer and better management techniques that are beyond the economic and skill levels of all but the most sophisticated farms and farmers in Mali. Many of these costly technologies, however, can still have major impacts on both wealth and food security even if the technologies are only partially adopted or managed. At the same time low resource and low skill farmers can easily adopt many of the technologies described below. Especially encouraging is the large number of technologies that are available that merely involve farmers making slight modifications to their current practices in terms of new seeds, new planting techniques, new storage methods, new pest management techniques.

1. Maize

Maize like rice holds a fairly unique place in Malian crop technologies as being both a cash and subsistence crop. Maize also, like rice, has the potential for enormous yield improvements with existing technologies. Currently yields are on average 1.6 tons/hectare across the whole country with parts of the country, such as the Sikasso region with yields above 2 tons/hectare.

The technology exists in Mali to double current yields with open pollinated varieties (OPVs) that can get 3-4 tons/hectare and to triple them with hybrid varieties that can get 5-6 tons/hectare. The potential in maize for further yield improvements is very high with the plant's potential being up above 10 tons/hectare.

A great advantage of maize over sorghum and millet is that the market for maize both within the country and within the sub-region is very strong. In Mali, maize is increasingly demanded by flour mills, chicken producers, and food processors. In addition traders from neighboring countries flood into Mali's maize growing areas to buy maize for export to the sub-region.

In the case of both OPV and hybrid varieties there are outstanding questions on whether the seed sector can supply enough seeds for a great expansion of use of improved varieties. Likely in the near term the seed sector will remain a key constraint in the expansion of use of improved, especially hybrid, maize seed varieties.

In addition a number of more drought resistant maize cultivars are in the process of being introduced that can extend the feasible maize growing areas further north than is currently possible and reduce the risk levels of crop failure in current maize growing areas. Thus parts of central Koulikoro region up to Banamba and parts of the Segou region could become maize producing areas where they were not before. The drought resistant varieties also hold promise to help make maize a safety net crop for parts of southern Mali and thereby replace millet or sorghum with a more productive crop.

Quality protein maize (QPM) is another available innovation that has the potential to improve nutrition outcomes in Mali. In terms of agronomics these varieties are similar to other OPV or hybrids on the market

One particular possibility with maize is to help develop the intensification of maize grown in *champs de cas*, "home fields", a type of production primarily done by women. These fields tend to be small and well fertilized by locally available manure. With appropriate extension efforts, these *champs de cas* could be producing an intensive hybrid maize variety with better agronomic techniques. Such an extension effort shows great potential to improve women's income generation possibilities and add to food security of rural households with existing technologies and techniques. Such an effort would require trained female extension personnel as well as some financing to jump-start hybrid seed availability for women with low access to monetary resources.

Recent research suggests there are intercropping possibilities with the new maize varieties with such crops as Jatropha. The maize jatropha intercrop can provide the farmer with a steady income from the jatropha plants and a cashcrop from the maize. The press cake from jatropha oil production can make a high nitrogen fertilizer to be put back on maize fields that has potential to alleviate some of the credit needs of maize producers.

An issue that looms on the horizon is the loss of a vital cotton sector that has been one of the major catalysts for Mali's maize production boom. Much of the major maize acreage is in cotton growing areas where it is in rotation with cotton and benefits from residual fertilizer and from farmers taking out loans from CMDT for cotton fertilizer and using it on maize. The continuing disarray in the cotton sector is likely to impact both maize acreage and the ability of producers to borrow money for fertilizer and adopt new maize technologies. A key complementary input therefore to success in maize is providing farmers access to credit, alternative financing sources such as savings products, or alternative fertilizer sources at lower cost.

2. Rice

a. Riz bas-fond

Bas-fond rice production has great potential for expansion and yield increases through better water control, better rice management and planting, and better seed varieties including NERICA varieties. It is a production primarily controlled by women, so any increases in production and incomes from this sector are likely to have a direct gendered impact. That said it is often the case in *bas-fonds* rice projects that improving water control often gets men to assert their rights to *bas-fonds* lands. Thus efforts in this area need to be cognizant of both the gendered impacts and the potential for male takeover of the benefits.

b. Rainfed

The key rainfed rice technology is NERICA rice, which has the potential to allow rice production on fields that normally produce cotton, corn, or sorghum. Nerica can transform a field currently producing 1 ton/hectare or less in cereals and allow that same land to produce 2-3 tons if the farmers make the appropriate investments in fertilizers. Given the higher price of rice than other crops, the extra ton produced in rice is better able to pay back the costs of fertilizer than sorghum, millet, or corn. That said farmers are currently getting closer to 1 ton/hectare in Nerica and the risk levels in Nerica production are still unknown. Thus while promising, more effort is needed particularly in diffusing NERICA varieties and helping farmers with the necessary information to grow them well.

c. Irrigated

In irrigated rice production there are two key elements, more irrigated land area under full water control management and improvements in farming techniques. With respect to the former, there is some debate on whether large or small investments make the most sense. As concluded by Dillon for northern Mali, the effects of small scale and large scale irrigation are similar and large with respect to agricultural production, but the effects of small scale irrigation has a larger effect on agricultural income then large scale irrigation (Dillon, 2010). This suggests a two pronged approach that first privileges the irrigation expansion and second in the interest of poverty alleviation tries to put an emphasis on small scale projects rather than larger projects.

With respect to rice management, the SRI program recently initiated in northern Mali to intensify the techniques used in rice holds a lot of promise. Adoption rates of SRI have been slow elsewhere, but nonetheless given the clear yield benefits it is a technology worth promoting.

3. Cowpea

IER has some new cowpea varieties that can either provide higher bean yields or better forage or in some cases both, relative to the current varieties used by Malian farmers. Cowpeas are one of the few crops where there already exists an active seed market, but it is for the moment not well linked to the research establishment. Key interventions in cowpeas would be to help link the seed sector with the research sector to speed diffusion of existing technologies.

In addition IPM techniques to reduce insect problems in cowpeas has shown a lot of promise, but has not yet been readily adopted by farmers. More effort in diffusing known pest management, especially in post-harvest pests, would produce large dividends in a crop that is often grown by women. In addition support for the international efforts to

produce a viable Bt-cowpea would be a useful complement to the on-farm IPM measures. Bt cowpea addresses one of the key cowpea pests that cannot be addressed except with pesticides and the current ones most often used (typically cotton pesticides) are often toxic to humans.

4. Fonio

Fonio is a highly valued crop for its low labor needs, early season production, drought resistance, and women are its primary producers. In the Sahelian regions of Mali, many of the poorer farmers all grow fonio, an ancient grain crop that grows relatively vigorously with limited resources.

Fonio has the rare distinction of being one of the few grains grown by poor smallholders for their own consumption that also have a market as a luxury good for the wealthy of the country. Fonio is highly appreciated as a food crop by all sectors of society and contains many nutritive qualities (methionine, cysteine and other amino acids vital to human health) lacking in other local grains such as sorghum and maize and it can have protein levels as high as 11%. It typically receives a premium in the markets of the countries where it is grown. In Mali, where it sells for a 30-50% premium over rice, fonio is considered the fanciest grain that one could serve at a festival such as a wedding or a baptism. This premium comes both from its desirability as a luxury good and the low levels of supply of fonio due to its low yield.

From a macro-economic perspective, since fonio is a welcome substitute for rice in most diets, increasing fonio production can reduce Sahelian country's dependence on imported rice. Because fonio grows faster than most grain crops it is grown as a crop to break the hungry season in August and September. This agronomic characteristic makes it an extremely desirable crop for poor farmers. Crops such as fonio that break the hungry season can help increase the yields of other field crops since the calories they provide poor farmers are key to the farmers having energy to weed and maintain their other crops.

Fonio requires relatively less maintenance as a crop than the typical Sahelian field crop (sorghum, millet, maize, rice) because its planting density often out-competes most weeds. It also has low water requirements and is extremely drought resistant; although there are cultivars/ varieties that thrive in wetter climates. An additional attribute of fonio is its resistance to root nematodes *Meloidogyne incognita* and other pathogens. This low maintenance makes fonio an ideal crop for women to grow and in fact across the region women are in charge of most of the fonio cultivation. This implies that increases in fonio production can create important improvements in women's incomes across Mali. In addition, as increasing numbers of young Sahelians leave rural towns and villages for cities and foreign migration, the low labor requirements of fonio make it an ideal crop for those who remain in rural areas who are typically the elderly and women with young children.

Fonio also grows well in poor to fair soil conditions. Producing fonio requires no fertilizer, no pesticides, and it is well adapted to drought conditions. It thus already has

many of the properties most desired in a cultivar. This makes it an ideal crop on marginal and reclaimed lands and lands depleted by production of cash crops such as cotton. It is often the last crop before a parcel is put into fallow in the typical fallow cycle of the Sahel.

Unfortunately fonio yields are low and this has reduced the acreage devoted to fonio despite its evident benefits and high prices in the market. Improvements in fonio seeds and cultivation techniques would go directly to addressing women's income, especially in the dogon plateau and southwest Mali where fonio is grown extensively. Better fonio cultivars could also extend the reach of fonio cultivation into other areas where it was formerly grown. More research is needed to provide women farmers with higher yielding fonio varieties and better agronomic techniques.

5. Sorghum/Millet

Since sorghum and millet together account for 73% of the land area devoted to cereals production and 51% of the cereals produced, small changes in the productivity of those lands can have large impacts on overall food security of the nation. In addition because it is often the poorest, low resource farmers who grow millet and sorghum there are significant poverty benefits from better millet and sorghum technology. Malian farmers, while often willing to try new crops are typically loath to give up sorghum/millet cultivation since it represents the major part of their effort to provide self-sufficiency to their families.

Despite, or perhaps because if its importance there are important difficulties in marketing millet and sorghum. Much of this stems from consumer, livestock, and processor preferences for other grains (maize, rice, fonio, wheat) and a lack of successful transformation technologies to add value.

In the sorghum/millet technology nexus there exist two opposing views as to how to push increased production. One, a high input solution, represented by the INTSORMIL and Sasakawa Global projects, which see chemical fertilizers and fertilizer responsive millet and sorghum varieties as the best technology. While the other, a low input solution, represented mostly by ICRISAT efforts tries to produce new seed varieties that can produce more under the low input conditions that farmers actually experience. An unfortunate dichotomy has developed between these two camps that is not in the best interests of Mali or Malian farmers.

The low input solutions can produce a 20-30% increase in yields over farmers' conventional seeds with the farmer using the same techniques as before. Meanwhile the high input solutions require farmers to put ~$100 into chemical fertilizers, work best with animal traction, but can produce yield increases of 75-100% over traditional varieties grown with traditional levels of fertilizer. Both systems work best with water conservation efforts and with additions of organic fertilizers such as manure.

It should be a farmer's choice as to which of these techniques makes most sense for his/her individual farm, situation, budget, and risk profile. Rather than having a dichotomy pushed on them, farmers need access to both of these possibilities and training in how to maximize their benefit from both of these strategies. This is in fact what Malian farmers are already doing in the areas where both have been rolled out. One sees farmers for example in the Doila area who have a hectare of high input INTSORMIL sorghum while they are growing a few hectares of low input ICRISAT sorghum. Farmers typically see the high input sorghum/millet as a cash crop that is separate from their subsistence crop which is typically also sorghum/millet but without heavy input use.

A future scenario with farmers using the low input ICRISAT varieties on their subsistence production land to give themselves a more productive safety net and then the high input varieties on land they are willing to devote to cash crops would make sense.

6. Wheat

While there exists better seed varieties from CIMMYT in wheat production that could receive higher diffusion rates, the key to expansion of wheat production is acreage expansion and improvements in cultivation techniques. The Government of Mali has set forth an ambitious plan to increase wheat acreage up to ten-fold in the next 5 years, from ~5,000 ha to 50,000 ha. Most of this area expansion would be from increased irrigated acreage and so is dependent on the creation of perimetre irriguée villageois and small moto-pump based fields in northern Mali. There is little evidence that this can be accomplished in this time frame. In addition, wheat is relatively more management intensive than rice, especially with respect to the timing of flooding and other water management issues, which are often poorly done in PIV's. Thus, it may make more sense for farmers, especially resource poor farmers, to grow rice on these irrigated areas than to grow wheat.

The just started system de blé intensif SBI program shows some promise as a way to address the management issues in wheat production, but many of the water management issues are going to be community or PIV-wide and need better organization. In addition more effort is needed in the production and replication of the CIMMYT seed varieties, perhaps by importing them from higher productivity places. A key constraint in producing wheat seeds in Mali is that the low yields and high seed requirements make it hard to devote enough area to seed production.

7. Intensive Intercropping

An important line of intervention is to push intensification of intercropping systems that have long since been developed in Mali. Better planting and fertilization techniques applied to intercropping of millet/sorghum with cowpea/soy/sesame/peanuts can increase farmer yields of both grains and legumes while reducing their risk profiles in terms of both climate and market risk as well as reducing the need to purchase expensive

fertilizers. These techniques are well tested and can go directly to pilot extension programs.

In Mali, experiment station work has demonstrated that intercropping sorghum/millet with cowpeas/soybeans using added chemical fertilizers can be done such that sorghum/millet yields per hectare are comparable to intensive mono-cropping (1.5 – 3 tons per hectare) and cowpea/soybean yields are 300 – 500 kg/ha all with fertilizer applications that are 33% lower in quantity and 45% lower in monetary terms. Economic studies have also demonstrated the income risk reducing properties of intercropping. High yielding, fertilizer responsive sorghum, millet, cowpea, and soybean varieties have already been developed at IER that are appropriate to the biotic and abiotic stresses in the region and could succeed in intercropping.

New cash crop also potential exists in sesame and soybeans, especially where one can intercrop them with existing subsistence crops such as sorghum and millet. Both of these are likely to be technologies available and beneficial for women farmers.

8. Jatropha curcas

Another new crop with intercropping potential is jatropha-curcas, which can provide farmers with a steady source of income and potential fertilizer from the jatropha press-cake. Jatropha curcas has received a lot of hype in the biofuels world and on the internet as the next "miracle" crop that can create biodiesel and solve a myriad of social ills. The tree produces seeds containing 27–40% inedible oil, which is easily convertible into biodiesel. The literature is replete with competing claims that it will deprive the world of enough food acres, turn Africa into a single jatropha plantation thereby impoverishing the continent, or that it will reclaim barren lands, turn Africa into a major biofuel producer, and solve the world's fuel problems. Yet relatively little scientific research has been done on the crop, especially little is known about its economic costs and benefits in an agro-forestry intercropping system for smallholders in the Sahel.

Sahelian smallholder farmers face low (less than $100 per hectare) and risky incomes from current farming practices. One of the key problems they face is environmental degradation and deforestation, which leads to low soil fertility and abiotic stresses on the crops they grow. Studies in Mali have shown that intercropped jatropha reduces soil erosion, increases water infiltration, and improves yields of food crops by 20%. In addition the presscake from jatropha oil production is rich in nutrients and can further increase yields by providing a low cost organic substitute for chemical fertilizers, whose prices have doubled in the last 5 years in Mali.

Despite the potential of jatropha, few studies have been done to quantify the socio-economic effects and to help farmers optimize the agronomic outcomes. While it is clear that jatropha can grow on marginal lands with little water, research has yet to determine the costs and benefits of such a strategy relative to planting jatropha on higher value lands. Studies are needed to assess the tradeoffs between food versus fuel, or whether

through intercropping it can become a synergy of food and fuel. Also jatropha cultivation has labor requirements that are for the moment not well studied, research is needed on how those labor requirements intermesh with current labor demands of rural smallholders. More research is needed on testing which crops are best for this intercrop. Women are likely to be involved in collecting and maintaining jatropha and it has a lot of potential around women's garden plots.

9. Better storage technology at a local level

Along with increased production of cash crops, better training and diffusion of simple methods to store grains could yield great dividends on the marketing end. Currently losses to pests and spoilage are very high for stored grain and simple improvements in storage techniques using existing facilities and equipment could reduce these losses and lower storage risks. Simply getting storage facilities to i) check the cleanliness of grain when it comes in for storage, ii) place grain on palettes and away from walls, and iii) when necessary use the right insecticides; would reduce grain losses and risk as well as increase returns to warrantage schemes. These are known techniques that merely need better diffusion.

10. Fruit and vegetable cash crops

In terms of the export crops that compromise the USAID value chains such as onions, mangoes, garlic, potatoes, the biggest need is to start testing international quality versions of the crops grown here. It is not too soon to start testing to see how well the key varieties of these crops that sell internationally would potentially grow in Mali.

11. Labor savings technologies: herbicides, plows, tractors

As set out in the introduction, the future of Malian agriculture will be increasingly determined by labor constraints. Herbicide use in Mali has doubled in the last 5 years in part in response to labor constraints and is likely to increase substantially in the future. Herbicide use has very positive spillover effects on women's time and ability to work on their own crops or collect karité nuts. More extension work and agribusiness training is needed, along the lines of USAID's IPM CRSP's work in pesticide literacy and safety, to ensure safe and effective use of herbicides. In addition Mali needs research work testing the safety and long-term consequences of increased herbicide use in a savanna environment.

Increased use of plows, multiculteurs, and tractors will likely also be warranted to face the lack of rural labor supply. Research and extension on the best use of tractors and multiculteurs in Mali in terms of soils, crops, and profitability is warranted. Further expansion of use of multifunctional platforms for grinding, threshing, and other post

harvest chores is another area worthy of donor investment, because of the potential benefits in freeing up women's time.

b. Livestock production

Recent livestock research has shown a number of promising genetic improvements that can be used by livestock holders at all scales. These genetic improvements can improve the productivity, weight gain, without significantly changing herder practices or risk profiles. These include improve breeds of cattle, goat, sheep, and crosses of Rhode Island Red chickens with local varieties. This last one has the potential to greatly improve backyard chicken raising; an important income generation activity for women. More effort on getting these genetically improved varieties out into the general livestock population would be useful. There are also significant improvements in feeding practices, forage production, conservation and use that could increase livestock production.

At the same time as improved feeding and genetics shows great promise, more effort in making available and pushing farmer interest in vaccinations and anti-parasite efforts for their animals has strong potential to increase animal production, incomes, and lower risks at relatively low costs.

c. Dairy development

Dairy development has the potential to increase women's income, increase protein intake, and substitute for an expensive component of Mali's import bill, namely powdered dried milk. There is a ready and severely underserved market for milk in almost all areas of the country. Milk production in Mali has been expanding rapidly over the last 20 years with total milk production in 2006 being 66% higher than in 1990 (PNIA, 2009) and 2010 figures are likely even higher than that. Perhaps the greatest part of the success in dairy development comes from the creation of successful milk cooperatives along the major roads outside of key cities of Bamako and Segou. These milk cooperatives have succeeded in providing pasteurized milk to customers, using heat as a preservation tool and typically being able to maintain milk quality without refrigeration. Typically motorcycle collectors will collect in a 30km radius around the cooperative. Sales from these rural milk cooperatives tend to be both local and to urban consumers. For example despite a business plan predicated on selling to the nearby Segou market, the Cinzana milk cooperative sells most of its milk to customers in Cinzana, suggesting that there was an underserved local market.

Further expansion of the dairy sector can be done with existing technologies. Organizing dairy cooperatives in order to provide a market and expertise in pasteurization techniques, and economies of scale is a necessary first step. In terms of cows, the best technology at the moment is to improve feeding and care of existing local varieties of cows, which can produce significant increases in milk production. There is a lot of work

to be done improving forage production and feeding techniques. Again this can be done with known technology, but some adaptation to local growing conditions will be necessary. A significant untapped potential in forage production can come from intercropping of grains and legumes such as millet and dolique, or sorghum and soybeans. More effort in research and extension in this type of forage intercropping could yield significant benefits.

Women in Mali dominate milk production and marketing and it is the most likely part of the livestock sector to be able to produce a significant improvement in women's incomes. Women also dominate forage markets both of agriculturally produced forages and those collected in the savanna. Thus dairy development is likely to have both direct and indirect benefits for women in Mali. It is also an activity that has potential in all corners of Mali from Kidal to Kayes, Taoudenni to Tominian.

d. Fish Farming

Increased development of fish farming also shows promise, both as an intercrop with rice and as either the stocking of existing local ponds or of specifically built fish-ponds. Mali has a perfect environment to expand fish farming where water is available. With a potential production of 9 tons/hectare worth 9 million CFA, the returns to fish farming are well above those of other crops, although the investment costs will be prohibitive for all but the most wealthy. Cooperatives may be able to alleviate some of these costs.

Another type of intercropping that shows great promise is the addition of fish raising to irrigated rice ponds. Adding fish can produce up to 1.5 tons of fish per hectare and at the same time maintain the same or better rice yields. With the correct control of water, fish farming in rice fields could be more lucrative than rice farming. Intercropping of fish and rice will require both research and extension efforts.

e. Improving Ecological system services

i. Soil & Water Conservation and IPM

A key line of technology diffusion is to help farmers reduce their risks, through improving their planting, soil conservation, and water retention techniques (SWC). In areas where land is being continuously cropped and not rotated through fallow periods there is some evidence of farmer interest in SWC measures, but in other areas it seems to be hard for farmers to make those kinds of long-term investments for land that they believe will at some point be fallowed. There is likely to be an increase in continuous cropping without fallow throughout Mali, which should favor SWC, but there will also be a reduction in the available labor force, which will make it more expensive. SWC techniques that are most likely to be adopted in this setting are those that are least labor intensive or most easily done with mechanical or animal traction.

Integrated pest management IPM also shows much promise where small changes in farmer practices; e.g., changing planting schedules by a few weeks, can reduce or eliminate pest damages. In addition there are clearly needed extension and diffusion efforts needed in pesticide use and understanding especially for women farmers.

Most of these SWC and IPM improvements require only an investment of time and change of technique from the farmer end, but a lot of investment in extension by the government and partners is necessary to bring the necessary information to farmers. Rather than focus on one or two technologies, this kind of work should provide farmers with a menu of planting, soil, and water conservation and integrated pest management techniques. This portfolio approach is especially important because in many parts of Mali farmers are still rotating their land through fallow periods, which severely reduces the incentives to invest in soil and water conservation techniques.

ii. **Forest, Grasslands, and Tree-parklands**

Malian rural areas have a symbiotic relationship with their forests, grasslands, and tree-parklands in their fields. Increased mechanization of farming, the use of herbicides, and climate change has the potential for negative effects on the productivity and regeneration of these spaces. Relatively little is known about this and therefore more research is needed into how to maintain and regenerate the productivity of these spaces.

Aside from natural regeneration, IER and ICRAF have done some promising research into making more productive, faster growing tree species that have yet to be diffused. These include improved varieties of baobab, jujubier, and tamarind trees as well as grafting techniques to speed up the production cycle of karité, reducing the period before it fruits from 30 to 7 years. While there is still much work to be done continuing the research process, a number of these technologies, such as karité grafting, are worthy of more diffusion effort.

From the available data there is clearly a larger quantity, up to half of the production, of karité and other wild fruits that goes uncollected in Mali. Barriers to doing so include women's access to appropriate transport devices, market access, and creation of markets for locally eaten, but rarely sold local fruits. Investments in market development and in cooperatives are likely to have the greatest effect on this by creating an economic incentive for women and women's groups to put more effort into collection. In addition, labor saving technologies such as plows, tractors, and herbicides can paradoxically have a positive effect on the collection of these forest products because they can free-up women's labor at key moments when it is needed for fruit collection.

Finally women are the major collectors and beneficiaries of the ecological system services of forests, grasslands, and in the field tree parklands. Efforts to regenerate and make these areas more productive can have significant benefits to women.

IV. Key constraints in agricultural diffusion

A number of key constraints stand in the way of the effective creation and diffusion of the new technologies sited below. They are: (i) imperfect input, credit, and output markets, (ii) the lack of an effective extension system, (iii) problems in the incentives for researchers in IER and elsewhere to connect to the diffusion of their technologies, (iv) transport problems including poor roads, trucks and high costs and levels of corruption, (v) donor incentives and desire for short-term measurable outcomes rather than more nebulous but potentially more important research outcomes, (vi) high levels of weather and health risk that cannot be easily mitigated by insurance products or credit, (vii) fragmentation of efforts across sectors, value chains, and actors which can lead to a lack of coordination.

(i) Imperfectly operating input, credit, and output markets will continue to be a problem in Mali. Most important of these is the lack of a developed seed market. The private seed sector is a vital cog in the diffusion of new seed varieties and despite some signs of growth it is currently a long way from the ability to provide seeds to farmers who need them. Continued effort in the seed sector by multiple actors is a necessary pre-requisite to the diffusion of most seed varieties in Mali.

Agricultural credit is also not available in Mali at the levels necessary. The access to credit situation is likely to get worse before it gets better with the dissolution of CMDT. Some possibilities of amelioration come from recent efforts to sell farmer cooperative grains under contract with credit given as part of the deal. However, this will still not reach most of those most in need of credit. Creative efforts to find new solutions to the agricultural credit problem are warranted, such as mobile and cellphone banking and commitment savings devices for fertilizer purchase.

A non-competitive fertilizer market also poses challenges to the adoption of fertilizer responsive crops, by often raising the cost of fertilizers and making access a function of connections rather than need. This sector would most likely be helped by the government reducing its interventions, since most of the evidence seems to point to government efforts to subsidize fertilizer as one of the causes of the lack of competition and supply problems. Continued efforts in improvement on the marketing side are also warranted.

(ii) The lack of an effective extension system is one of the key constraints that is currently and will in the future hold Malian agriculture back from its potential. The solution is quite simple, greater monetary investments to hire more personnel. Nothing will substitute for more personnel out in rural areas. If new people are hired, more effort can be made to increase the density of extension agents and more effort needs to be done in better training of agents. There are also not enough female extension agents. Efforts to hire more female agents and place them in rural areas are a necessary condition for the successful diffusion of a number of the gender specific agricultural technologies listed in this report.

(iii) Along with the problems in the extension system, the research system is as disconnected from the extension system as the extension system is disconnected from farmers. Researchers often lack the incentives to produce easily adopted packages for farmers and if they do there is no help for them to extend them, thus PhD scientists end up doing the extension work. Some revision of the incentives within IER will be necessary to help push technologies out the door.

There are still very weak links between research and extension. The creation of the users' committees and the farming systems division were attempts to replicate some of the links between farmers and researchers that a well-functioning extension system would provide. But apart from the CMDT extension system (which is now focusing mainly on cotton, having pulled back from its general development activities), extension services in Mali are extremely weak. There is thus insufficient feedback to researchers about farmers' needs and the suitability of technologies developed by the research system.

In addition, while the trained personnel in the Malian research establishment are hard-working and well trained, there need to be many more people in the system. Certain areas are clearly undermanned as for example in socio-economic analysis where there is not a critical mass of well-trained economists.

(iv) Problems in transport and logistics remain key constraints particularly to the production of cash crops and the integration of markets. The Malian government is investing heavily, with donor support, in new transport infrastructure including roads and airport improvements. This should help, but more needs to be done. More effort in reducing corruption on import and export fees and petty corruption on the roads of Mali and neighboring countries is also important.

(v) Most of the key donors who would finance the necessary research tend to have overly short-term thinking in their funding strategies. Often there is a preference for measurable and short-term outcomes rather than a number of the outcomes that the technologies listed above are likely to produce. They will tend to be long-term high value outcomes, but often progress in reaching them will not be measurable in convenient metrics such as number of hectares, seeds, trainings, etc. Success in the creation and diffusion of the technologies in this report hinges on donors who are willing to make long-term investments in people, research laboratories, research projects, extension systems, seed marketing infrastructure, and innovative credit schemes. Short-term goals measuring hectares of new varieties or numbers of fish-ponds will not achieve the goals of poverty reduction and food self-sufficiency.

(vi) Malian farmers face high and not easily mitigated weather and health risks. Financial market insurance schemes (e.g., index insurance) as risk reduction technologies can at best account for one of the risks that farmers face, low rainfall, and current efforts to do so have run into major institutional constraints (imperfect/corrupt regulatory structure, poor collection of weather and yield data) that could delay implementation for decades. Interviews with farmers suggest that the currently in vogue index insurance idea is highly unlikely to reach poor farmers in Mali. The only farmers likely to buy insurance

are the already wealthy farmers who already participate in financial markets. Poor farmers uniformly expressed strong risk aversion to insurance as a technology and well founded distrust in the associated institutions. This lack of insurance markets and potential climate change means that successful technologies will have to help farmers diversify their risk portfolio rather than specialize it.

(vii) Finally these technologies need efforts across the whole system in order to be successful rather than a fragmentation of efforts across sectors, value chains, and actors.

References

Balme, M., Galle, S., Lebel, T., 2005. Démarrage de la saison des pluies au Sahel: variabilité à des échelles hydrologique et agronomique. *Sécheresse* 16 (1), 15– 22.

Cooper, P.J.M., Dimes, J., Rao, K.P.C., Shapiro, B., Shiferaw, B., Twomlow, S. 2008. Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? *Agriculture, Ecosystems and Environment* 126: 24–35.

Dillon, Andrew. 2010. "Do differences in the scale of irrigation projects generate different impacts on poverty and production? Evidence from large and small-scale projects in Northern Mali." IFPRI Mimeo.

Hulme,M. 2001. Climate perspectives on Sahelian dessication: 1973-1998. *Global Environmental Change*, 11: 19-29.

IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In: Solomon, S., Quin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L. (Eds), *Regional Climate Projections*. Cambridge University Press, Cambridge, UK. pp. 996 (Chapter 11).

Lau KM, Shen SSP, Kim K-M, Wang H. 2006. A multimodel study of the twentieth-century simulations of Sahel drought from the 1970s to 1990s. *J Geophys Res* 111.

Lebel, T., Cappelaere, B., Hanan, N., Levis, S., Descroix, L., Galle, S., Kergoat, L., Mougin, E., Peugeot, C., Séguis, L., Vieux, B., 2009. AMMA-CATCH studies in the Sahelian region of West-Africa: an overview. *Journal of Hydrology* 375 (1–2), 3–13.

Mertz, O. Mbow, C., Reenberg, A., and Diouf, A.2009. Farmers' Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel. *Environmental Management*, 43:804–816

Mortimore MJ, Adams WM (2001) Farmer adaptation, change and 'crisis' in the Sahel. Global *Environmental Change-Human and Policy Dimensions*, 11:49–57.

Neelin, J.D., Munnich, M., Su, H., Meyerson, J.E., and Holloway, C.E. 2006. Tropical drying trends in global warming models and observations. *PNAS*, 103 (16): 6110–6115

Nicholson, S.E., Grist, J.P., 2001. A simple conceptual model for understanding rainfall variability in the West African Sahel on interannual and interdecadal time scales. *International Journal of Climatology* 21, 1733–1757.

Nicholson, S.E., Some, B., Kone, B., 2000. A note on recent rainfall conditions in West Africa, including the rainy season of the 1997 ENSO year. *Journal of Climate* 13, 2628–2640.

Nicholson, S.E., 2005. On the question of the ‘‘recovery” of the rains in the West African Sahel. *Journal of Arid Environment* 63, 615–641.

PNIA (Programme National D’Investissement Agricole). 2009. *Resultats Du Secteur Agricole Revue des Politiques, Strategies et Programmes.* Direction National d’Agriculture, Bamako, Mali. October, 2009.

Ruosteenoja, K., T. R. Carter, K. Jylhä, and H. Tuomenvirt. 2003. Future climate in world regions: An intercomparison of model-based projections for the new IPCC emissions scenarios. *Finnish Environment Institute* 644. Helsinki.

Appendix 1: Summary Tables for Opportunities and Investment Strategies
External Effects on the Agricultural Sector in Mali

Issue	*Likely Effect*	*Effects on Agriculture*	*Best Response*	*Suggested Technologies*
Climate Change	More volatility in rainfall, heat, and more extreme weather events	Increased risk, reduced ability for farmers to specialize	Maintain farmer's diversified portfolios, intercropping, increased research to speed cropping changes and identify climate regime changes	Drought resistant crops (fonio, sorghum, millet, new maize varieties), irrigated agriculture (rice, wheat), extensive livestock production
Expansion of Mineral and Oil production in Mali	Higher labor costs for agriculture, rural labor shortages	Difficulty commanding sufficient labor, reduction in cropping areas.	Labor saving technologies	Plows, multiculeurs, tractors, multifunctional platforms, judicious use of herbicides,
Commodity prices	Likely continued high commodity prices for Mali's major cereals, some rebound likely in cotton	High prices for Malian farmers, better returns to high yielding crops, but continued demand from urban areas for lower priced food	Intensify and increase agricultural production, improve operation of output markets	All technologies
Fertilizer prices	High fertilizer prices likely to continue for the next decade	Lower profitability of fertilizer responsive crops, increased credit needs for rice, corn, and wheat farmers	Locally produced chemical fertilizer alternatives, better techniques, and more efficient plant use of fertilizers	Low input sorghum/millet, fonio, livestock intensification (dairy), jatropha, cereal/legume intercropping
International migration	Increases in international migration and higher levels of remittances	Difficulty commanding sufficient labor, reduction in cropping areas, increases in access to credit	Labor saving technologies, more capital intensive technologies	Plows, multiculeurs, tractors, multifunctional platforms, judicious use of herbicides, fertilizer responsive crops

Food Security Technologies

Technology	Benefits	Poverty Impact	Gender Impact	State of the Technology	Necessary Effort	Constraints
Genetically improved, low input sorghum and millet varieties	Affects 73% of cereal area and 51% of cereal production, possible 10-15% increase in overall cereal production	Very High	Avg	OPV's in diffusion, hybrids near to diffusion	Extension efforts, seed creation and distribution	Seed markets, extension, information, markets for sorghum/millet
Improved fonio varieties	Drought resistant crop, cuts the hungry season, low labor and input requirements, ready market for output, could replace imported rice	High	Very High	More research needed in increasing yields, testing varieties,	Funding for applied and basic research	Few world experts on fonio, low donor and Gov't of Mali effort and interest
Improved livestock genetics	Can increase livestock production with similar efforts and inputs	Avg	High	Improved livestock types exist	More effort in promoting new livestock types	Knowledge, scale-up
Intensified intercropping of cereals and legumes	Lower market and weather risk production, lower fertilizer needs, builds on existing techniques	Avg	High	Techniques are known and tested, but not well diffused	Demonstration and extension efforts to improve diffusion	Slow changes in farmer cultivation habits, lack of extension system
Fish/rice intercropping	Addition of fish to full-control irrigated rice can double per hectare income	High for irrigated rice areas, Average overall	Low	Well known outside Mali, but more testing, research, & demonstration needed in Mali	Research, test plots, and demonstration	Lack of current research knowledge on fish in Mali
Soil and Water Conservation techniques	Increased yields, lower risks, lower fertilizer needs, through long-term	Avg	Low	Well known technologies and techniques	Better extension efforts to provide farmers with	Mostly applicable where land is in permanent

	investments in soil and water conservation				possible soil and water conservation techniques, more research on local alternatives to chemical fertilizers	cropping, farmers unlikely to adopt where they still fallow land, labor constraints also pose a problem, since it is labor intensive
Integrated Pest management	Reduction in pest risks through better techniques	Avg	High	Known and tested, but more research work can be done	Knowledge dissemination, further research	Slow changes in farmer cultivation habits, low levels of knowledge by extension services

Income Generating Technologies

Technology	Benefits	Poverty Impact	Gender Impact	State of the Technology	Necessary Effort	Constraints
Drought resistant maize	Increased production of maize in more zones, lower risks to existing production, ready output market	High	Avg,	OPV varieties in diffusion, more work needed on hybrids	Extension and diffusion, improvements in seed production, hybrid research	Seed industry, availability of affordable fertilizer, credit, trained hybrid researchers
Fertilizer responsive sorghum & millet	Increased production of a crop already understood, lower risks than other cash crops such as maize,	High	Avg	In diffusion, needs more scaling up	Scaling up, seed production, increased effort on the marketing side	Seed industry, availability of affordable fertilizer, credit, marketing of sorghum/millet to alternative sources
Bas-fond Rice	Increased production of bas fond rice, has direct small holder and gendered impact on food security and incomes	High	Very High	Existing technologies, slow diffusion	Extension and diffusion, seed production, better water management techniques	Female extension agents, seed industry, availability of affordable fertilizer, credit
Rice SRI	Improved management of rice fields without adding new costly inputs	High	Avg	SRI has started diffusion,	Follow-up, evaluation, and scaling-up	Trained personnel
Small scale dairy development	Large potential to increase dairy production nationwide, large existing market, potential to improve women's	High	Very High	Most of the expansion can be done with known technologies, better forage	Cooperative organization, training in fresh milk pasteurizing and handling, and	Organization and training, donor support

	incomes, protein intake, and reduce foreign exchange costs of imported powdered milk			techniques needed, and future developments of genetically improved cows could also help later on	modest infusions of equipment	
Fish farming	Mali has ideal conditions for fish ponds, can create increased supply of protein, and there is a ready market for output	Avg	Low	Preliminary tests have shown promise, but little is known on the reasons for success, economics of fish ponds is as yet unclear	More research and testing needed to have packages for farmers to adopt, socio-economic research on returns	Lack of previous investment, only one IER researcher, low general knowledge base, high costs of fish ponds, credit
Export Crops: Improving Mali's ability to grow crops demanded by the world	Malian fruit and vegetable exports would be more competitive if it grew the major varieties of fruit and vegetables demanded on the world market	Avg	Avg	As yet untested, more research needed	Research and testing of major world varieties of fruit and vegetables on Malian farm conditions	Long time frame, lack of donor and private sector investment in research.

Gender Focus

Technology	Gender Specific Benefits	Necessary Effort to attain gendered benefits	Constraints to gendered benefits
Fonio	Fonio is specifically a women's crop, has low risks & labor requirements, ready market for output	Research into ways of increasing yields, reducing seed shattering, diffusion of improved processing techniques.	Lack of researchers focused on the crop, lack of donor interest.
Hybrid corn for *Champs de cas*	Intensification of *champs de cas* with hybrid corn can increase women's incomes and provide a ready market	Development/testing of hybrids for this purpose, training for women in intensified maize production, credit access	Credit for seeds and fertilizer
Intensive intercropping	Women already generally do intercropping, intensifying it would yield more benefits	Women focused extension program to teach improved techniques	Changing existing farmer practices is difficult
Small scale dairy development	Dairy is primarily a women's activity, intensifying it and creating a bigger market will have direct benefits, plus provide increased proteins to children	Training in animal management, creation and training of collection organizations (coops), credit for animal purchase, diffusion of improved forage management techniques	Organizational difficulties, lack of donor interest, training
Labor saving technologies, Multifunctional platforms, herbicide	Labor saving devices and technologies, even ones focused on male owned production, allow women more time to focus on other remunerative activities	Further dissemination of new technologies, access to credit for their purchase, training in the appropriate use of herbicides	Credit, training in their use.

Improved ecological system services	Women are the major collectors of products of the grasslands and forests. Increasing their productivity and marketability would have a direct gendered impact	Further efforts in research and dissemination on more productive forestry technologies, dissemination of improved processing techniques for shea and other forest products, creation of cooperative marketing organization, access to credit	Lack of investment in research and researchers working on forest and savanna resources. Intensification of agriculture may reduce ecological system services from fallowed land
Bas fond rice	Women are the major producers in bas fond rice, increases in yields would have direct benefits to women	Diffusion of better rice varieties, better techniques, and help with water control technologies	Seed availability, diffusion of techniques

Appendix 2: Tableaux des Stratégies d'Opportunités et d'Investissements
Effets Externes sur le Secteur Agricole au Mali

Sujet	*Effet Probable*	*Effet sur l'Agriculture*	*Meilleure Réponse*	*Technologies Suggérées*
Changement Climatique	Plus de volatilité dans les précipitations, la chaleur, et les événements climatiques extrêmes	Risque accru, capacité réduite pour les paysans de se spécialiser	Maintenir des portefeuilles diversifiés des paysans, les cultures intercalaires, l'augmentation de la recherche pour accélérer les changements de culture et d'identifier les changements de régime climatique	Cultures résistantes à la sécheresse (fonio, sorgho, mil, nouvelles variétés de maïs), l'agriculture irriguée (riz, blé), l'élevage extensif
Expansion de la production minérale et pétrolière au Mali	coûts salariaux plus élevés pour l'agriculture, le manque de main-d'œuvre rurale	Difficulté en suffisance du travail commandant, la réduction dans les zones cultivées.	Technologies pour économiser le travail	Charrues, multiculeurs, des tracteurs, des plates-formes multifonctionnelles, l'utilisation judicieuse d'herbicides
Prix des matières premières	Probable persistance des prix élevés des matières premières pour les principales céréales au Mali, un rebond probable dans le coton	Les prix élevés pour les agriculteurs maliens, une meilleure rentabilité de cultures à haut rendement, mais plus de demandes des zones urbaines pour l'alimentation à bas prix	Intensifier et accroître la production agricole, améliorer le fonctionnement des marchés de la production	Toutes les technologies

Les prix des engrais	Les prix élevés des engrais devraient se poursuivre pour la prochaine décennie	Faible rentabilité des cultures d'engrais adaptés, l'augmentation des besoins de crédit pour les pays de riz, de maïs, et de blé	Produits localement alternatives aux engrais chimiques, de meilleures techniques, et une utilisation plus efficace des engrais végétaux	Faibles inputs de sorgho, de mil, de fonio, l'intensification de l'élevage (produits laitiers), la jatropha, cultures intercalaires de céréales et de légumes
Les migrations internationales	Les augmentations des migrations internationales et des niveaux plus élevés de transferts d'argent	Difficulté en suffisance du travail commandant, la réduction dans les zones cultivées, l'augmentation de l'accès au crédit	Technologies pour économiser le travail, plus de technologies à forte intensité de capital	Charrues, multiculeurs, des tracteurs, des plates-formes multifonctionnelles, l'utilisation judicieuse d'herbicides, d'engrais des cultures sensibles

Technologies de Sécurité Alimentaire

Technologie	Bénéfices	Impact Pauvreté	Impact Genre	L'état de la Technologie	Effort Nécessaire	Contraintes
Variétés génétiquement améliorées, faible niveau d'intrants pour les variétés de sorgho et de mil	Affecte 73% de la superficie de céréales et 51% de la production céréalière, possible augmentation de 10-15% de toute la production céréalière	Très Elevé	Moyen	VPO dans la diffusion, hybrides près de la diffusion	Efforts de vulgarisation, la création et distribution de semences	Les marchés de semences, la vulgarisation, l'information, les marchés pour le sorgho / mil
Les variétés améliorées de fonio	Les cultures résistantes à la sécheresse, coupe la période de soudure, main-d'œuvre et les besoins en intrants, le marché disponible pour la production, pourrait remplacer le riz importé	Elevé	Très Elevé	Plus de recherches nécessaires à l'augmentation des rendements, les essais de variétés	Financement de la recherche fondamentale et appliquée	Peu de spécialistes mondiaux sur le fonio, peu de donateurs, d'effort et d'intérêt du gouvernement du Mali
Bétail génétiquement améliorées	Peut augmenter la production du bétail avec des efforts similaires et des intrants	Moyen	Elevé	Les types d'élevage améliorés existent	Plus d'effort dans la promotion de nouveaux types d'élevage	Connaissance, intensification
Cultures intercalaires intensifiées de céréales et légumes	Faiblesse du marché et de la production des risques climatiques, faibles besoins en engrais, s'appuie sur les techniques existantes	Moyen	Elevé	Les techniques sont connues et testées, mais pas très répandues	Efforts de démonstration et de vulgarisation pour améliorer la diffusion	Changements lents des habitudes de culture des paysans, le manque de

						système de vulgarisation
Culture intercalaire Poisson / Riz	Ajouter le poisson au riz irrigué à plein contrôle peut doubler le revenu par hectare	Elevé pour les surfaces de riz, Moyen en général	Faible	Bien connu de l'extérieur, mais plus de tests, de recherches, et de démonstrations nécessaires au Mali	Recherches, des parcelles d'essai et de démonstration	Le manque de connaissances actuelles sur la pêche au Mali
Des techniques de conservation du sol et de l'eau	L'augmentation des rendements, diminution des risques, plus faibles besoins en engrais, grâce à des investissements à long terme dans la conservation du sol et de l'eau	Moyen	Faible	Technologies et techniques bien connues	Efforts d'une meilleure vulgarisation pour fournir aux paysans des techniques de conservation du sol et de l'eau, plus de recherche sur des alternatives locales aux engrais chimiques	Applicable aux terres en culture permanente, peu probable que les paysans l'adoptent avec la jachère, les contraintes du travail posent aussi problème avec la main-d'œuvre intensive
Lutte antiparasitaire intégrée	Réduction des risques de parasites par de meilleures techniques	Moyen	Elevé	Connus et testés, mais plus de travail de recherche peut se faire	La diffusion des connaissances, de nouvelles recherches	Changements lents des habitudes de culture des paysans, faible niveau de connaissance des

	services de vulgarisation

Technologies Génératrices de Revenu

Technologie	Bénéfices	Impact Pauvreté	Impact Genre	L'Etat de la Technologie	Effort Nécessaire	Contraintes
Le maïs résistant à la sécheresse	Augmentation de la production de maïs dans plus de zones, moins de risques à la production existante, le marché des produits disponible	Elevé	Moyen	Variétés VPO dans la diffusion, plus de travaux nécessaires sur les hybrides	Vulgarisation et la diffusion, des améliorations dans la production de semences, de la recherche hybride	L'industrie des semences, la disponibilité d'engrais à prix abordable, le crédit, la formation des chercheurs hybrides
Engrais sensibles au sorgho et mil	Augmentation de la production d'une culture déjà comprise, moins de risques que d'autres cultures commerciales comme le maïs	Elevé	Moyen	En diffusion, a besoin de plus d'intensification	Intensification, production d'intrants, effort accru sur le côté commercial	L'industrie des semences, la disponibilité d'engrais à prix abordable, le crédit, la commercialisation du sorgho / mil à d'autres sources
Riz Bas-fond	L'augmentation de la production de riz bas fond a un impact direct sur la sécurité alimentaire et les revenus avec les petits exploitants et au genre	Elevé	Très Elevé	Technologies existantes, diffusion lente	Vulgarisation et diffusion, production d'intrants, meilleures techniques de gestion d'eau	Agents féminins de vulgarisation, industrie des intrants, disponibilité d'engrais abordables, crédit

Riz SRI	Gestion améliorée des champs de riz sans ajouter de couteux nouveaux intrants	Elevé	Moyen	SRI a commencé la diffusion	Suivi, évaluation, et intensification	Personnel formé
Développement à petite échelle des produits laitiers	Gros potentiel d'augmentation de la production laitière à l'échelle nationale, un grand marché existant, le potentiel d'améliorer les revenus des femmes, apport en protéines, et réduction des coûts en devises du lait en poudre importé	Elevé	Très Elevé	La plupart de l'expansion peut se faire avec les technologies connues, les techniques de meilleurs fourrages nécessaires, et les développements futurs de vaches génétiquement améliorées pourraient aussi aider plutard	Organisation coopérative, la formation à la pasteurisation du lait frais et à la manutention, et des infusions modestes d'équipements	Organisation et formation, appui des donateurs
L'élevage de poissons/aquaculture	Le Mali a des conditions idéales pour les étangs du poisson, peut créer un offre accru de protéines, et il y a déjà un marché disponible pour la production	Moyen	Faible	Des tests préliminaires sont prometteurs, mais on sait peu sur les raisons de la réussite, l'économie des bassins de pisciculture n'est pas très claire	Plus de recherche et les tests nécessaires pour avoir des paquets pour les agriculteurs à adopter, la recherche socio-économique sur les rendements	Le manque d'investissements antérieurs, seul un chercheur de l'IER, faible base en connaissances générales, les coûts élevés des étangs piscicoles, de crédit

Les cultures d'exportation: Améliorer la capacité du Mali à cultiver des plantes demandées dans le monde	Les exportations maliennes de fruits et légumes seraient plus compétitives si le Mali augmente les grandes variétés de fruits et légumes demandées sur le marché mondial	Moyen	Moyen	Pour l'instant non testé, plus de recherche nécessaire	Recherche et essais de variétés mondiales de fruits et légumes sur la situation agricole du Mali	Laps de temps long, le manque de donateurs et les investissements du secteur privé dans la recherche

Focalisation sur le Genre

Technologie	Bénéfices Spécifiques Au Genre	Effort Nécessaire pour atteindre de bénéficies liés au genre	Contraintes aux bénéfices liés aux genres
Fonio	Le fonio est précisément la culture des femmes, comporte de faibles risques et d'exigences du travail, marché disponible pour la production	La recherche sur les moyens d'accroître les rendements, la réduction de l'égrenage, la diffusion des techniques de transformation améliorées	Manque de chercheurs concentrés sur la culture, le manque d'intérêt des donateurs
Maïs hybrides pour les champs de cas	Intensification des champs de cas avec le maïs hybride peut augmenter les revenus des femmes et de fournir un marché disponible	formation des femmes dans l'intensification de la production de maïs, accès au crédit	Crédit pour les semences et les engrais
Culture intercalaire intensive	Les femmes font déjà généralement la culture intercalaire, l'intensification de ces mesures donnerait plus d'avantages	Les programmes de vulgarisation concentrés sur les femmes pour les enseigner des techniques améliorées	Le changement des pratiques existantes des pays est difficile
Développement à petite échelle des produits laitiers	La production laitière est principalement l'activité des femmes, l'intensifier et créer un marché plus important aura des avantages directs, en plus	Formation à la gestion des animaux, la création et la formation des organisations de collecte (coopératives), le crédit pour l'achat des animaux, la diffusion de techniques	Les difficultés organisationnelles, le manque d'intérêt des donateurs, la formation

	de fournir plus de protéines aux enfants	améliorées de gestion des fourrages	
Technologies d'économie de travail, plates-formes multifonctionnelles, herbicides	Dispositifs d'économie de travail et des technologies, même les plus axées sur la production appartenant aux hommes, permettre aux femmes de se concentrer plus souvent sur d'autres activités rémunératrices	Poursuite de la diffusion de nouvelles technologies, l'accès au crédit pour leur achat, la formation à l'utilisation appropriée d'herbicides	Crédit, formation dans leur utilisation
Amélioration des services système écologique	Les femmes sont les principaux collecteurs de produits des prairies et des forêts. Accroître leur productivité et la valeur marchande aurait un impact direct sur elles	Plus d'efforts de recherche et de diffusion de technologies productives des forêts, diffusion de techniques améliorées de traitement de karité et autres produits forestiers, création de l'organisation coopérative de commercialisation, crédit	Le manque d'investissements dans la recherche et des chercheurs travaillant sur les ressources forestières et de savane. L'intensification de l'agriculture peut réduire les services système écologique de la terre en jachère
Riz Bas fond	Les femmes sont les principaux producteurs de riz bas fonds, l'augmentation des rendements aurait des avantages directs pour elles	Diffusion de variétés de riz de meilleure qualité, de meilleures techniques, et aider avec des technologies de contrôle de l'eau	La disponibilité des semences, la diffusion des techniques