EARLY ADOPTION OF IMPROVED PEARL MILLET AND SORGHUM VARIETIES IN MALI

HOPE Project – Phase I (2009-2013)

Felix Badolo

ICRISAT
Science with a human face

International Crops Research Institute for the Semi-Arid Tropics

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Abbreviations and acronyms

ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
WCA	West and Central Africa
ESA	Eastern and Southern Africa
SA	South Asia
SSA	Sub-Saharan Africa
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	FAO Statistics
IER	Institut d'Economie Rurale
CILSS	Comite permanent Inter-Etats de Lutte contre la Sècheresse dans le Sahel
NGO	Non-Governmental Organization
FCFA	Franc de la Communauté Française Africaine
US$	United States dollar
NARS	National Agricultural Research Systems
FARM	Fondation pour l'Agriculture et la Ruralité dans le monde
AMSP	Association Minim Song Panga – Burkina Faso
UGCPA	Union des Groupements pour la Commercialisation des Produits Agricoles
FEPAB	Fédération de Professionnels Agricoles du Burkina Faso
AOPP	Association des Organisations Professionnelles Paysannes
AMEDD	Association Malienne d'Eveil au Développement Durable
UACT	Union des Agriculteurs du Cercle de Tominian

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Executive Summary

The HOPE project is an ICRISAT assisted project that officially started July 1st, 2009. The first phase of project is being implemented in eleven countries in three regions of world: West and Central Africa (Mali, Niger, Burkina Faso, Nigeria), Eastern and Southern Africa (Ethiopia, Eritrea, Kenya, Southern Sudan, Tanzania, Uganda), and South Asia (India). The project aims to increase the productivity of dryland sorghum, pearl millet and finger millet cereal production systems in dryland South Asia and sub-Saharan Africa, increasing incomes and food security. During this first phase, the project should contribute to improve farmer yields by 30% or more, benefiting 110,000 households in sub-Saharan Africa and 90,000 in South Asia. Within ten years the project will benefit 1.1 million households in sub-Saharan Africa and 1.0 million in South Asia.

The aim of this report is to assess adoption rates of improved pearl millet and sorghum varieties in the intervention sites in Mali. Specially, we perform an econometric and statistical analysis based on the difference-in-difference estimation using the baseline survey data conducted in 2009 as well as adoption survey data conducted in 2014.

The results showed that areas under pearl millet and sorghum are relatively stable during the first four years of project. However, pearl millet and sorghum production increased by 26% and 25% respectively over the same period (2009-2013). Yields increased on average by 21% for the two crops. Regarding household food security, it was observed that food consumption score increased from 51.50 in 2009 to 54.06 in 2013 for the pearl millet farmers in the intervention sites. Further, there was an improvement of vulnerability status in the project villages. About 10% of pearl millet farmers from the project villages were in severe food insecurity in 2013 against 24% in 2009. About 21% of pearl millet farmers from the project villages were in food security in 2013 against 19% in 2009. The same results are recorded for the sorghum farmers. The results also showed that 80% of the surveyed farmers knew at least one improved pearl millet variety in 2013, and about 52% planted at least one improved variety in their plot. The most adopted varieties were ToroniuoC1 (25.20%), Sanioba (21.26%) and Sanioteli (7.09%). About 90% of the sorghum farmers knew improved varieties in 2013, and 70% planted at least one improved sorghum variety. The most adopted varieties were Seguetana (16.71%), Kenikedje (15.44%), Jakumbe (15.44%), Tiemarifing (10.29%), and Tieble (6.62%).

The results derived from difference-in-difference estimation showed that the adoption rate of improved sorghum varieties was to the tune of 48.25% in 2013 (pearl millet and sorghum area under improved variety). The adoption gap has been considerably reduced and is positive (8.69). The impact of project on the adoption rates is positive. The results for the pearl millet farmers showed that the proportion of area under improved varieties was of 49.28% in 2013. The adoption gap remains negative but it has been reduced during the four years period of project operation. We also note that the impact of project on the adoption of new pearl millet varieties is

positive. The adoption rates of improved pearl millet and sorghum varieties among farmers who participated in testing technologies increased during the project period. The impact is high for the sorghum farmers participating in technologies testing under the HOPE project.

1. Introduction

According to Foundation for World Agriculture and Rurality, West Africa agriculture recorded a remarkable increase, all speculation combined (FARM, 2007). The volume of cereals has been multiplied by 2.9; it increased from 15,937,000 tons in 1980 to 49,246,000 tons in 2006 to achieve 52 million tons in 2009 (CILSS, 2009). This increase in cereal production was due to area led growth rather than productivity led growth. The main cereals cultivated in West Africa are pearl millet, sorghum, maize and rice. Pearl millet and sorghum production remains the prerogative of Sahelian countries particularly in Northern Nigeria, Burkina Faso, Niger and Mali.

Pearl millet and sorghum play a critical role in production and supply systems in Mali. These two cereals account to about 80% of area planted in this country. Over the period 2009/2010, the cereal production was estimated to about 6,192,800 tons in Mali, an increase by 29% compared to the period 2008/2009. Pearl millet and sorghum accounted to about 49% of this production. Between 2009 and 2010, pearl millet and sorghum production increased by 17% in Mali. Despite this increase in production, yields of pearl millet and sorghum remain low. They vary between 700 kg/ha and 800 kg/ha (Baseline survey data conducted in 2009/2010 in Mali).

Low yields in the pearl millet and sorghum sector in Mali are due to a combination of several factors. The lack of seed production systems is a major constraint to sector development. There is almost no structured market for certified seeds as in the case of irrigated rice where the private players play a crucial role in the seed production and marketing. Indeed, pearl millet and sorghum farmers use their own seeds which are often in poor condition. There are less than 50% of farmers who use improved varieties. The results of the baseline survey conducted in Mali within the framework of the HOPE project reveal that respectively 31% and 45% of pearl millet and sorghum farmers use at least one improved variety in their plot. This relatively leads to low levels of production which limit the ability of the pearl millet and sorghum sector to satisfy national demand particularly in urban areas with implications on the other stakeholders. Thus, the marketable surpluses remain low and the processing sector meets access difficulties to inputs such pearl millet and sorghum.

Considering this situation, International Crops Research Institute for the Semi-Arid Tropics in collaboration with the National Agricultural Research Systems (e.g. Institut d'Economie Rurale in Mali) are conducting research activities on millets and sorghum in order to make available to farmers the high yield varieties at lowest cost. A number of projects on the dissemination and adoption of new varieties have been developed and implemented. It is the case of the HOPE project which started its activities in Mali in 2009/2010.

The main objective of the HOPE project is to increase the productivity of dryland sorghum, pearl millet and finger millet cereal production systems in dryland South Asia and sub-Saharan Africa, increasing incomes and food security. One of its specific objectives is to target opportunities for technology development and delivery to maximize adoption and impacts of innovations on livelihoods. In its first 4 years, the project intends to increase farmer yields by 30% or more, benefiting 110,000 households in sub-Saharan Africa and 90,000 in South Asia. Within ten years the project will benefit 1.1 million households in sub-Saharan Africa and 1.0 million in South Asia.

The first phase of the HOPE project was completed in end of 2013 and a supplementary phase is in progress. This report analyzed the first phase of project highlighting the progress in terms of adoption of improved pearl millet and sorghum varieties in Mali. Thus, a second survey has been conducted in the main regions producing pearl millet and sorghum in Mali. The objective of this survey was to collect information on the socio-demographic and economic characteristics of farmers as well as on their production systems in order to measure the project progress compared to the reference situation (baseline survey).

The rest of the report is organized as follow. Section 2 briefly describes the HOPE project. Section 3 provides sampling procedure and comparative analysis of descriptive statistics. Section 4 presents the statistical and econometric method used to evaluate the adoption rates of improved pearl millet and sorghum varieties. Section 5 discusses the adoption rates derived from the difference-in-difference estimation. Section 6 describes the main constraints to adoption identified by the surveyed farmers. Section 7 concludes.

2. Description of the HOPE project: vision, objectives and main partners

The HOPE project is an ICRISAT assisted project that officially started July 1st, 2009. The first phase of project is being implemented in eleven countries in three regions of world: West and Central Africa (Mali, Niger, Burkina Faso, Nigeria), Eastern and Southern Africa (Ethiopia, Eritrea, Kenya, Southern Sudan, Tanzania, Uganda), and South Asia (India). All countries and regions participating in project are characterized by a high degree of poverty and relatively meagre and erratic rainfall. The direct beneficiaries of the project are poor smallholder farmers producing millets and sorghum and their households, and others involved in the crop commodity value chain. Consumers benefit indirectly through more stable and lower prices and better quality grain and products for their essential foodstuffs.

2.1. Vision of the HOPE project

The HOPE project operates under the following hypothesis: the combination of improved technologies (crop varieties and management) with institutional innovations that increase market access and demand will drive adoption and increase production of sorghum and millets in sub-Saharan Africa and South Asia. This will improve household food and nutritional security and facilitate transition to market-oriented and viable sorghum and millet economies that enhance livelihoods of the poor.

The Project has the following vision of success: To increase sorghum, pearl millet and finger millet yields for targeted and gender-differentiated farmers in sub-Saharan Africa and South Asia by 35-40% in the first four years of the project through improved cultivars and associated management practices, with adoption enabled and motivated through the development of markets and value chains, from input supplies to output markets. Improved, stress-tolerant and nutrient-responsive sorghum and millet varieties will be disseminated to 110,000 households in sub-Saharan Africa and 90,000 in South Asia. Within ten years the project will benefit 1.1 million households in sub-Saharan Africa and 1.0 million in South Asia.

Indeed, introduction of improved varieties accompanied by complementary agronomic practices are much more effective at boosting yields. This can boost yields by 30-35% or to 1-1.5t/ha. Adding the modest levels of fertilizer to the improved variety (about 30-50kg/ha) accompanied by controlling weeds including Striga, and planting at the correct plant density will lead to yields of 2.5-3.5t/ha. The higher yields considerably increase the efficiency of use of labour, land and water, and leads to a reduced cost per unit grain produced and a reduction in food costs. This will often result in a marketable surplus.

The HOPE project adopts an integrated value chain approach that links the “pull” of markets to the practices used on farm. The goal of the value chain analysis is to reduce transaction costs among the components of the chain (input suppliers; farmers; wholesale buyers; processors; retailers; consumers) so a larger proportion of the value of the item sold to consumers is returned to farmers. This in turn makes the farmers more responsive to market signals and should result in greater output, a marketable surplus, better use of scarce natural and human resources and a greater and more stable income for farm households.

2.2.Objectives of the HOPE project

The main objective of the HOPE project is to increase the productivity of dryland sorghum, pearl millet and finger millet cereal production systems in dryland South Asia and sub-Saharan Africa, increasing incomes and food security. To achieve this global objective, six specific objectives have been defined in the first phase of project:

<u>Objective 1</u>: Target opportunities for technology development and delivery to maximize adoption and impact of innovations on livelihoods in WCA, ESA and SA. Objective 1 will provide critical baseline information and methodologies needed to orient, monitor and evaluate progress in the other objectives over the course of the project.

<u>Objective 2</u>: Improve sorghum cultivars and management options to increase productivity in WCA, ESA and SA. Objective 2 will pursue the identification of opportunities for increasing sorghum production and new sources of genetic variation for key disease and insect pests. This will be associated with improved crop management practices. The focus is on developing stable

and high yielding hybrids and open-pollinated varieties adapted to specific regions and ecologies, and involving farmers in participatory varietal selection.

Objective 3: Improve pearl millet cultivars and management options to increase productivity in WCA and SA. These are the same activities as the objective 2, but they are implemented in the main regions producing pearl millet. Objective 3 particularly aims to strengthen national program capacity to screen key pests, and in this cross-pollinated crop focuses more strongly on the development of populations as a means of open-pollinated varieties.

Objective 4: Improve finger millet cultivars and management options to increase productivity and production in ESA. Objective 4 describes the evaluation of existing and new collections of finger millet from within the target region, and particularly focuses on collections resistant to blast and drought, while attempting to identify stable and adapted varieties among collections evaluated under participatory variety selections.

Objective 5: Discover and develop improved market strategies for sorghum, pearl millet and finger millet to stimulate adoption of improved technologies in WCA, ESA and SA. Objective 5 will discover and develop larger market opportunities by investigating new marketing approaches that minimize the transaction costs and link key actors together. This enable to farmers to receive a greater proportion of the final price of the commodity. One of the important elements of this objective is the identification of best opportunities in the processing sector in order to improve returns from marketable surpluses.

Objective 6: Enable technology adoption of sorghum, pearl millet, and finger millet by improving access to inputs and markets differentiated according to both women and men's needs in WCA, ESA and SA. Objective 6 will accelerate the delivery of improved, ready-to-go technologies and will deliver market opportunities by connecting and catalyzing the key actors and overcoming past bottlenecks. Delivery of these outputs will be through partnerships that are locally-attuned and build capacities in the process. Better market opportunities will increase and stabilize the prices received by farmers.

2.3. Main partnerships - HOPE project

The HOPE project is implemented through partnerships that are carefully chosen according to need and objective. Main collaborating institutions in the HOPE project are:

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT): has the global mandate for crop improvement in sorghum and millets, as well as groundnuts, chickpea, and pigeon pea. ICRISAT is the executing agent of the HOPE project. It has four main research programs, three of which have input into the project, these are Dryland Cereals Program, Resilient Dryland Systems, and Markets, Institutions and Policies.

National Agricultural Research Systems (NARS): include national organizations funded by government. NARS staff is full partners in the project, which help ensure commitment to achieving project objectives and shared ownership of the approaches used to implement them.

Seed companies: They use the technology and improved germplasm provided by the HOPE project through Government-supported national programs or from community seed producers to deliver quantities of quality seed of open-pollinated varieties and hybrids to farmers. They may also participate in regional testing of improved products, and sponsor varieties through any National Performance Trial process that is prerequisite to official release.

Non-Government Organizations (NGOs): there are Africa harvest, as well as farmer groups such as UACT, AMEDD and AOPP in Mali; FEPAB, UGCPA and AMSP in Burkina Faso; and Mooriben and Fuma Gaskya in Niger. The World Food Program plays important role through its Purchase for Progress (P4P) grain purchase. P4P buys grain locally for food aid use, and carefully manages its storage and release into the marketplace to stabilize demand.

3. Sample design and data analysis

Adoption rates assessment of improved pearl millet and sorghum varieties after the four first years of implementation of the HOPE project in the intervention sites in Mali uses household survey data. The surveys were carried out in two waves. The baseline survey was conducted in project and non-project sites from December 2010 to January 2011. The non-project villages were selected based on proximity to project villages. Villages located around 10 to 20 km from project villages were considered to be diffusion villages i.e. villages where technologies and innovations will easily spill-over and control villages are those located 40 to 60 km from control villages where it is assumed that technologies being developed in project villages cannot easily spill-over in those villages. The baseline survey covered 78 villages in 6 regions where pearl millet and sorghum are grown. On average 10 households were randomly selected in each village. Most of households interviewed are both sorghum and pearl millet producers. A total of 728 households were interviewed of which 531 households were pearl millet producers and 702 were sorghum producers. Data were collected at village, household and plot levels. At household level, data were gathered on household socio-demographic and economic profile such as land stocks and agricultural equipment, agricultural production, use of modern technologies, social capital, access to credit, and other characteristics.

The adoption survey (second wave) was conducted in February 2014. Only 32 villages and 272 households were interviewed in this second round (see table 1). The main reason is that we surveyed the villages that really benefited from the HOPE project as well as diffusion and control villages located at proximity to project villages while respecting the sampling method implemented during the baseline survey.

Table 1: Sample design by region in Mali

	Surveyed Regions					
	Kayes	Koulikoro	Mopti	Segou	Sikasso	Total
Baseline Survey (first wave)						
Pearl millet producers						
Project village	37	74	78	52	61	302
Diffusion village	52	17	0	30	25	124
Control village	15	26	20	10	34	105
Sub-Total	104	117	98	92	120	531
Sorghum producers						
Project village	38	127	71	51	68	355
Diffusion village	58	65	0	28	29	180
Control village	28	74	15	10	40	167
Sub-Total	124	266	86	89	137	702
Early adoption survey (second wave)						
Pearl millet producers						
Project village	0	27	49	24	27	127
Diffusion village	0	1	0	19	16	36
Control village	0	8	8	9	26	51
Sub-Total	0	36	57	52	69	214
Sorghum producers						
Project village	0	39	46	24	27	136
Diffusion village	0	24	0	19	16	59
Non-project village	0	24	8	9	27	68
Sub-Total	0	87	54	52	70	263

Source: constructed using baseline survey data and early adoption survey carried out in Mali, in 2010 and 2014.

To perform data analysis, we consider the same number of villages and households in the two surveys particularly the villages that really benefited from the project and the diffusion and control villages at proximity. Thus, we consider as non-project villages all diffusion and control villages of our sample.

3.1. Socio-demographic profile of pearl millet and sorghum farmers

The socio-demographic profile of households can influence adoption of technologies and innovations in the agricultural sector. These include for example formal education, household size, total workforce, access to credit, affiliation to agricultural group. The results of adoption survey showed that household size has on average increased from 21 members in 2009 to 23 members in 2013 both in intervention villages and non-project villages. The proportion of educated household heads increased by 28% in the project villages through adult literacy during the first four years of implementation of the HOPE project. However, the number of educated members is remained relatively stable between 2009 and 2013. The total workforce is estimated to about 14 and 13 adult equivalents in the intervention villages and non-project villages respectively highlighting increases by 38% and 24% between 2009 and 2013 in both types of villages. The number of farmers having access to credit has increased from 29% to 56% in project villages and from 28% to 61% in non-project villages between 2009 and 2013. Between the two surveys, we recorded more households affiliated to agricultural association such as agricultural production association, seed production group, and selling group of agricultural products. About 95% of pearl millet farmers from project villages are member of one agricultural association in 2013 against 57% in 2009. They are estimated to about 96% in non-project villages to be member of one agricultural association in 2013 against 53% in 2009. The same results have been recorded for the sorghum farmers in Mali.

Table 2: Socio-demographic profile of farmers by type of village in Mali

	Baseline survey		Early adoption survey	
	Project village	Non-project village	Project village	Non-project village
Pearl millet producers				
Household size	21.33	21.42	23.40	23.62
Number of educated members	7.07	4.75	7.30	5.25
Adult equivalent	8.76	10.00	14.11	13.15
Educated household head (%)	16.54	11.49	22.83	12.64
Access to credit (%)	29.13	27.59	55.91	60.92
Member of agricultural group (%)	57.48	52.87	95.28	96.55
Sorghum producers				
Household size	21.86	22.21	23.92	24.26
Number of educated members	7.49	8.07	7.80	8.16
Adult equivalent	9.07	10.14	14.50	14.13
Educated household head	16.91	11.02	24.26	14.17
Access to credit	27.94	28.35	56.62	58.27
Member of agricultural group	54.41	39.37	94.12	96.06

Source: constructed using baseline survey and early adoption survey conducted in Mali in 2009/2011 and 2014.

3.2.Pearl millet and sorghum production systems

This section focuses on the evolution of areas under pearl millet and sorghum, agricultural equipment used for production, pearl millet and sorghum production, yields and income generated by agricultural activities during the first four years of the HOPE project in Mali.

The results from table 3 show that on average area under pearl millet are remained relatively stable in the intervention villages between 2009 and 2013. It is estimated to about 3 ha. However, area under peal millet decreased from 2.65 ha to 1.76 ha in the non-project villages during the same period. The value of agricultural equipment considerably increased both in the two types of villages between the two periods. Agricultural equipment used by the pearl millet farmers was estimated to about 163,014 FCFA and 183,336 FCFA in the project villages and non-project villages respectively in 2009 against 1,273,326 FCFA and 858,772 FCFA respectively in 2013. Pearl millet production increased during the first four years of implementation of the HOPE project both in project villages and non-project villages in Mali. In the intervention sites, pearl millet production increased by 26% against 16% in the non-project villages. Regarding yields, they increased from 692 kg/ha in 2009 to 874 kg/ha in 2013 in the project villages (21%) against 757 kg/ha in 2009 to 839 kg/ha in 2013 in the non-project villages (10%). Each pearl millet farmers from project villages generated on average agricultural income estimated to about 536,798 FCFA in 2013 against 222,767 FCFA in 2009. In the non-project villages, agricultural income generated by each farmer is estimated to 477,858 FCFA in 2013 against 320,430 FCFA in 2009. The results obtained for sorghum farmers are almost similar to those of pearl millet farmers.

Table 3: Pearl millet and sorghum production and yields by type of village in Mali

	Baseline survey		Early adoption survey	
	Project village	Non-project village	Project village	Non-project village
Pearl millet producers				
Pearl millet area (ha)	2.95	2.65	2.97	1.76
Value of equipment (FCFA)	163013.8	183336.2	1273236	858772.1
Production (kg)	1533.42	1069.03	2063.71	1269.38
Yields (kg/ha)	692.46	757.06	873.94	839.14
Agricultural income	222767	320430	536798	477858
Sorghum producers				
Sorghum area (ha)	2.15	3.12	2.70	2.95
Value of equipment (FCFA)	158816.2	175334.6	1284590	925944.3
Production (kg)	1653.89	1611.96	2216.76	1919.27
Yields (kg/ha)	729.07	731.96	920.17	815.67
Agricultural income	212880	364768	528340	418344

Source: constructed using baseline survey and early adoption survey carried out in Mali in 2009/2011 and 2014

3.3. Food security and vulnerability status of pearl millet and sorghum farmers in Mali

This section describes the food security situation and vulnerability status of the surveyed farmers in Mali. The results from table 4 indicate that household food security has known a slight improvement during the first four years of the HOPE project. Household food security is measured by Food consumption score, which is defined as a score calculated using the frequency of consumption of different food groups consumed by a household during the 7 days before the survey. The method of calculation of Food consumption score is detailed in appendix 1. The results show that Food consumption score increased from 51.50 in 2009 to 54.06 in 2013 in the intervention sites. The rate is above the standard cut-offs. This means that the surveyed pearl millet farmers have acceptable food consumption. The increase in household consumption could be due to increase recorded in production and yields during the same period. We note an improvement of vulnerability status in the project villages. The results from table 4 reveal that

10% of pearl millet farmers from the project villages were in severe food insecurity in 2013 against 24% in 2009. We can also note that 21% of pearl millet farmers from the project villages were in food security in 2013 against 19% in 2009. The first four years of the HOPE project in the intervention sites has had a positive effect on household food security as well as on their vulnerability status. However, in the non-project villages, household food security and vulnerability status are deteriorated. The same results are recorded among the sorghum farmers.

Table 4: Food security situation and vulnerability status in Mali

	Baseline survey		Early adoption survey	
	Project village	Non-project village	Project village	Non-project village
Pearl millet producers				
Food Consumption Score	51.50	49.32	54.06	44.87
Vulnerability status[1]				
Severe	24.00	12.00	10.00	15.00
Food secure	19.00	5.00	21.00	4.00
Sorghum producers				
Food Consumption Score	50.07	47.53	52.55	45.60
Vulnerability status				
Severe	26.00	29.00	12.00	22.00
Food secure	18.00	14.00	22.00	5.00

Source: constructed using baseline survey and early adoption survey carried out in Mali in 2009/2011 and 2014

3.4.Exposure and Farmers having planted improved pearl millet and sorghum varieties

This section presents exposure rate and the proportion of farmers having planted at least one improved pearl millet and sorghum variety during the first four of implementation of the HOPE project in Mali.

The results from table 5 show that during the first four years of implementation of the HOPE project in Mali, 80% and 78% of pearl millet farmers from project and non-project villages were exposed to improved varieties respectively. The exposure rates were respectively 45% and 55% in the project and non-project villages. The proportion of pearl millet farmers from project villages having planted at least one improved variety is estimated to 52% in 2013 against 34% in 2009. In the non-project villages, they are estimated to about 58% having planted at least one improved variety in 2013 against 53% in 2009. The most adopted varieties in project villages were ToroniouC1 (25.20%), Sanioba (21.26%), and Sanioteli (7.09%). Regarding sorghum farmers, the exposure rate is estimated to 90% in 2013 in the project villages against 48% in 2009. The exposure rate was of 60% in 2013 in the non-project villages against 40% in 2009. The proportion of the sorghum farmers from intervention sites having planted at least one improved variety during the first years of the implementation of the HOPE project is estimated to about 70% in 2013 against 40% in 2009. In the non-project villages, there are around 50% of

[1] Vulnerability status of households is determined using Food Consumption Score. It is explained in appendix B.

sorghum farmers who planted at least one improved sorghum variety in 2013 against 32% in 2009. The most adopted sorghum varieties in the intervention sites in 2013 were Seguetana (16.71%), Kenikedje (15.44%), Jakumbe (15.44%), and Tiemarifing (10.29%)

Table 5: Pearl millet and sorghum farmers exposed and having planted improved varieties

	Baseline survey		Early adoption survey	
	Project village	Non-project village	Project village	Non-project village
Pearl millet producers				
Exposure to improved varieties (%)	45.00	55.00	80.00	78.00
Planted at least one improved variety (%)	34.00	53.32	52.00	58.22
Most adopted varieties[2]				
ToroniouC1	3.94	0.00	25.20	2.30
Sanioba	22.83	26.44	21.26	28.40
Sanioteli	5.51	9.20	7.09	8.05
Guefoue16	7.09	11.49	2.36	3.45
Sorghum producers				
Exposure to improved varieties (%)	48.00	40.00	90.00	60.00
Planted at least one improved variety	40.00	32.00	70.00	50.39
Most adopted varieties				
Seguetana	15.44	14.17	16.71	30.71
Kenikedje	14.71	14.17	15.44	3.94
Jakumbe	6.62	1.57	15.44	7.09
Tiemarifing	3.68	2.36	10.29	2.40
Tieble	1.47	0.00	6.62	0.79

Source: constructed using baseline survey and early adoption survey carried out in Mali in 2009/2011 and 2014

3.5.Production systems of participants in technologies testing

This section presents the levels of production and yields of farmers who have participated in technologies testing under the HOPE project. Table 6 provides comparative statistics of production systems. The results reveal that area under improved pearl millet varieties was about 57% of total area for the participants in technologies testing against 45% for the non-participants in the project villages. The production and yields were respectively 2604 kg and 921 kg/ha for the participants against 2102 kg and 828 kg/ha for the non-participants. Regarding sorghum farmers, area under improved varieties is estimated to about 50% for the participants in technologies testing against 45.55% for the non-participants. The production and yields are

[2] We presented here the most adopted varieties. Whole varieties include varieties from baseline survey and other new varieties (e.g. hybrids). Most of varieties have been popularized by the HOPE project. Testing seeds are provided by the HOPE project. Most of farmers obtained the seeds either from friends or they bought them.

estimated to 2426 kg and 990 kg/ha respectively against 2108 kg and 865 kg/ha for the non-participants.

Table 6: Production and yields of participants in technologies testing under HOPE project

	Early adoption survey	
	Participated in technologies testing	Non-participated in technologies testing
Pearl millet producers		
Adoption rate (% of area)	57.00	45.00
Production (kg)	2604	2102
Average area	2.83	2.54
Yields (kg/ha)	921.00	828.00
Sorghum producers		
Adoption rate (% of area)	50.00	45.55
Production (kg)	2426	2108
Yields (kg/ha)	990	865

Source: constructed using early adoption survey carried out in Mali in 2009/2011 and 2014

4. Analysis methodology of adoption rates of improved millets and sorghum varieties

Adoption of new technologies in agriculture has attracted considerable attention among agricultural economists because the most of population from developing countries derives their livelihood from agricultural production and also because new technologies apparently offer opportunities to increase production and income. But adoption rates assessment of new technologies has met partial success. The constraints to non-adoption of innovations include for example limited access to information on technology, lack of training on use of technology, aversion to risk, absence of reliable equipment, and lack of credit.

Several development projects in agricultural sector have attempted to remove some these constraints by introducing facilities to provide information on management of new technologies such improved varieties and controlling weeds (Striga), new production practices of improved varieties, and supply of seeds. The HOPE project has facilitated the introduction of improved pearl millet and sorghum varieties through its objective 1 using technologies testing methods. Removal of these constraints is expected leads to high rates of adoption of improved varieties as well as increase in production and incomes.

This part of report discusses the econometric method used for the adoption rates assessment of improved pearl millet and sorghum during the first phase of the HOPE. Before focusing on the analysis methodology, we review definition of the concept of adoption of new technologies in agriculture.

4.1.Concept of technology adoption in agriculture

Rogers (1962) defines the adoption process as the mental process an individual passes from first hearing about an innovation to final adoption. Such a definition does not distinguish between individual adoption and aggregate adoption. Individual adoption is defined as the degree of use of a new technology in long term equilibrium when the farmer has full information about the new technology and its potential. Aggregate adoption is defined as use at the aggregate level of a specific new technology within a given geographical area or within a given population. Generally, agricultural technologies are introduced in packages with several components such as improved varieties, fertilizers, new production practices. The farmer may either decide to use all package of new technologies introduced in the region or to use a subset of package. In these circumstances, many processes of adoption may occur with sequential patterns (Mann, 1978). Another distinction is crucial in terms of adoption of innovations: divisible innovations and non-divisible innovations. The adoption of divisible technologies refers to the intensity of adoption which is measured at the individual farm level in a given time period by the amount or share of farm area utilizing the technology or by the per hectare quantity of input used. Regarding non-divisible innovations, adoption at the individual level in a given period is a dichotomous measure; but adoption at the aggregate level is continuous (percentage of farmers having adopted).

4.2.Assessment method of adoption rates

We aim to estimating the rates of adoption of improved pearl millet and sorghum after the four first years of the HOPE project in the intervention sites in Mali. In order to identify such rates of adoption, one would need to compare the rates of adoption in the villages benefiting from the HOPE project with those from the non-project villages. Since the adoption rates under both villages cannot be simultaneously observed for the same farmer, the individual adoption rate related to project can never be observed. However, given information on all farmers, some of them benefit from project and some of them do not, the average effect of project can be identified.

Formally, let Y the adoption rate of improved varieties. The adoption rate in the villages benefitting from the project is Y_1 and the adoption rate in the non-project villages is Y_0. Further, let $D_i = 1$ if the farmer is exposed to project (treated) and $D_i = 0$ otherwise (untreated). The causal effect of the participation in the project for the farmer i is the difference between Y_1 and Y_0 :

$$\Delta_i = Y_1 - Y_0$$

Since it is impossible to observe both Y_1 and Y_0 for the same farmer. Y_i is defined as follow:

$$Y_i = D_i Y_1 - (1 - D_i) Y_0$$

There is a problem of missing data in the determining of the causal effect Δ_i. This missing data is called counter-factual in the econometric literature on impact analysis (Rubin 1977). However, it is possible to determine the average causal effect of project (Moffitt, 1991). It is to make the difference between the adoption rate of improved varieties in the project village and that of the non-project villages. We then obtain the average treatment effect Δ^{ATE} defined by:

$$\Delta^{ATE} = E_i[\Delta_i] = E[Y_1 - Y_0] = E[Y_1] - E[Y_0]$$

The average effect treatment is unbiased if the population of non-participants in the project is well defined. This would mean that the non-participants and participants are similar, and that the only difference observed between these two populations is participation in the project. Such a counter-factual is possible if participation in project is done randomly. However, most of development project does not random selection for the participation in project. Generally, participation in project takes into account the socio-economic factors. The difference between the counter-factual and participants in the project during the assessment could come from two sources: either from the previous difference before the implementation of the project, which implies the existence of a selection bias, or from the project effect. Thus, it is noted that the problem of counter-factual leads to a problem of selection bias if participation in program is not done randomly. In this case, Rosenbaum and Rubin (1983) define the project effect by the average treatment effect on the treated $\Delta^{ATE|T}$:

$$\Delta^{ATE|T} = E_i[\Delta_i | D_i = 1] = E[(Y_1 - Y_0) | D_i = 1] = E[Y_1 | D_i = 1] - E[Y_0 | D_i = 1]$$

The counter-factual is given by $E[Y_0 | D_i = 1]$ which is unobserved and represents the average adoption rate that farmers from project villages would have if they had not benefited from the project activities. However, what is observable and could be an approximation of counter-factual is $E[Y_0 | D_i = 0]$ which represents the average adoption rate of the farmers from non-project villages. The gap between the counter-factual and its approximation would lead to selection bias which is determined as follow.

Add and subtract $E[Y_0 | D_i = 1]$ to the expression $E[Y_1 | D_i = 1] - E[Y_0 | D_i = 0]$ where the counter-factual is replaced by its proxy:

$$E[Y_1 | D_i = 1] - E[Y_0 | D_i = 0] = E[Y_1 | D_i = 1] - E[Y_0 | D_i = 1] + E[Y_0 | D_i = 1] - E[Y_0 | D_i = 0]$$

$$= E[(Y_1 - Y_0) | D_i = 1] + E[Y_0 | D_i = 1] - E[Y_0 | D_i = 0]$$

$$= \Delta^{ATE|T} + [E[Y_0 | D_i = 1] - E[Y_0 | D_i = 0]]$$

Thus, the selection bias is defined by: $BS = E[Y_0|D_i = 1] - E[Y_0|D_i = 0]$

The selection bias could also come from unobservable difference between the two types of villages (farmers) such as for example willingness to pay to have the improved varieties.

In sum, the main problem of impact assessment is the counter-factual issue and its approximation leads to problem of selection bias. The determination of counter-factual may be carried out by several methods that enable to resolve the problem of selection bias. In the framework of the HOPE project, villages were selected using propensity score matching method and farmers were selected randomly. The propensity score matching determines the probability of participation in project given the observed characteristics before the implementation of project. This method enables to remove the selection bias due to observables. As this has been noted in this section below, the selection bias could also come from unobservable characteristics. To take into account of this unobservable component of selection bias, we will use the Difference-in-Difference method for adoption rates assessment of improved varieties related to the project.

4.2.1. Differences-in-Differences estimation

Differences-in-Differences estimation has become an increasingly popular way to estimate causal relationships. Differences-in-Differences estimation consists of identifying the effect of a specific intervention. One then compares the difference in outcomes after and before the intervention for groups affected by the intervention to the same difference for unaffected groups. The great interest of Differences-in-Differences method comes from its simplicity as well as its potential to circumvent many of the endogeneity problems that typically arise when making comparisons between heterogeneous individuals.

We wish to assess the impact of the HOPE project on the adoption rates of improved pearl and sorghum varieties (Y) over a population of farmers. There are two groups of farmers indexed by the project $F = 0, 1$ where 0 indicates farmers who not benefited from project (control group), and 1 indicates farmers who benefited from project (treatment group). We observe farmers in two time periods, $t = 0, 1$ where 0 indicates the time period before the implementation of the project (pre-treatment), and 1 indicates the time period after the implementation of the project (post-treatment). Each observation is indexed by the letter $i = 1, \ldots, N$; farmers will typically have two observation each, one pre-treatment and one post-treatment. For the sake of notation let Y_0^T et Y_1^T be the sample averages of the adoption rates for the treatment group before and after the project, respectively, and let Y_0^C et Y_1^C be the corresponding sample averages of the adoption rates for the control group. Subscripts correspond to time period and superscripts to the treatment status.

The adoption rate of improved varieties is defined by the following equation:

$$Y_i = \alpha + \beta F_i + \theta t_i + \gamma(F_i * t_i) + \varepsilon_i$$

Where ε_i is a random, unobserved error term which all determinants of Y_i that the model omits. Y_i is the intensity of adoption at individual level which is equal to the amount or share of farm area utilizing the technology or by the per hectare quantity of input used. The coefficients α, β, θ and γ have the following interpretations:

- α = constant term
- β = treatment group specific effect (to account for average permanent differences between treatment and control)
- θ = time trend common to control and treatment groups
- γ = true effect of treatment

Given the data that we have available, the purpose is to find a best estimate unbiased of γ: $\hat{\gamma}$. This will only be possible if the following assumptions are correct: (i) the model in equation (adoption rate) is correctly specified; (ii) the error term is on average zero ($E(\varepsilon_i) = 0$); and the error term is uncorrelated with the other variables in equation: $cov(\varepsilon_i, F_i) = 0$, $cov(\varepsilon_i, t_i) = 0$, and $cov(\varepsilon_i, F_i * t_i) = 0$.

Under these assumptions, we may determine the average net effect of project on the treatment group (project villages) using the difference-in-difference estimation. It is defined as the difference in average adoption rate in the project villages before and after the project minus the difference in average adoption rate in the non-project villages before and after project:

$$\hat{\gamma}_{DD} = \bar{Y}_1^T - \bar{Y}_0^T - (\bar{Y}_1^C - \bar{Y}_0^C)$$

Taking the expectation of this estimator, we will see that it is unbiased:

$$\hat{\gamma}_{DD} = E[\bar{Y}_1^T] - E[\bar{Y}_0^T] - (E[\bar{Y}_1^C] - E[\bar{Y}_0^C]) = \alpha + \beta + \theta + \gamma - (\alpha + \beta) - (\alpha + \theta - \alpha) = \gamma$$

Table below summarizes Difference-in-Difference estimator.

Table 7: Difference-in-Difference Estimator

	$t = 0$	$t = 1$	**Difference**
Control group	α	$\alpha + \theta$	θ
Treatment group	$\alpha + \beta$	$\alpha + \beta + \theta + \gamma$	$\theta + \gamma$
Difference	β	$\beta + \gamma$	γ

4.2.2. Differences-in-Differences with covariates

A test of robustness of our findings involves studying the effect of the project on the adoption rates of improved varieties integrating a number of village and household characteristics in our specification. Equation of adoption rate becomes as follow:

$$Y_i = \alpha + \beta F_i + \theta t_i + \gamma(F_i * t_i) + \delta X_i + \varepsilon_i$$

Where X_i denotes village and household characteristics. While inclusion of these covariates changes the point estimates somewhat, but it is no affect the basic story in which the HOPE project would have a positive impact on the adoption rates of improved varieties in the intervention sites.

5. Empirical results on adoption of improved pearl millet and sorghum varieties

In this section, we first present the estimation results at the village level. In particular, we report the average effect of the HOPE project on the adoption rates of improved varieties with the difference-in-differences estimator. Second, we assess whether there is impact heterogeneity taking into account observable characteristics and we evaluate the effectiveness of the HOPE project on the adoption rates in the intervention sites. Finally, we are interested in the effect of the project on the adoption rates for those who participated in field school, varietal tests or seed production activities.

5.1.Average adoption rates of improved varieties at the village level

Table 8 reports difference-in-difference estimates of the average effect of the HOPE project on adoption rates of improved varieties in the project villages. The adoption rate used here is intensity of adoption[3] which is measured at the individual farm level in a given time period by the amount or share of farm area utilizing the technology or by the per hectare quantity of input used.

The results from table 8 indicate that before implementation of the project, adoption rates of improved sorghum varieties were estimated to about 32% and 31% in the project and non-project villages respectively with a difference of -0.79. During the first four years of project, the adoption rates are about 48% in the project villages and 40% in the non-project villages with a difference of 8.69. This means that area under improved sorghum varieties increased by 16% from 2009 to 2013 in the intervention sites of the HOPE project. The average effect of project on adoption rates is given by the difference-in-difference value (9.48), but this effect isn’t significant. This could explain by the fact that the project is only four years old, and that the dissemination and adoption of new varieties might take a long time. The increase in adoption rates in the non-project villages is led to spillover effects.

[3] Intensity of adoption is defined here as the proportion of area under the HOPE cultivar, out of the total cultivated area under that crop and over the years

The results from table 9 show that the proportion of area under improved pearl millet before the implementation of project were 29% and 53% in the project and non-project villages respectively with a significant difference (-23.68). The HOPE project has led to an increase in area under improved pearl millet varieties by 40% in the intervention sites of the project. The net impact of the project on the adoption rates of improved pearl millet is estimated to about 15% which is not significant. We also note the presence of spillover effects in the non-project villages producing pearl millet, thus leading to an increase in adoption rates of 9% in these villages.

Table 8: Adoption rates of improved sorghum varieties under the HOPE project

Outcome Variable	Non-project village	Project village	Difference before project	Non-project village	Project village	Difference after project	Difference in Difference
Adoption rate	32.17	31.38	-0.79	39.56	48.25	8.69	9.48
Standard deviation	4.86	4.73	6.78	4.84	4.11	6.35	9.29
t-student	6.62	32.00	-0.12	33.70	41.07	0.70	1.02
p-value	0.00	0.00	0.91	0.00	0.00	0.17	0.31

Source: estimation results using baseline survey and early adoption survey carried out in Mali in 2009/2011 and 2014

Table 9: Adoption rates of improved pearl millet varieties under the HOPE project

Outcome Variable	Non-project village	Project village	Difference before project	Non-project village	Project village	Difference after project	Difference in Difference
Adoption rate	53.11	29.43	-23.68	58.04	49.28	-8.75	14.92
Standard deviation	5.82	5.32	7.89	5.73	4.57	7.33	10.77
t-student	9.12	48.66	-3.00	53.97	37.62	-21.64	1.39
p-value	0.00	0.00	0.003***	0.00	0.00	0.23	0.17

Source: estimation results using baseline survey and early adoption survey carried out in Mali in 2009/2011 and 2014

5.2.Adoption rates with inclusion of covariates

We test the robustness of our results adding in our specification a number of covariates including age of household head, education of household head, access to credit, seed production group, number of adult equivalents, area under pearl millet, area under sorghum, household size, off-farm income and source of information.

The results from table 10 taking into account covariates show that during the first four years of project, the adoption rates of improved sorghum varieties increased by 16% in the intervention sites against about 1% in the non-project villages. The adoption rate is estimated to about 37.09%. We can note that the net effect of project on adoption rates of improved sorghum is positive, but the point estimate is different from that obtained previously (14.97).

Table 11 gives the results of the adoption rates of improved pearl millet varieties taking into account some village and household characteristics. The results reveal that area under improved pearl millet varieties increased by 26% in intervention sites against 11% in the villages that are not benefitted from project. The gap between the adoption rates in the two types of villages was significant before implementation of project. The net effect of project on adoption rates is estimated to about 15% in the villages benefiting from project.

Table 10: Adoption rates of improved sorghum varieties with control for heterogeneity

Outcome Variable	**Non-project village**	**Project village**	**Difference before project**	**Non-project village**	**Project village**	**Difference after project**	**Difference in Difference**
Adoption rate	25.79	21.37	-4.41	26.54	37.09	10.55	14.97
Standard deviation	23.18	24.04	7.08	24.48	25.01	6.59	9.57
t-student	1.11	25.61	-0.62	25.83	22.72	-2.15	1.56
p-value	0.26	0.37	0.53	0.27	0.13	0.11	0.11

Source: estimation results using baseline survey and early adoption survey carried out in Mali in 2009/2011 and 2014

Table 11: Adoption rates of improved pearl millet varieties with control for heterogeneity

Outcome Variable	**Non-project village**	**Project village**	**Difference before project**	**Non-project village**	**Project village**	**Difference after project**	**Difference-in-Difference**
Adoption rate	50.13	28.76	-21.37	60.66	54.46	-6.20	15.17
Standard deviation	25.50	26.23	8.08	26.98	27.20	7.58	11.00
t-student	1.97	49.31	-2.64	50.52	39.85	-19.37	1.38
p-value	0.05	0.27	0.009***	0.03	0.05	0.41	0.17

Source: estimation results using baseline survey and early adoption survey carried out in Mali in 2009/2011 and 2014

5.3.Adoption rates among farmers having participated in technologies testing

Here we interested in adoption state among participants in technologies testing. The farmers can participate in technology testing and then decide to not adopt it for different reasons that we will discuss in the next section. The results from table 12 show that area under improved sorghum varieties increased from 17.13% in 2009 to 49.57% in 2013 (32%) for the participants in technologies testing under the HOPE project. The adoption rate is largely above that obtained at the village level. The double difference estimator shows that the net impact of the project is significant at 5% level and it is estimated to about 26%. Regarding pearl millet farmers having participated in technologies testing under the HOPE project, area under improved varieties increased from about 21% in 2009 to 44.57% in 2013 (24%). We can also note that the adoption rate is higher than that at the village level.

Table 12: Adoption rates of improved sorghum varieties among participants in technologies testing

Outcome Variable	Non-project village	Project village	Difference before project	Non-project village	Project village	Difference after project	Difference in Difference
Adoption rate	35.40	17.13	-18.27	41.94	49.57	7.64	25.90
Standard deviation	3.77	7.56	8.45	3.91	5.31	6.59	10.72
t-student	9.39	32.98	-2.16	37.07	28.55	-14.34	2.42
p-value	0.00	0.02	0.031**	0.00	0.00	0.25	0.016**

Source: estimation results using baseline survey and early adoption survey carried out in Mali in 2009/2011 and 2014

Table 13: Adoption rates of improved pearl millet varieties among participants in technologies testing

Outcome Variable	Non-project village	Project village	Difference before project	Non-project village	Project village	Difference after project	Difference in Difference
Adoption rate	44.61	20.99	-23.62	58.32	44.57	-13.75	9.87
Standard deviation	4.36	9.11	10.10	4.54	6.01	7.53	12.60
t-student	10.23	42.01	-2.34	47.63	36.34	-22.31	0.78
p-value	0.00	0.02	0.020**	0.00	0.00	0.069*	0.43

Source: estimation results using baseline survey and early adoption survey carried out in Mali in 2009/2011 and 2014

6. Constraints to adoption of improved pearl millet and sorghum varieties

Several constraints limit adoption of improved pearl millet and sorghum varieties in the intervention sites of the HOPE project in Mali. Table 14 presents the major adoption constraints reported by pearl millet and sorghum farmers. Both among pearl millet and sorghum farmers, the key constraints are lack of information on variety management, unavailability of seeds, low yields of varieties, and late maturity. Other constraints identified by the farmers: high cost of seeds, early maturity, unavailability of plots, doubt about the quality, lack of credit, etc.

Table 14: Main constraints to adoption of improved pearl millet and sorghum varieties

	Early adoption survey
Constraints to adoption	Proportion of farmers
Pearl millet producers	
Seed unavailable	13.04
Low yields	4.35
Lack of information on management	47.83
Late maturity	4.35
Other constraints	34.78
Sorghum producers	
Seed unavailable	20.59
Low yields	8.82
Lack of information on management	38.24
Late maturity	8.82
Other constraints	26.47

Source: constructed using early adoption survey carried out in Mali in February 2014

7. Conclusion

This report assesses the adoption rates of improved pearl millet and sorghum varieties under the HOPE project using difference-in-difference estimation, and the survey data conducted in Mali (baseline survey and adoption survey).

The results of our analysis showed that areas under pearl millet and sorghum were relatively stable during the four years of project. However, pearl millet and sorghum production increased by 26% and 25% respectively over the same period (2009-2013) in the intervention sites. Increase in yields is estimated to about 21% for the two crops. The results also showed that 80% of the surveyed farmers were exposed to improved pearl millet in 2013, and about 52% planted at least one improved variety in their plot. These rates are largely above those obtained in 2009. The most adopted varieties were ToroniuoC1, Sanioba and Sanioteli. About 90% of the sorghum farmers were exposed to improved varieties in 2013, and 70% planted at least one improved sorghum variety. The most adopted varieties were Seguetana, Kenikedje, Jakumbe, Tiemarifing, and Tieble.

Use of the difference-in-difference method to evaluate the intensity of adoption (pearl millet and sorghum area under improved variety) showed that the adoption rate of improved sorghum varieties is estimated to 16% in 2013. The impact of project on the adoption rates is positive. The results for the pearl millet gave an adoption rate estimated to 49.28% in 2013 (an increase by about 9%). We also note that the impact of project on the adoption of new pearl millet varieties is positive. The adoption rates of improved pearl millet and sorghum varieties among farmers who participated in testing technologies increased under the HOPE project. The impact is high among the sorghum farmers having participated in technologies testing under the HOPE project.

Despite increase in adoption rates under the first phase of the HOPE project, lack of information on variety management, seed unavailability, low yields of varieties, and late maturity of varieties have been identified by the surveyed farmers as being the main constraints to high adoption of improved pearl millet and sorghum varieties.

Efforts should be made in the framework of the second phase of the HOPE project in collaboration with the National Agricultural Research Systems (NARS) for a development of seed production companies, and proliferation and diversity of dissemination mechanisms of information on new varieties management. Research on varieties should be oriented towards high-yielding varieties (HYV) with a time to maturity acceptable by the farmers and easily available.

References

Adebgola P. Y. and S. A. Adekambi, (2008) « Taux et déterminants de l'adoption des variétés améliorées d'igname développées par l'IITA », Rapport d'étude.

Arcand J-L. and L. Bassole, (2011) "Does community driven development work? Evidence from Senegal", Working Papers halshs-00564574, HAL

Badolo F., J. Ndjeunga, and A. Ibro, (2013) "Baseline survey of sorghum and pearl millet production in Mali, Niger and Northern Nigeria (2009/2010)"

Card D. and A. B. Krueger (1985) "Minimum wages and employment: A case study of the fast-food industry in New Jersey and Pennsylvania", The American Economic Review, vol. 84 No.4

Fall Abdoulaye, (2011) « Etude sur la chaine de valeur du mil/sorgho au Mali », Initiatives intégrées pour la croissance économique au Mali (IICEM).

Feder G., R. E. Just and D. Zilberman, (1985) "Adoption of agricultural innovation in developing countries: a survey", World Bank Staff Working Papers, Number 542.

International Crops Research Institute for the Semi-Arid Tropics, (2009) "Harnessing Opportunities for Productivity Enhancement (HOPE) of Sorghum and Millets in Sub-Saharan Africa and South Asia", A proposal submitted to the Bill and Belinda Gates Foundation.

Ndjeunga J., J. Umar, B. Ahmed, A. Aba, A. Ibro, A. Abdoulaye and K. Gwadi, (2011) "Adoption and impacts of modern sorghum and pearl millet varieties in Northern Nigeria", Working Paper, September 2011.

World Food Program, Vulnerability Analysis and Mapping (VAM), (2008) "Food consumption analysis, Calculation and use of the food consumption score in food security analysis". Prepared under the umbrella of the "Strengthening Emergency Needs Assessment Capacity" (SENAC).

Appendix A: Calculation methodology of the Food Consumption Score

Food consumption score is defined as a score calculated using the frequency of consumption of different food groups consumed by a household during the 7 days before the survey. Calculation steps of Food consumption score are as following:

- Using standard Vulnerability Analysis and Mapping Unit of World Food Program 7-day food frequency data (an example of food consumption module is given in table A.1), group all the food items into specific food groups (see groups in table A.2).
- Sum all the consumption frequencies[4] of food items of the same group, and recode the value of each group above 7 as 7.
- Multiply the value obtained for each food group by its weight (see food group weights in table A.2 below) and create new weighted food group scores.
- Sum the weighed food group scores, thus creating the food consumption score (FCS).
- Using the appropriate thresholds (see table A.3), recode the variable food consumption score, from a continuous variable to a categorical variable.

These are the standard Food Groups and current standard weights used in all analyses.

Table A.1: Food consumption module

Food item	**Days eaten in past week (0-7 days)**		**Sources of food (see codes below)**	
			Primary	**Secondary**
#.1 – Maize				
#.2 – Rice				
#.3 – Bread/wheat				
#.4 – Tubers				
#.5 – Groundnuts & Pulses				
#.6 – Fish (eaten as a main food)				
#.7 – Fish powder (used for flavor only)				
#.8 – Red meat (sheep/goat/beef)				
#.9 – White meat (poultry)				
#.10 – Vegetable oil, fats				
#.11 – Eggs				
#.12 – Milk and dairy products (main food)				
#.13 – Milk in tea in small amounts				
#.14 – Vegetables (including leaves)				

[4] Missing data for individual food items could be interpreted as 0 consumptions days, or as missing. The food consumption data should be properly cleaned to change missing values to 0 where appropriate. Where the data are truly missing, it is recommended not to calculate the FCS for that household.

#.15 – Fruits				
#.16 – Sweets, sugar				

Source: *Food consumption analysis,* Calculation and use of the food consumption score in food security analysis. Prepared by Vulnerability Analysis and Mapping Unit HQ Rome, version 1 February 2008.

Table A.2: food items, specific food groups and weight

	Food items (examples)	**Food groups (definitive)**	**Weight (definitive)**
1	Maize , maize porridge, rice, sorghum, millet pasta, bread and other cereals	Main staples	2
	Cassava, potatoes and sweet potatoes, other tubers, plantains		
2	Beans. Peas, groundnuts and cashew nuts	Pulses	3
3	Vegetables, leaves	Vegetables	1
4	Fruits	Fruit	1
5	Beef, goat, poultry, pork, eggs and fish	Meat and fish	4
6	Milk yogurt and other diary	Milk	4
7	Sugar and sugar products, honey	Sugar	0.5
8	Oils, fats and butter	Oil	0.5
9	spices, tea, coffee, salt, fish power, small amounts of milk for tea	Condiments	0

Source: *Food consumption analysis,* Calculation and use of the food consumption score in food security analysis. Prepared by Vulnerability Analysis and Mapping Unit HQ Rome, version 1 February 2008.

Table A.3: Typical thresholds

Food Consumption Score	**Profiles**
0 - 21	Poor
21.5 - 35	Borderline
> 35	Acceptable

Source: *Food consumption analysis,* Calculation and use of the food consumption score in food security analysis. Prepared by Vulnerability Analysis and Mapping Unit HQ Rome, version 1 February 2008.

A score of 21 was set as barely minimum, scoring below 21, a household is expected NOT to eat at least staple and vegetables on a daily base and therefore considered to have poor food consumption. The value 21 comes from an expected daily consumption of staple (frequency * weight, 7 * 2 = 14) and vegetables (7 * 1 = 7).

Between 21 and 35, households are assessed having borderline food consumption, while households that score above 35 are estimated having acceptable food consumption. The value 35 comes from an expected daily consumption of staple and vegetables complemented by a frequent (4 day/week) consumption of oil and pulses (staple*weight + vegetables*weight + oil*weight + pulses*weight = 7*2+7*1+4*0.5+4*3=35).

The determination of weights is based on the nutrient density of the food groups. The highest weight is attached to foods with relatively high energy, good quality protein and a wide range of micro-nutrients that can be easily absorbed. Table A.4 provides justification the weights attached to food groups.

Table A.4: Justification of weights attached to food groups

Food groups	Weight	Justification
Main staples	2	Energy dense/usually eaten in larger quantities, protein content lower and poorer quality (PER less than legumes, micro-nutrients (bound by phytates).
Pulses	3	Energy dense, high amounts of protein but of lower quality (PER less) than meats, micro-nutrients (inhibited by phytates), low fat
Vegetables	1	Low energy, low protein, no fat, micro-nutrients
Fruit	1	Low energy, low protein, no fat, micro-nutrients.
Meat and fish	4	Highest quality protein, easily absorbable micronutrients (no phytates), energy dense, fat. Even when consumed in small quantities, improvements to the quality of diet are large.
Milk	4	Highest quality protein, micro-nutrients, vitamin A, energy. However, milk could be consumed only in very small amounts and should then be treated as condiment and therefore re-classification in such cases is needed.
Sugar	0.5	Empty calories. Usually consumed in small quantities
Oil	0.5	Energy dense but usually no other micro-nutrients. Usually consumed in small quantities.
Condiments	0	These foods are by definition eaten in very small quantities and not considered to have an important impact on overall diet.

Source: *Food consumption analysis,* Calculation and use of the food consumption score in food security analysis. Prepared by Vulnerability Analysis and Mapping Unit HQ Rome, version 1 February 2008.

Appendix B: Determination of household vulnerability status

Household vulnerability status is determined using the results obtained for Food Consumption Score. It is defined in following Table:

Table B.1: Determination of household vulnerability status

Food Consumption Score (FCS)	Vulnerability status
FCS < 28	Severe
28 ≤ FCS < 52	Moderate

$52 \leq FCS < 80$	At risk
$80 \leq FCS < 112$	Food secure