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A combined ex-post/ex-ante impact analysis for improved sorghum and finger millet varieties in Uganda

Albert Gierend, Henry Ojulong and Nelson Wanyera
ICRISAT, Nairobi, Kenya, a.gierend@cgiar.org

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Sorghum group

Dr. Robert Olupot, breeder	NARO/NaSARRI
Ms. Hellen Opie, socio-economist	NARO/NaSARRI
Mr. Ebiyau John, breeder	NARO/NaSARRI
Mr. Joseph Okalebo, socio-economist	NARO/NaSARRI

Finger Millet group

Mr. Peter Obuo, agronomist	NARO/NaSARRI
Ms. Stella Namazzi, socio-economist	NARO/NaSARRI
Ms. Stella Adio, social scientist	NARO/NaSARRI

Executive Summary

This country-level impact study for Uganda combines ex-post and ex-ante estimation of research gains from improved sorghum and finger millet varieties developed by the National breeding program of Uganda together with its collaboration partners from international, national research institutions such as ICRISAT and private companies.

The methodological framework for the impact study is the standard economic surplus framework embedded in the 'DREAM' model with a multi-market configuration, full price spill-over across markets and separate impact parameters (adoption path and yield differentials) for each variety at stake. A set of scenarios are applied to test the robustness of certain parameters and incorporate some of ICRISAT's major intervention areas. One group of scenarios refers to ICRISAT's traditional breeding and agronomic activities (in cooperation with its NARS), the other group captures some elements of ICRISAT's IMOD strategy (Inclusive Market Oriented Development) by defining various market set-ups.

A three days impact assessment workshop has been conducted in September 2013 organised by ICRISAT and NaSARRI in Soroti, Uganda. Sorghum and finger millets, breeders, agronomist and socio-economists were invited to discuss the economics of improved sorghum and millet varieties and to develop the set of impact parameters necessary to run the DREAM model.

Common findings: The Sorghum and finger millet program in Uganda suffered both from initial difficulties due to sub-standard breeding technologies, the quality of breeding material and limited competitiveness of the released modern varieties. As a result, early generation varieties performed much poorer than later generations. This is reflected in relatively low Internal Rate of Returns (IRR) as well as modest research benefits since release.

Aggregate economic gains from research in USD terms are constrained by the low value of production in both crop sectors. On average, the Internal Rate of Returns are fairly high due to moderate research expenditures. Model results across the various scenarios follow similar pattern for sorghum and finger millets. Markets scenarios with low/high price elasticity coefficients and increased cross-border trade do not affect the overall size of research benefits but have a pronounced re-distributional effect between consumers and producers. Sorghum with a lower price elasticity compared to finger millet seems to react more vividly to different market set-ups causing consumer and producer surplus fluctuate within a wider bandwidth.

Results for sorghum: Sorghum research started in 1980 and released its first generation varieties Epuripur and Sekedo in 1995. Three more varieties were released in 2011 by NaSARRI, and five more are under current development and expected to be released in 2016. Based on an optimistic assessment regarding yield differentials between local and improved varieties and further uptake by farmers in the future, the returns to investments over a simulation period of 50 years (1980 – 2030) are very satisfactory. The Internal Rate of Returns IRR vary between 28 and 60%. At the lower range of IRR are the second generation varieties Seso2 and Seso3 with 28% respective 35%. Total benefits (total economic surplus

in modelling terms) account for USD 125 Mio. which translates into annual benefits of approximately USD 3.7 Mio./year since release of the first varieties in 1996.

Disaggregation of the benefits into ex-post and ex-ante shows that only a fraction of 20% are past benefits while 80% are expected in the future until 2030. This does not come as a surprise as only Epuripur and Sekedo are in the field since 1996 and Seso1-3 have been released only two years ago. Comparing the annual flow of benefits, the ex-post rate amounts to ‘only‘ USD 1.5 Mio. in benefits/year which lacks behind future annual benefits of USD 5.9 Mio./year. The spatial distribution of benefits shows a strong bias towards the Teso and Northern Region with a 90% share in benefits but only 50% in production. Most varieties are assumed to perform better and have higher adoption rates in these regions if compared with any other region.

Results for finger millet: Finger millet breeding in Uganda started early in 1965. The first generation varieties Engenyi, Gulu E and Serere 1 were released by NaSARRI in 1969/70. The next interval of varieties ended 2002 with the release of Seremi 1-3. Three more varieties are in the pipeline and ready for formal registration and release. In contrast to the sorghum working group, the finger millet experts’ variety assessment led to a rather diverse performance picture. First generation varieties that were released in the 70s and 80s show low IRRs especially Eugenyi and Serere 1 with 16% and 11 % IRR. The reasons are simple breeding techniques and poor parent material at that time that resulted in low profitability and adoption. The second-generation four varieties that came into the market in 2002 perform much better in case of Pese 1 and Seremi 2 with IRR of 96% and 107%. The other two varieties from 2002, Seremi 1 and Seremi 3, are low performers as well as they were rejected by the finger millet growers but not on grounds of low yield potential. The three new varieties are expected to perform well with IRR between 80-90%.

The breeding program’s total returns aggregated between 1969 at the year of release of the first improved varieties and 2030 are USD 160 Mio. and USD 2.7 Mio on an annual base. The returns are equally spread among the three major production regions in the North, East and Western region with each region generating around USD 40 Mio.

A breakdown of research benefits into ex-post and ex-ante underlines the difficulties in coming up with a set of attractive new varieties at an early stage in the breeding program. During the last 44 years since the first release in 1969, only USD 23 Mio. benefits were generated, which is only 500,000 USD/year and 20% of the total benefits. On the other hand, the future potential gains are remarkable with USD 140 Mio. until 2030 and USD 8.2 Mio. on an annual base under the conditions that agricultural practises, yields and seed availability improve the way that experts’ had in mind while assessing future performance.

Poverty targeting: Poverty comes along with sorghum and finger millet as both crops are grown exclusively in the dry and semi-dry areas of Uganda with a high prevalence of poverty and underdevelopment. Based on available district poverty rates and consumption information by location and income level, the poverty rates in the sorghum sector expressed in terms of share of production and consumption attributed to poor households is high. 63 % of sorghum is grown by poor farmers and 77 % is consumed by poor households with a high

proportion of own consumption. The finger millet sector has a much weaker connotation with poverty, with ‘only’ 48 % in production and 44 % in consumption.

By comparing the sector-wide poverty rate with the share of research benefits being allocated to poor households, it is possible to indicate the efficiency of the breeding programs towards targeting poverty. Both programs are fairly ***poverty neutral***. The share of benefits (producer and consumer surplus) allocated to the ‘poor’ is very similar (+-3%) the sector-wide share. This applies to all model results, base run and scenarios. On a per unit base, aggregated benefits to poor farmers between 1996–2030 are 180 USD/mt for sorghum and 300 USD/ mt for finger millet. The benefits for poor consumers are 106 USD/mt and 300 USD/mt. for sorghum and finger millet.

Keywords: Sorghum, finger millet, research impact, Uganda

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Acronyms

Abi-ZARDI	
CPI	Consumer Price Index
CS	Consumer Surplus
DIVA	Free computer program for mapping and geographic data analysis
DRC	Democratic Republic of Congo
DREAM	Dynamic Research Evaluation for Management
EAGC	East African Grain Council, Nairobi, Kenya
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
GS	Government Surplus
IFRPRI	International Food Policy Research Institute Wash. DC
IMOD	Inclusive Market Oriented Development
IRR	Internal Rate of Return
NaBWIN-ZARDI	
NARO	National Agricultural Research Organisation
NARS	National Agricultural Research Station
NaSARRI	National Semi-Arid Resources research Institute, Serere, Uganda
NBL	Nile Breweries Limited
NGO	Non-Government Organisation
OECD	Organisation for Economic Co-operation and Development
OPV	Open Pollinating Varieties
PS	Producer Surplus
R&D	Research and Development
RoU	Rest of Uganda
SAAR	Serere Agricultural and Animal Research Institute, Serere, Uganda
TS	Total Surplus
UBOS	Uganda Bureau of Statistics, Kampala
UNHS	Uganda National household Survey
UNPS	Uganda National Panel Survey
USD	United States of America Dollar
UShs	Uganda Shillings
WFP	World Food Programme

Units

AE	Adult Equivalent
Ha	Hectare
Kg	Kilogram
Mt	Metric ton

1. Introduction

The rationale of this impact study is based on the need to carry out a comprehensive country-level economic assessment of the sorghum and finger millet breeding programs in Uganda, including past performance and future potential and regardless of the breeding institutions, locations and source of breeding material. Despite ICRISATs intensive adoption, evaluation and impact monitoring activities, there has been a gap in updated sector information as well as adoption and profitability estimates for improved varieties that are grown across all major regions and agro-ecological zones in Uganda. Results from this study are useful for donors and research institutions during periods of reviews and planning by examining in the economic returns to breeding programs and the performance of each single variety and their underlying factors in more detail. Special attention is given to disaggregation of model results as much as possible, by time period (ex-post-ex-ante), by regions, by producers and consumers and household income and poverty line.

Sorghum is the most important dryland cereal in the ESA region followed by millets. Both crops have experienced little progress in the use of modern crop management techniques, higher yields and better profits. The overall importance of the dryland cereal sector has fallen short of its rival cereals, in particular Maize and recently even rice and wheat/barley. Area and production in dryland cereals are -at best- growing at a small pace, but often remained stagnant over the last 10 years, for example in Uganda, Kenya and Tanzania. The only country in which dryland cereals kept pace with other cereals is Ethiopia. There seems to be a structural supply side problem in the ESA region where ICRISAT's research efforts in germplasm improvement and modern crop management can help overcome the existing supply side bottlenecks and contribute to sustained and dynamic growth. On the other hand, demand for dryland cereals is forecast to grow strongly in ESA countries. Growth in demand is fuelled by population growth but also by new market opportunities, such as demand for clear sorghum beer, millets as a healthy dietary component for weaning children, and demand from the livestock sector.

This study contributes to the CGIAR Research Program on Dryland Cereals CRP 3.6 in which ICRISAT is the lead centre and the HOPE project (Harnessing Opportunities for Productivity Enhancement for Sorghum and Millets). The overall objectives of the two research programs (projects) is to achieve farm-level impacts, primarily through higher and more stable dryland crop productivity on smallholder farms in Africa and Asia that will increase incomes and reduce rural poverty, increase food security, improve nutrition, and help reduce adverse environmental impacts (especially in dryland crop-livestock systems).

2. Agricultural Production in Uganda

The country of Uganda possesses abundant natural resources and the potential to not only feed itself, but possibly neighbouring countries as well. Uganda is heavily reliant on agricultural productivity for its economic stability. The agriculture sector provides 73.3 percent[1] of employment and the sector's GDP contribution in 2008 was 21.5 percent. Recovering from a civil war spanning two decades, Uganda's north is severely underdeveloped. Approximately 1.8 million people were displaced, leaving widespread poverty, malnutrition and instability. Small-scale subsistence farmers is the predominant type in the country's agricultural production. Farmers often lack access to inputs, agronomic knowledge and specialized skills, and have low capital or little access to affordable credit in order to improve farm yields. Compounding these deficiencies, this non-market-oriented production typically occurs on less than two hectares of land, suffers from significant post-harvest losses, and relies on a very poor network of storage technology and feeder roads. As a result, Uganda's agricultural productivity remains low while much of its potential stays unutilized. Despite these constraints, Uganda's agricultural production increased slightly from 2007 to 2008 by 2.6 percent.

2.1. Production Zones and Characteristics

Seasonally, many areas in Uganda benefit from two rainy seasons. The main season begins in March and lasts until to May, the secondary season, from August to November. These bi-modal seasonal structure determines not only what can be cultivated, where in the country, but also the commodity prices upon harvest.

Northern Uganda: In the northwest region, there is atypically one long rainy season spanning from April to November. The region which includes; Arua, Apac, western Lira and Gulu grows the following crops; beans, sesame (simsim), maize, and sorghum. The soil fertility north of Gulu up until the border of Southern Sudan is said to be very good. Commercial farming activities are taking root along with out-grower schemes. In the north-northeastern grasslands region of the country there is typically one long rainy season spanning from April to October. This region of Uganda which includes; Pader, Kitgum and eastern Lira, produces a variety of staple crops, but the following crops were preferred by farmers; sunflower, simsim, cassava, beans, sorghum, and finger millet. Upland rice is also cultivated north of Kitgum, close to the border with Southern Sudan.

Central Uganda: South of the northwest region, in the area encompassing southwestern Gulu district, and Masindi there is also typically one rainy season spanning from March to November. Soil fertility is also thought to be good, and farmers prefer to cultivate maize, and cassava. Along Lake Victoria spanning from Entebe through Jinja toward southern Busia, there are two rainy seasons. One rainy season begins in March, and ends in May, and another from October to December. This region is experimenting with rice production, but also benefits from its proximity to Lake Victoria. Closer to Busia, beans and maize are

[1] Uganda National Bureau of Statistics (UBoS) 2009

cultivated and are preferred by farmers.

Eastern Uganda: In the eastern highlands along the Kenyan border, from northern Mbale through Kapchorwa, coffee is produced, but maize is also under cultivation. This area also experiences two rainy seasons; one from March to October, and another, which starts in August, ending in early November. Because of the volcanic rock from which crops grow, the soil is very fertile. In the southeast, from the border of Kenya (including places like Tororo, and Busia), around Kyoga Lake, and up to southern Lira (to include Soroti) there are two rainy seasons. The first rainy season is generally from March to May, with the second from August to November. Generally, beans, maize, cassava, and fisheries are the staple crop activities preferred by farmers. Soya bean is also being introduced and is showing promise near Tororo.

Western Uganda: In South western Uganda, in the farmlands around Mbarara and Bushenyi, the main rainy season begins in August and ends in November. The second, shorter season begins in March and lasts until May. In this region, farmers prefer fisheries, and matooke, but also grow maize and beans.

Map 1: Map of Uganda

Source: own design, Shape files and layers from http://www.diva-gis.org/

2.2. Crop Production

According to the Food and Agriculture Organization (FAO), Uganda's most produced crop remains green plantains (locally known as matooke). Production volumes in 2007 were at 9,231,000 metric tons. Root crops round out the top three most produced crops with 2007 production at 4,973,000 metric tons, and 2008 production at 5,072,000 metric tons for cassava, and 2007 production at 2,654,000 metric tons, and 2008 production at 2,707,000 metric tons for sweet potatoes. Maize is Uganda's most produced cereal crop, representing 46% of all cereal production. It is estimated that approximately 50 districts grow maize in Uganda with Iganga, Kapchorwa, Mbale, Masindi, and Kasese as the largest producers respectively. In 2007, Uganda produced 1,262,000 metric tons, and in 2008, Uganda produced 1,266,000 metric tons.

Table 1: Distribution of agricultural household by type of crop produced by region (1st season 2009)

	Central		Eastern		Northern		Western		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%
Maize	340,734	18.6	689,060	37.7	401,781	22.0	397,739	21.7	1,829,314	100
Finger Millet	9,488	2.2	217,617	51.1	164,206	38.5	34,819	8.2	426,130	100
Sorghum	8,348	1.5	209,760	38.6	179,916	33.1	145,066	26.7	543,090	100
Rice	2,844	3.7	46,702	60.8	22,003	28.6	5,319	6.9	76,868	100
Beans	315,853	29.2	349,067	32.3	208,767	19.3	206,767	19.1	1,080,454	100
Field Peas	480	0.7	13,567	18.9	39,454	54.9	18,314	25.5	71,815	100
Cow peas	782	2.0	23,133	58.6	14,514	36.7	1,066	2.7	39,495	100
Pigeon Peas	0	0.0	1,159	2.4	47,514	96.5	589	1.2	49,262	100
Grundnuts	81,165	10.4	285,975	36.7	217,017	27.8	195,254	25.1	779,411	100
Simsim	3,655	2.8	44,330	34.1	80,342	61.8	1,739	1.3	130,066	100
Soya	3,690	4.3	28,688	33.5	44,039	51.4	9,310	10.9	85,727	100
Banana (food)	463,866	33.7	217,771	15.8	16,896	1.2	677,529	49.2	1,376,062	100
Cassava	271,672	25.9	346,126	33.0	150,262	14.3	279,480	26.7	1,047,540	100
Sweet potatos	244,672	26.0	299,686	31.9	100,512	10.7	295,596	31.4	940,466	100

Source: UBOS 2010c

Uganda's basic crops that are cultivated on most farms and across all regions are Maize, beans, groundnuts banana, cassava and sweet potato. Other crops are more region specific like sorghum, finger millet, simsim and soya (Table 1). According to *Regional Market Assessment* (2009) matooke (starchy banana also tops Uganda's list of area under cultivation, increasing from 1,670,000ha planted in 2004 to 1,680,000ha planted in 2008. Beans is Uganda's second most cultivated crop with 896,000 ha under cultivation in 2008, an increase of 10.3 percent over 2004 figures. Maize ranks third with 862,000 ha planted in 2008, growing from 750,000 ha in 2004. This recent increase in hectares under cultivation can be attributed to many factors, one of which is increased demand from urban center agri-processors, as well as the introduction of the World Food Programme's (WFP). Cassava, despite being Uganda's second most produced crop in terms of volume, is only cultivated on 398,000 ha of land, which is less land than Uganda plants in sweet potatoes, and finger millet, and only slightly higher than land under cultivation for sorghum.

A significant change in the cropping pattern and the composition of cereal production took place over the last 12 years, see Table 2. Three different developments are apparent: a mostly constant development for food staples in the non-cereal fraction, such as plantain, sweet potato and cassava, and a sharp decline in the sector value for dry-land cereals, namely sorghum at the expense of maize. Finger millet is still reported as the second most important cereal in several publications but this fact does not hold true anymore. The same applies to sorghum. Newest FAOSTAT data for 2012 suggest that even rice- a minor cereal crop for a long time- has now surpassed sorghum and finger millet in terms of production value.

Table 2: Gross production value of major crops (constant 2004-2006) in '000 USD

	Cereals					Others (roots and tubers, legumes)				
	Maize	Sorghum	Millet	Rice paddy	Wheat	Plantains	Sweet potatoes	Cassava	Ground-nuts	Soybeans
2012	387,312	51,678	44,273	59,076	3,156		200,149	514,434	133,087	42,049
2011	361,387	67,212	52,983	64,928	3,629	1,981,997	192,899	497,014	147,524	58,507
2010	336,242	60,103	48,623	60,779	3,156	1,971,674	214,348	551,774	124,410	49,768
2009	333,573	57,570	45,273	57,338	3,156	1,963,829	208,910	541,014	116,380	49,373
2008	327,942	52,645	49,872	49,562	2,998	1,934,718	204,454	529,836	103,599	48,824
2007	178,753	70,377	132,820	45,143	2,998	1,905,814	200,429	519,495	106,019	48,276
2006	178,219	67,674	124,655	42,914	2,840	1,869,271	198,488	514,585	103,763	48,001
2005	175,240	69,058	121,933	42,635	2,367	1,867,413	196,675	582,486	101,507	43,338
2004	152,998	61,368	119,574	33,718	2,367	1,999,752	200,149	574,547	99,703	43,338
2003	184,165	64,751	116,127	36,783	2,367	2,002,643	197,128	569,323	99,251	51,293
2002	172,406	65,674	107,054	33,439	2,209	2,041,457	195,769	561,280	66,769	45,533
2001	166,315	65,059	105,966	31,767	2,209	2,009,249	189,953	549,998	65,867	39,498
2000	155,265	55,523	96,893	30,374	1,893	1,946,486	181,116	518,763	62,709	35,110

Source: FAOSTAT 2013, Online data portal at http://faostat.fao.org/

2.3. Cereal Production

The production of major cereals in Uganda has been dynamic over the last 20 years. Total area increased from just over 1.1 Mio. ha in 1992 to around 1.75 Mio. ha in 2012 (Table 3). Like in other East African countries, the area under maize grew much faster than other cereal crops and substituted part of the dry-land cereals such as Sorghum and Finger Millet.

The dominance of maize grew from 38 % (1992) to over 62 % in 2012 while the share of sorghum and finger millet declined accordingly. The area cultivated with wheat and rice stabilized over the last 5 years at a high level. In terms of production (Table 4) rice has outpaced all other cereals by a large margin and doubled production within a ten years period from 120,000 mt (1992) to 212,000 mt in 2012.

Table 3: Area under major cereals in Uganda (1992 – 2012)

	Area harvested (ha)								
	Maize		Sorghum		Millet		Rice paddy	Wheat	Total Cereals
Year	ha	% of total	ha	% of total	ha	% of total	ha	ha	ha
2012	1,094,000	62.6	373,000	21.3	175,000	10.0	92,000	14,000	1,748,000
2011	1,063,000	62.5	364,000	21.4	172,000	10.1	90,000	13,000	1,702,000
2010	1,032,000	62.4	355,000	21.5	167,000	10.1	87,000	12,000	1,653,000
2009	942,000	59.9	340,000	21.6	192,000	12.2	86,000	12,000	1,572,000
2008	862,000	56.6	321,000	21.1	200,000	13.1	128,000	11,000	1,522,000
2007	844,000	48.9	314,000	18.2	437,000	25.3	119,000	11,000	1,725,000
2006	819,000	48.8	308,000	18.3	429,000	25.6	113,000	10,000	1,679,000
2005	780,000	48.6	294,000	18.3	420,000	26.2	102,000	9,000	1,605,000
2004	750,000	48.4	285,000	18.4	412,000	26.6	93,000	9,000	1,549,000
2003	710,000	47.5	290,000	19.4	400,000	26.8	86,000	9,000	1,495,000
2002	676,000	46.8	285,000	19.7	396,000	27.4	80,000	8,000	1,445,000
2001	652,000	46.3	282,000	20.0	389,000	27.6	76,000	8,000	1,407,000
2000	629,000	45.8	280,000	20.4	384,000	28.0	72,000	7,000	1,372,000
1999	608,000	45.6	275,000	20.6	376,000	28.2	68,000	6,000	1,333,000
1998	616,000	45.1	280,000	20.5	401,000	29.4	64,000	5,000	1,366,000
1997	598,000	44.8	276,000	20.7	395,000	29.6	60,000	5,000	1,334,000
1996	584,000	44.3	271,000	20.6	400,000	30.3	58,000	5,000	1,318,000
1995	571,000	44.2	266,000	20.6	395,000	30.6	55,000	5,000	1,292,000
1994	563,000	43.5	260,000	20.1	412,000	31.8	55,000	5,000	1,295,000
1993	503,000	41.2	255,000	20.9	404,000	33.1	53,000	5,000	1,220,000
1992	438,000	38.5	250,000	21.9	396,000	34.8	50,000	5,000	1,139,000

Source: FAOSTAT 2013, Online data portal at http://faostat.fao.org/

Table 4: Production of major cereals in Uganda (1992 – 2012)

	Production (in metric tons)								
	Maize		Sorghum		Millet		Rice, paddy	Wheat	Total Cereals
Year	mt	% of total	mt	% of total	mt	% of total	mt	mt	ha
2012	2,734,000	77.1	336,000	9.5	244,000	6.9	212,000	20,000	3,546,000
2011	2,551,000	72.1	437,000	12.4	292,000	8.3	233,000	23,000	3,536,000
2010	2,373,501	72.6	390,779	11.9	267,973	8.2	218,111	20,000	3,270,364
2009	2,354,664	73.5	374,309	11.7	249,510	7.8	205,765	20,000	3,204,248
2008	2,314,909	74.0	342,286	10.9	274,857	8.8	177,857	19,000	3,128,909
2007	1,261,803	47.9	457,578	17.4	732,000	27.8	162,000	19,000	2,632,381
2006	1,258,029	49.2	440,000	17.2	687,000	26.9	154,000	18,000	2,557,029
2005	1,237,000	49.0	449,000	17.8	672,000	26.6	153,000	15,000	2,526,000
2004	1,080,000	47.5	399,000	17.5	659,000	29.0	121,000	15,000	2,274,000
2003	1,300,000	51.8	421,000	16.8	640,000	25.5	132,000	15,000	2,508,000
2002	1,217,000	51.4	427,000	18.0	590,000	24.9	120,000	14,000	2,368,000
2001	1,174,000	50.8	423,000	18.3	584,000	25.3	114,000	14,000	2,309,000
2000	1,096,000	51.9	361,000	17.1	534,000	25.3	109,000	12,000	2,112,000
1999	1,053,000	48.3	413,000	19.0	606,000	27.8	95,000	11,000	2,178,000
1998	924,000	44.3	420,000	20.1	642,000	30.8	90,000	9,000	2,085,000
1997	740,000	45.5	294,000	18.1	502,000	30.9	80,000	9,000	1,625,000
1996	759,000	47.8	298,000	18.8	440,000	27.7	82,000	9,000	1,588,000
1995	913,000	45.0	399,000	19.7	632,000	31.1	77,000	9,000	2,030,000
1994	850,000	43.9	390,000	20.1	610,000	31.5	77,000	9,000	1,936,000
1993	804,000	42.8	383,000	20.4	610,000	32.4	74,000	9,000	1,880,000
1992	657,000	37.7	375,000	21.5	634,000	36.4	68,000	8,800	1,742,800

Source: Source: FAOSTAT 2013, Online portal at http://faostat.fao.org/

In the context of this impact analysis it is important to mention that area and production statistics for sorghum and finger millet vary significantly in the literature, even within the Uganda Bureau of Statistics (UBOS) and FAOSTAT, the two main official data sources. Data are consistent until 2008, from then on reported harvested area for finger millet diverge between UBOS (200,000 ha) and FAOSTAT (450,000 ha). It is known that political unrest during that period had an adverse impact on agriculture in the Northern region which affected finger millet as the prominent crop in the region particularly hard. This study works with the UBOS finger millet data that shows a sharp drop: Area and production almost halved in 2008 compared to 1 year ago and continued to remain at that level for the consecutive years (see Tables 3 & 4). The reason is that the only district-level production data available from the UBOS agriculture census report (2010b) provides a good match with the national level data that incorporate the sharp decline since 2008.

However, the mismatch and inconsistency in the finger millet sector statistics does not pose a great challenge for the validity of the study results. The economic gains from improved varieties grow approximately linear with the market size which implies that any other assumption regarding market size can be accommodated in a simple way by using appropriate adjustment factors in the economic benefits.

2.4. Marketing

In Uganda, the food markets can be characterized as being thin and volatile in terms of prices and trading volumes as well as little liquidity. This absence of large well developed marketing system explains the inadequacy of viable market outlets, high costs of transaction as well as minimal value addition. Besides, poor access to markets in terms of long distances, limited information flows and inadequate transportation means constrain efficient market exchanges (Grains Subsector Analysis 2007). Since liberalization, the marketing of agricultural produce in general and crops in particular is largely done individually by the farmers and mostly during the peak harvest seasons. Over supply in a given season causes the price to fall because of limited storage and surplus produce on the market. The lack of collective marketing initiatives and storage facilities as well as viable market outlets contributes to a glut immediately after the harvest.

The main sources of market information on price and markets include friends, fellow farmers, local leaders and occasionally the radios. The chain between producers and consumers is long with minimal value addition ensured. In the case of grains, most of the smaller traders sell to urban traders/millers and also to the larger urban buyers. The large produce buyers mainly based in Kampala, in turn sell to the urban population and sometimes export to neighbouring countries.

3. The Sorghum Economy: Selected Overview

In Uganda, sorghum ranks now as the 3rd most important cereal after maize and rice. The crop is grown mainly in the South-western highland and in the lowland areas of the East and Northern regions of Uganda. Sorghum is a staple crop for many people and serves as an important base for locally brewed beers and processed traditional foods. The area allocated to sorghum production has been increasing for the last decade from 280,000 ha (2000) to 370,000 ha in 2012 (Table 5). Correspondingly, the total sorghum production has also been increasing but at a somewhat lower pace as a result of disappointing yields. Sorghum yields have stagnated at a low level of 1.5 mt/ha during 2000-2007 but then dropped close to 1 mt/ha. Data for 2012 indicate yields under 1 mt/ha, which is very low compared to national standards and even more by international standards (e.g. in Ethiopia, sorghum yield is over 2 mt/ha) The main constraints limiting increased sorghum production in Uganda include low genetic potential of local cultivars grown by farmers, long maturity periods, poor grain quality, poor agronomic practices, infertile soils, drought and pests and diseases including birds (Grain Subsector Analysis 2007). The economic factors that limit production and adoption of improved production technology are the high costs associated with better agronomic practices, poor marketing infrastructure, high post-harvest losses, and lack of diversified utilization and market outlets.

Table 5: Sorghum production and trade between 2000 and 2012

	Area Harvested	Production	Seed	Yield	Gross Prod. Value	Exports	Export Value	Imports	Import Value
	ha	mt	mt	mt/ha	'000 USD	mt	'000 USD	mt	'000 USD
2012	373,000	336,000	11,190	0.90	51,678	n/a	n/a	n/a	n/a
2011	364,000	437,000	11,190	1.20	67,212	1,016	346	1,570	805
2010	355,000	390,779	10,920	1.10	60,103	6,826	1,404	5,786	1,200
2009	340,000	374,309	10,650	1.10	57,570	11,029	1,839	7,561	1,600
2008	321,000	342,286	10,200	1.07	52,645	15,509	4,034	74,368	19,000
2007	314,000	457,578	9,630	1.46	70,377	141	23	77,590	19,500
2006	308,000	440,000	9,420	1.43	67,674	349	109	100,500	25,350
2005	294,000	449,000	9,240	1.53	69,058	442	158	72,700	18,900
2004	285,000	399,000	8,820	1.40	61,368	499	79	37,900	9,700
2003	290,000	421,000	8,550	1.45	64,751	420	56	2,368	843
2002	285,000	427,000	8,700	1.50	65,674	81	18	2,714	728
2001	282,000	423,000	8,550	1.50	65,059	188	32		
2000	280,000	361,000	8,460	1.29	55,523	1,120	276		

Source: FAOSTAT 2013

Cross-border trade is sporadic at best. Some sorghum exports occurred in 2008-2009 (11-15,000 mt) but constitutes only a fraction of 5 % compared to domestic production Imports took place between 2005 and 2008 despite no obvious harvest failures during that period. 60 % of domestic supply is further processed within the local communities, nearby district cities or in larger scale commercial processors in other regions that supply the major consumer markets. In 2009, around 150,000 mt was processed at the farm for home consumption. Around 10 % of the crop goes into the animal feed industry; the same amount is lost as industrial waste from processing (Table 6).

Table 6: Supply and utilization balance (2000 – 2012)[2]

	Production	Export quantity	Import quantity	Domestic supply	Utilisation					
					Food supply	Processing	Seed	Feed	Waste	Stocks
	mt	mt	mt	mt	mt	mt	mt	mt	mt	mt
2009	497,000	11,029	7,561	493,532	153,088	229,632	9,900	50,456	50,456	0
2008	477,000	15,509	74,368	535,859	166,286	249,429	9,870	55,137	55,137	0
2007	456,000	141	77,590	533,449	166,840	250,261	9,630	53,359	53,359	0
2006	440,000	349	100,500	540,151	169,052	253,579	9,420	54,050	54,050	0
2005	449,000	442	72,700	521,258	163,071	244,607	9,240	52,170	52,170	0
2004	399,000	499	37,900	436,401	136,080	204,121	8,820	43,690	43,690	0
2003	421,000	420	2,368	422,948	131,890	197,834	8,550	42,337	42,337	0
2002	427,000	81	2,714	429,633	133,996	200,994	8,700	42,971	42,971	0
2001	423,000	188	0	422,812	131,865	197,797	8,550	42,300	42,300	0
2000	361,000	1,120	0	369,880	114,888	172,332	8,460	37,100	37,100	10,000

Source: FAOSTAT 2013

More than two-third of Sorghum is produced in the Northern and Eastern region under very dry conditions (Table 7). Some Sorghum is produced in the southern part of the west region, close to Rwanda and the Congo DRC. In term of area, sorghum is grown at equal shares in the first and second season. Because of higher yields, the second season provides around 60 % of production, the first season only 40 %.

Table 7: Total area and production of sorghum by region

	Second season 2008		First season 2009		Total for 2008/09		
	Area	Production	Area	Production	Area	Production	Yield
	ha	mt	Ha	mt	ha	mt	(mt/ha)
Central	1,594	1,965	667	713	2,261	2,678	1.2
Eastern	54,681	67,592	46,964	65,721	101,645	133,313	1.3
Northern	129,627	124,578	119,703	52,510	249,330	177,088	0.7
Western	14,437	23,330	31,579	39,386	46,016	62,716	1.4
Uganda	200,338	217,465	198,914	158,330	399,252	375,795	0.9

Source: UBOS, 2010b

[2] Sorghum production statistics from FAOSTAT for Uganda diverge starting with 2007. Table 5 and table 6 are both based on the FAOSTAT data base but show different production figures. The same phenomenon can be observed for Finger Millet (next section).

Table 8: Sorghum production and its disposition by type and region

Region	Production (mt)	Disposition type (mt):						
		Sold	%	Consumed	%	Stored	%	Other purposes
Central	2,678	1,716	*64.1*	282	*10.5*	322	*12.0*	82
Eastern	133,313	16,348	*12.3*	68,996	*51.8*	37,951	*28.5*	9,857
Northern	177,088	20,250	*11.4*	89,440	*50.5*	49,990	*28.2*	17,407
Western	62,716	15,365	*24.5*	17,367	*27.7*	25,014	*39.9*	4,821
Uganda	375,795	53,678	*14.3*	176,085	*46.9*	113,277	*30.1*	32,168

Source: UBOS, 2010b

Table 8 underlines the subsistence function of sorghum. Among producers, only 14 % is sold at national level, while 47 % is consumed locally or stored for consumption later in the season (30 %). This disposition is very pronounced in the Northern and Eastern region. In the Western and Central region, sorghum has a higher exposure to markets, with higher shares being sold and less consumed at home.

Mode of production (*summary based on Grain Sub Sector Analysis 2007***):** Production of sorghum is mainly done by simple hand tools such as hoes, axes, pangas e.tc. Farmers who own oxen use them for ploughing and the implements used for ploughing include a draught power plough mounted on an ox. Generally farmers use their own seed for planting but improved varieties are now being to be introduced by NGO's and NARS. The new varieties have been selected based on a number of characteristics such as resistance to pests, diseases, drought, their colour size and quick maturity and commercial value. Sorghum grows well in the North East and is one of the most extensively grown cereals. Its peculiar characteristics have made it a highly adaptable crop to the harsh conditions found in this region. These, among others include: resistance to drought sections of the North East are semi-arid with rains that are erratic and unpredictable. It is estimated that in some part of the region especially in Karamoja, crop fail at least one year in five.

On the resistance of sorghum to drought, it has been reported that 40% of sorghum varieties are tolerant to drought. While most crops are susceptible to attack from a range of pests and diseases, some sorghum varieties are resistant to certain pests and diseases like stalk – borer and sorghum shoot fly. In the North East, sorghum has got two growing seasons; one from March to May and the other from September to November.

The production process involves the following activities: land clearing by slashing and burning to remove vegetation, 1st and 2nd ploughing by ox plough to prepare a good seed bed, planting by broadcasting, 1st and 2nd weeding to eliminate weeds and harvesting when the crop is mature. Harvesting is carried out by cutting the heads with knives. The harvested crop is transported to the farmer's home and spread on the ground to dry. When the drying is complete, threshing by beating the crop with sticks is done to remove the grain from the plant. This is followed by winnowing to remove chuff and bagging in plastic bags. Most farmers keep the produce in their houses because of lack of storage facilities.

Table 9: Sorghum production in pure and mixed stand

	Plots for 2008/09						
Region	Pure	%	Mixed	%	Total	Area (ha)	Mean Plot Size (ha)
Central	12,657	82.2	2,742	17.8	15,399	2,261	0.15
Eastern	293,028	81.2	67,972	18.8	361,000	101,645	0.28
Northern	327,951	56.7	250,170	43.3	578,121	249,330	0.43
Western	190,649	73.9	67,395	26.1	258,044	46,016	0.18
Uganda	824,285	68.0	388,279	32.0	1,212,564	399,252	0.33

Source: UBOS (2010b)

Sorghum is grown both in pure and mixed stand, see Table 9. According to UBOS (2009b) the number of plots under finger millet was estimated to be 1.2 Mio. Out of these 68 % were of pure stand while 32 % were of mixed stand. In terms of regions, the Central Region with 82.2 percent had the highest percentage of its sorghum plots in pure stand followed by the Eastern region (81.2 %) while the Northern region had the least (56.7 %) share in pure stand. The national mean plot size was estimated to be 0.33 ha. The Northern Region has the highest estimated mean plot size MPS of 0.43 ha followed by the Eastern Region with 0.28 ha while the Central Region had the smallest plot size among Sorghum growers (0.20 ha).

Profitability: Sorghum profitability stands very low among its peers of staple crops, and ranks last together with finger millet and groundnuts. Some of the reasons for the low profitability are the high labour requirements for hired and family labour. Due to the dry climate in which sorghum is grown, significant labour resources are required for preparation of land for sorghum production, including weeding, ploughing, and bush clearing. Difficulties in estimating overall labour requirements on a seasonal basis as well as a general overestimation of labour costs may contribute to the overestimation of variable costs. Table 10 indicates a negative gross margin in the first season, and a low positive gross margin (around 54,000 UShs/ha, approx. 25 USD/ha) in the second season under a low input regime and local variety.

Kraybill D. and Kidoido M. (2009) studied profitability in more detail and distinguished low and high input regime as well as local and improved varieties. Sorghum production is mostly profitable under high-input technology and not necessarily under improved varieties. Relative profitability analysis of sorghum indicates that production of local sorghum varieties under high-input technology generate up to UShs 150,000 per hectare. Under all other conditions with low input use, the gross margin is relatively low, an indication of relative unprofitability of the crop.

However, gross margins remain highly arbitrary if recorded from a single season and not from long term observation to smooth out seasonal yield conditions. Malaiyandi et al. (2010) calculated sorghum gross margin from the Soroti district for local varieties under subsistence conditions of -130,605 in the first season and 67,587 UShs/ha in the second season, even though sorghum yields in the Soroti districts are twice as high as national average.

Table 10: Gross margins for crop enterprises (season 2008/09) in UShs/ha

Gross Margin	Maize	**Sorghum**	Finger Millet	Rice	Beans	Groundnut	Cassava	Banana
First Season	100,352	**-24,468**	12,530	177,370	129,637	-104,350	343,441	509,929
Second Season	291,991	**53,834**	74,696	426,430	208,496	40,554	321,471	547,361

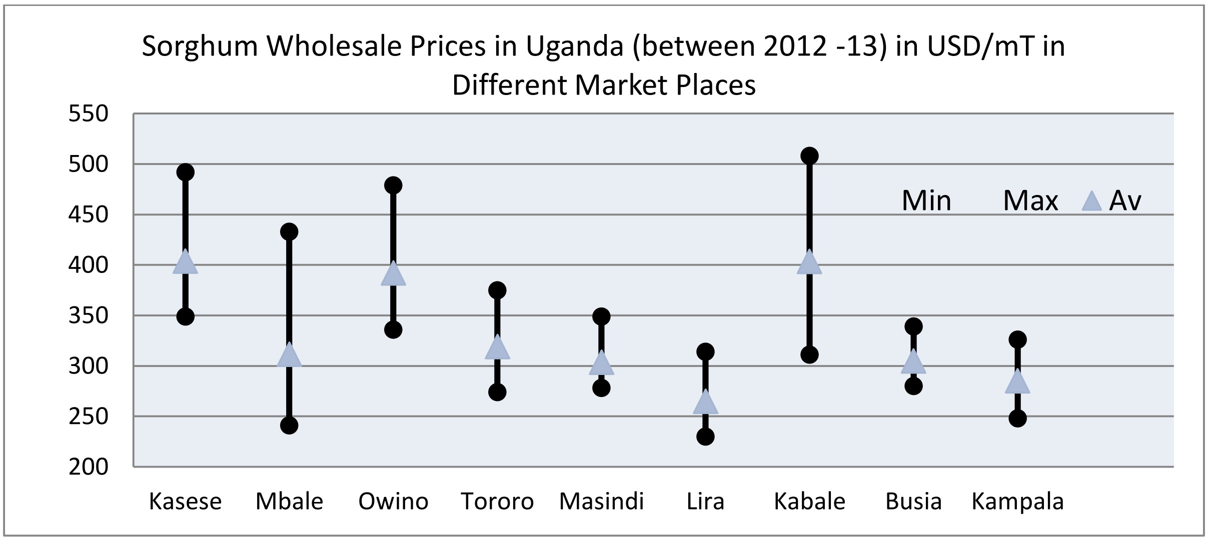
Sorghum Gross Margins

	First Season	Second Season		First Season	Second Season	
	Local type	Local type	Improved type	Local type	Local type	Improved type
	low input use (subsistence)			high input use (recommended)		
Value of output	156,336	141,978	100,631	483,127	344,712	208,329
Family labour	156,339	78,262	59,570	150,231	100,540	192,282
Hired Labour			4,940	98,800	74,100	55,987
Total Input costs	24,465	9,880		24,601	13,405	9,880
Draft power / mechanisation			22,230	59,743	62,746	62,746
Total Costs	180,804	88,142	86,740	333,375	250,791	320,895
Gross Margins	**-24,468**	**53,836**	13,891	149,752	93,921	-112,566

Source: (Kraybill D. and Kidoido M. 2009)

Prices and market places: Prices for sorghum and other major crops in the ESA region are monitored by 'RATIN NET' and can be retrieved at http://www.ratin.net/. Price series from the last 3 years under RATIN NET monitoring indicate little price differences between the market places even though traded volumes are light and sorghum production is concentrated and far from the consumer markets. Prices show a seasonal pattern and vary +- 30 % within a year. Kampala as consumer market and cities located close to the border show slightly lower prices compared to the market places in the production areas.

Figure 1: Sorghum wholesale prices in Uganda between 2009 and 2013, USD/mt



Source: own calculations, based on price data from Ratin Net

Consumption and use: Sorghum and finger millet consumption in Uganda has been analysed by ICRISAT (2012) based on the data sets from the Uganda National Household Survey (UNHS) 2009/2010 and the Uganda National Panel Survey (UNPS) 2009/2010. Some of the findings are outlined here in Table 11 & 12). Sorghum consumption follows a strict pattern. By far the highest consumption levels per head or per adult equivalent (AE) are found in the rural areas close to the major production areas. On national level it amounts to 97 kg/AE/year, with peaks in the North-East (212 kg/AE/year) and Mid-Northern sub-region (189 kg/AE/year). Then follow the urban centres close to the production areas with 36 kg/AE/year. Thus, most of the Sorghum is consumed where it is grown, in the villages and in the district cities. Very little Sorghum is sold across the regional borders as a consequence of low demand. Consumption in urban centres (2.7 kg/AE/year) and rural areas (25 kg/AE/year) far from sorghum production is extremely low.

Table 11: Consumption patterns for sorghum by sub-region (kg/AE/year)[3]

Sub-region	Total	Rural	Rural (Sorghum area)	Rural (non-sorghum area)	Urban	Urban close to sorghum area	Urban far from sorghum area
	Mean	Mean	Mean	Mean	Mean	Mean	Mean
National	**59.62**	**70.51**	**97.19**	**25.1**	**10.02**	**36.7**	**2.68**
Kampala	1.79				1.8		1.8
Central 1	1.17	1.32	6.77	0	0.28		0.28
Central 2	2.09	2.39	0.52	3.38	0		0
East Central	7.03	7.25	7.83	6.5	5.13	5.74	4.7
Eastern	80.89	84.38	104.39	22.45	42.6	61.44	16.97
Mid-Northern	191.78	204.72	189.82	259.85	65.11	111.34	10.62
North-East	200.75	212.46	212.46		7.05	7.05	
West Nile	92.38	97.76	97.76		49.93	48.07	82.87
Mid-Western	18.81	20.41	14.71	22.32	2.52	0	2.64
South-Western	14.93	15.81	18.32	7.32	1.17	2.09	0

Source: ICRISAT 2012

Table 12 captures sorghum consumption from an income perspective. Sorghum is the poor man’s crop with high negative income elasticity. Consumption not only drops in relative terms compared to expenditures for other crops but also in absolute terms with rising income. On a national level, consumption among the low income group is three times higher (113 kg/AE/year) than among affluent households (only 18 kg/AE/year). Even in the sorghum regions the difference between and poor rich households’ consumption remains extreme.

[3] The OECD approach is using weights that count as 1.0 for the first adult, 0.7 for the second and subsequent adults, and 0.5 for each child under 15. The modified OECD or EU approach, which is applied in this study, is using 1.0 for the first adult, 0.5 for the second and subsequent and 0.3 for each child. There are more elaborate weights in use however from national governments, but as long as the above weights are used uniformly inside a sample, they can be legitimate substitutes of the simpler head-counting or adult-counting.

Table 12: Consumption of sorghum by income group (kg/AE/year)

Income Group	National	Kam-pala	Central 1	Central 2	East Central	Eastern	Mid-Northern	North-East	West-Nile	Mid-Western	South Western
Consumpt../AE (kg/y)	59.62	1.79	1.17	2.09	7.03	80.89	191.78	200.75	92.38	18.81	14.93
Low	113.44	0	5.68	1.27	10.93	101.2	219.41	216.18	80.37	49.21	2.5
Middle	47.95	0.5	0	1.14	6.54	71.47	167.89	192.35	107.01	1.42	14.3
Upper	18.39	2.19	0.23	3.14	2.8	36.11	130.59	64.58	73.46	13.28	19.08

Source: ICRISAT 2012

National sorghum consumption derived from the per-unit consumption figures (ICRISAT 2012) and general population/AE data shows a mismatch of over 20% between consumption (540,000 mt) and production (435,000 mt). For the impact study, adjustments are necessary in order to close the gap by excluding some of the sorghum areas with relatively minor production and a low sorghum/maize acreage ratio from the list of sorghum/finger millet area that have a high per unit consumption. The remaining gap was further reduced by applying a 15% discount across all regions which sets off some effects from increased population (lower per unit consumption at stagnant production) that is not discounted for in the original 2007 UNHS & UNPS data sets.

Processing is either done in the home or at grain mills. At the household level, processing involves grinding the grain together with cassava flour in a mortar. Farmers with large quantities take the grain to mills where it is also ground together with cassava flour. Cassava is blended with millet to give it taste and to bind it togther when making local bread called Atap (Ugali). Grinding mills are mostly located in towns and close to big village markets. Towns where mills can be found include Monrapesur, Agip, Nakatunya, Pamba and Soroti. Sorghum is primarily grown for domestic consumption although, increasingly, some is sold to raise cash for basic home requirements such as soap, salt medical care, school fees etc. Sorghum is consumed in various forms including as 1) local bread called Atap, 2) fermented into a local brew called Ajono, and 3) as porridge called Euji.

Domestic Trade: In the absence of a comprehensive market monitoring system, it is hard to estimate the volume and value of sales transactions between regions. Traditionally, only prices are monitored (e.g. by RATIN NET) at wholesale and retail level but not volumes and values. However, based on the production and consumption balance for a region or sub-region, which has been done as a preliminary step in this report and necessary to define markets for the 'DREAM' model it is possible to estimate the share of sorghum that is traded across (sub) regions. The trade matrix from Table 13 captures the extent to which Sorghum is traded between sub-regions from a consumer and producer perspective. In the surplus sub-regions around 68% of production is consumed in the sub-region and 32 % of sorghum is sold to markets in other sub-regions. In the deficit sub-regions, around 50 % of the consumption is sourced from other sub-regions and the rest from local supply.

Assuming that all production in the deficit regions stays in the region, the share of national production that is traded outside sub-region borders is around 20.8 %. On the other hand, the trade share for national consumption comes close to 30 %.

Table 13: Sub-regional trade matrix for sorghum

All figures in %	Destination of Local Production		Origin of Local Consumption	
	Consumed in the region	Traded with other Regions	From the region	From other regions
Surplus regions	**68.2**	**31.8**		
Teso	88.6	11.4	%	
Karamoja	66.8	33.2		
South West Highlands	19.5	80.5		
Deficit regions			**51.0**	**49.0**
Northern	%		78.6	21.4
West Nile			33.8	66.2
Rest of Uganda			33.4	66.6
Total Uganda	* Production Trade Share: 20.8%		** Consumpt. Trade Share: 29.47 %	

* Share of production (from total Uganda) that is traded with other regions; ** Share of consumption (from total Uganda) that comes from other regions. Source: Own calculations.

Market channels: (summary findings from the *Grain Sub Sector Analysis 2007)* Sorghum is sold by farmers either at the farm gate or at the nearest rural market. Of the total sorghum marketed about 80% is sold at the rural markets and 20% is sold at the farm gate. At the rural markets, sorghum is purchased by consumers, millers and agents. Agents buy the produce on behalf of buyers who collect it from hired stores at the nearest market or town. The big buyers have stores with large storage capacity which are located in big towns like Jinja, Iganga, Soroti , Mbarara where produce is kept before being transported to outlets in Kampala Jinja and Busia. In the South West there is very little buying of sorghum at the farm gate. Very little produce is marketed beyond the region due to the strong local market and the weak demand in Kampala the centre for mass consumption and distribution.

In the North-east, the demand for sorghum staple food for Teso, Lango, Karamoja Acholi and West Nile districts. Marketing of sorghum in the North East generally follows three steps: from the farm gate to the rural markets, from the rural markets to agent's stores or millers, from the agent's store to the urban market. Farmers take sorghum to the nearest rural market for selling but, to a lesser extent, sorghum is sold by farmers to middlemen who reside in the rural areas. From the rural market, agents who operate on behalf of big buyers in Mbale, Sironko, Jinja and Busia buy the bulk of the produce. The produce is then transported by the agents to the stores in urban centres. At the urban centres the produce is sold either internally or transported to final outlets in Kampala, Tororo, Soroti Mbale and Busia town.

4. The Finger Millet Economy: Selected Overview

Finger millet (Eleusine corocana) is one of the most important cereals in Uganda. Finger millet has traditionally been grown in many different locations, with predominance in the Northern (Lira, Apac, Gulu, Pader, Kitgum districts), Eastern (Mbale, Tororo, Busia, Manafa, Iganga, Bukedea, Kumi, Pallisa, Soroti, Katakwi, Amuria, Kaberamaido districts) and Western Uganda (Masindi, Bulisa, Hoima, Mbarara, Ntungamo and Kabale districts). The crop particularly thrives in semi-arid climatic areas with well distributed moderate to low rainfall and well drained sandy soils due to its high tolerance for drought conditions. The crop is mostly grown under low input conditions. It can also tolerate conditions in marginal areas. Even with limited research, the crop continues to thrive even under changing climatic conditions, and gives a promising yield under farmer conditions. Uganda is a primary centre of diversity and is endowed with highly diverse finger millet land races and germplasm collections, which have not been fully characterized.

The following table summarizes the agronomic considerations for growing finger millet:

Ideal Growing Conditions:	
Rainfall:	750 to 1200 mm during the growing season
Temperature:	Average of 23^{0}C
Altitude:	1,000—2,000m
Day Length:	12 hours
Soil:	Well drained, sandy or sandy loams
pH:	pH 5—7 but can tolerate alkaline soils
Planting:	
Weeding:	Fields must be weed free in advance of planting

Production: Finger millet lost much of its standing in Uganda's cereal production compared to 10 years ago when it ranked as the second most important cereal crop behind maize in terms of area of cultivation and value of production. Area, production and sector value declined steadily between 1992 and 2012 and experienced a sharp drop in 2008 due to political unrest in the Northern region (Table 14). Another discouraging sign is the lack of yield dynamics with no progress that could have been achieved with high yielding varieties and use of modern inputs. Foreign trade with neighbouring countries is low in volume (around 1,000 – 2,000 mt) and only sporadic in nature.

Based on the newest available statistics from UBOS (2010) the Northern and Eastern region have the highest production with over 200,000 mt combined and 80 % of national production (Table 15). Around 60% is grown in the second season and 40 % in the first season at national level. The first season is more important for the Northern and eastern region, the second season more important for the minor production regions in the West and Central. Soil fertility and higher rainfall contribute to much higher yields in the Western and Central regions.

The share of Finger Millet sold to the market is higher in the Central and Western region with 39.6 % and 20.3 % while own consumption is lower. In the Northern and Eastern region, finger Millet is more subsistence oriented with higher shares in own consumption and storage (for sales later in the year), and lower sales share.

Table 14: Finger millet production, yield and trade between 1992 and 2012

Year	Area Harvested (Ha)	Production (mt)	Seed (mt)	Yield (mt/ha)	Gross Prod. Value (const. 2004-06, 1000 USD)	Export Quantity (mt)	Export Value (1000 USD)	Import Quantity (mt)	Import Value (1000 USD)
2012	175,000	244,000	4,375	1.39	44,273				
2011	172,000	292,000	4,375	1.70	52,983				
2010	167,000	267,973	4,300	1.60	48,623	1,587	384	29	2
2009	192,000	249,510	4,175	1.30	45,273	340	100	153	9
2008	200,000	274,857	4,800	1.37	49,872	1,735	442	128	11
2007	437,000	732,000	5,000	1.68	132,820	1,028	230		
2006	429,000	687,000	10,925	1.60	124,655	2,043	383		
2005	420,000	672,000	10,725	1.60	121,933	198	41		
2004	412,000	659,000	10,500	1.60	119,574	2,067	473		
2003	400,000	640,000	10,300	1.60	116,127	1,272	281		
2002	396,000	590,000	10,000	1.49	107,054	710	65		
2001	389,000	584,000	9,900	1.50	105,966	148	17		
2000	384,000	534,000	9,725	1.39	96,893	32	3		
1999	376,000	606,000	9,600	1.61	109,957	2	1		
1998	401,000	642,000	9,400	1.60	116,490	477	431		
1997	395,000	502,000	10,025	1.27	91,087	217	72		
1996	400,000	440,000	9,875	1.10	79,837	491	244		
1995	395,000	632,000	10,000	1.60	114,675	1,582	755		
1994	412,000	610,000	9,875	1.48	110,683	301	136		
1993	404,000	610,000	10,300	1.51	110,683				
1992	396,000	634,000	10,100	1.60	115,038	0	0		

Source: FAOSTAT 2013

Table 15: Area and production of finger millet by region

	Second season 2008		First season 2009		Total for 2008/09		
	Area ha	Production mt	Area ha	Production mt	Area ha	Production mt	Yield (mt/Ha)
Central	4,077	12,924	1,755	811	5,832	13,734	2.4
Eastern	26,025	28,609	60,886	78,230	86,911	106,838	1.2
Northern	38,061	49,693	67,595	28,879	105,656	78,572	0.7
Western	47,713	71,833	3,875	5,950	51,588	77,784	1.5
Uganda	115,876	163,058	134,111	113,870	249,987	276,928	1.1

Source: UBOS 2010b

Table 16: Finger millet production (mt) and its disposition (mt) by type and region

Region	Production (mt)	Disposition (Mt) type:						
		Sold	%	Consumed	%	Stored	%	Used for other purposes
Central	13,734	5,432	*39.6*	3,126	*22.8*	1,873	*13.6*	3,174
Eastern	106,838	20,689	*19.4*	39,123	*36.6*	38,728	*36.2*	8,286
Northern	78,572	10,572	*13.5*	35,775	*45.5*	23,271	*29.6*	8,942
Western	77,784	15,812	*20.3*	26,378	*33.9*	28,938	*37.2*	6,697
Uganda	276,928	52,505	*19.0*	104,402	*37.7*	92,810	*33.5*	27,099

Source: UBOS 2010b

Finger Millet is grown both in pure and mixed stand, see Table 17. According to UBOS (2009b) the number of plots under finger millet is estimated to be 936,000. Out of these, 459,000 (49.0%) are of pure stand while 477,000 (51.0%) are of mixed stand. In terms of regions, the Central Region with 61.7 percent has the highest percentage of its finger millet plots in pure stand followed by the Western Region (58.7%) while the Eastern Region has the least (44.4%). The national mean plot size is estimated to be 0.27 ha. The Northern region has the highest estimated MPS of 0.34 ha followed by the Eastern region with 0.25 ha while the Western region has the least (0.20 ha).

Table 17: Finger millet production in pure and mixed stand

	Plots for 2008/09						
Region	Pure	%	Mixed	%	Total	Area (ha)	Mean Plot Size (ha)
Central	15,885	61.7	9,861	38.3	25,746	5832	0.23
Eastern	151,584	44.4	189,600	55.6	341,184	86911	0.25
Northern	140,214	45.0	171,629	55.0	311,843	105656	0.34
Western	150,935	58.7	106,176	41.3	257,111	51588	0.20
Uganda	458,618	49.0	477,266	51.0	935,884	249,987	0.27

Source: UBOS (2010b)

Yields and yield response: Finger millet yields are responsive to good agronomic practices and input use. High crop yields are obtainable with strict observance to proper agronomic practices such as line planting of high-yielding improved seed varieties, correct seeding rates, maximum weed control and sound harvest and post-harvest handling practices (Pelrine R.J. and Besigye A. 2009). Good yield response is also realized with use of inorganic fertilizer, with yield of more than 3,000 kg per ha being possible under correct agronomical practices. Reported yields for finger millets vary widely across location, year and survey. In farm surveys, farmers estimate average unfertilized finger millet yields at 1.2 (range of 0.3 to 2.7) mt/ha for, most likely, local varieties. The use of fertilizer more than doubles average finger millet yields in on-farm trials to 2.2 mt/ha (Fermont et al. 2011). Farmers recall yield estimates are lowest for Central and Northern regions at 0.8 and 0.9

t/ha, respectively, and much higher in Western Region at 1.6 mt/ha. Unfertilized yields reported in the cost of production surveys by the APEP and LEAD projects (Regional Market Assessment, 2009) show a narrower yield range (1.2 to 1.6 mt/ha. Average finger millet yield estimates reported by the agricultural censuses and annual surveys increase from 1.1 (0.4 to 1.8) mt/ha in 1965 to 1.5 (0.5 to 3.4) mt/ha in 1990/91. With an average national millet yield of 1.5 (1.1 to 1.8) mt/ha, the MAAIF estimate for 1970–2009 is very similar. Estimates of the 1999/2000 and 2005/06 UNHS are much lower at 0.6 and 0.7 mt/ha, respectively.

Profitability: The Kampala office of the International Food Policy Research Institute (IFPRI) studied the profitability of agricultural crops and livestock in different production zones based on farm household data from the 2005/06 Uganda National Household Survey (Kraybill D. and Kidoido M. 2009). Extracts from the IFPRI analysis outlined in Table 18 indicate that production of finger millet is barely profitable. Gross margins generated with low-input technology are estimated at UShs 12,500 per hectare for the local varieties and at UShs 74,500 per hectare for improved varieties. However, production of the crop is more profitable under high-input technology, generating up to three times the gross margins generated under low-input technology. The cost of family labour is a major component of the total variable costs and it significantly affects the overall profitability of the enterprise.

Table 18: Gross margins for crop enterprises (season 2008/09) in UShs/ha

Gross Margin	Maize	Sorghum	**Finger Millet**	Rice	Beans	Groundnut	Cassava	Banana
First Season	100,352	-24,468	**12,530**	177,370	129,637	-104,350	343,441	509,929
Second Season	291,991	53,834	**74,696**	426,430	208,496	40,554	321,471	547,361

	Finger Millet First Season		Finger Millet Second Season	
	Low Input Use	High Input use	Low Input Use	High input use
Value of output	187,596	409,299	264,678	606,263
Family Labor	175,066	147,237	172,696	210,624
Total costs	175,066	322,607	189,982	388,494
Gross Margin	12,530	86,692	74,696	217,769

Source: (Kraybill D. and Kidoido M. 2009)

Constraints: ICRISAT's finger millet scientists investigated the major production constraints during a 'Hope' Project Training Workshop (ICRISAT 2010) and arrived at the following conclusion. Important production constraints in finger millet are labour intensiveness of the crop and inaccessibility of quality seed affected farmers. Poor soil fertility, low farm gate prices and erratic weather affect the Eastern region more prominently than the Northern region.Use of improved high quality seed, row planting, use of integrated pest and disease management (including use of diseases resistant varieties, early planting, field hygiene, clean seed), use of clean seedbed and promotion of post-harvest equipment and sensitization on gender roles in provision of labour in finger millet production were recommended for both Eastern and Northern zones. Promotion of micro-dosing and soil water conservation techniques were recommended for Eastern zone while thorough and timely weeding was recommended for the Northern zone.

Prices and market places: Finger millet prices in the ESA region are monitored by 'Ratin Net' at (http://www.ratin.net/) which is owned and run by the East African Grain Council in Nairobi (EAGC). Over the last 3 years there have been major price wedges between market places with higher prices in the cross-border markets and somewhat lower prices in the central market places in producing areas and even city markets (Table 19).

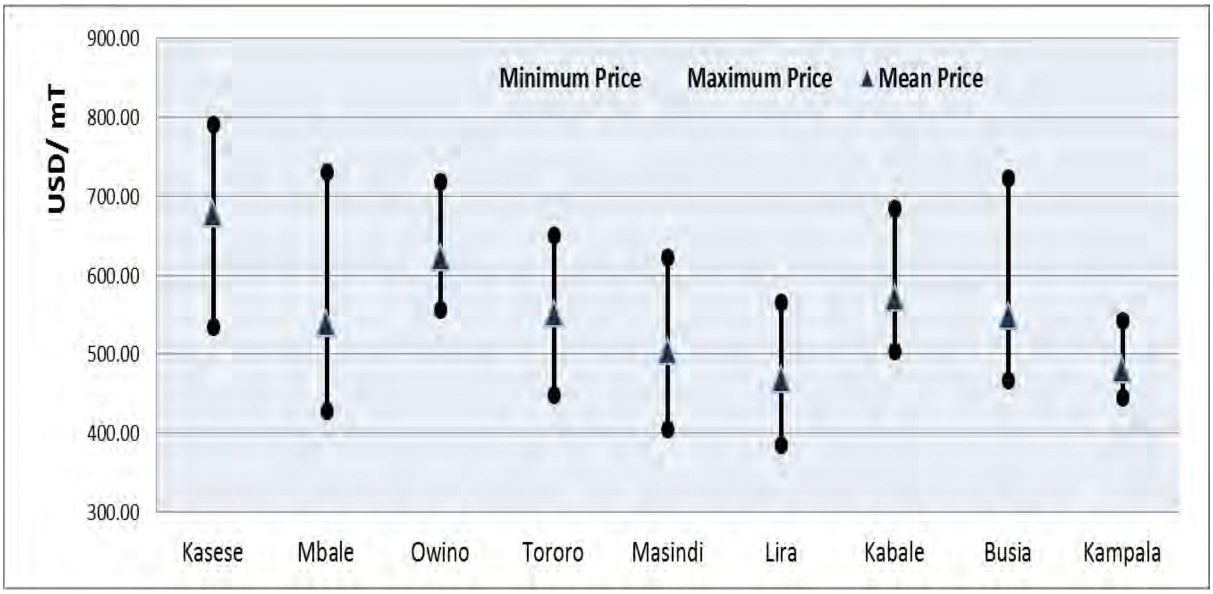
Table 19: Wholesale finger millet prices for Uganda for June 2009-Sep. 2013 (USD/mt)

Location	Market/City	Minimum Price	Maximum Price	Mean Price	Std.Dev
Border Ug-DRC	Kasese	535.0	792.0	677.8	99.0
Border UG-Ke	Mbale	428.0	731.0	539.8	82.1
Owino Market Kampala	Owino	557.0	718.0	622.5	49.0
Border UG-Ke	Tororo	448.0	650.0	551.1	62.6
West Uganda	Masindi	405.0	623.0	503.1	67.9
North Uganda	Lira	386.0	565.0	467.8	53.5
Border UG-Rw	Kabale	504.0	685.0	571.2	53.0
Border UG-Ke	Busia	467.0	724.0	548.9	72.1
	Kampala	446.0	542.0	480.8	25.0

Source: Ratin Net

The reason why prices in Kampala are lower than in other markets is a technical one: prices for the Kampala market have been collected only between 2009 and 2010 while prices in other markets included 2011/12, a season of power prices. Price volatility seems to be higher compared to sorghum, including highly price volatile markets alongside the borders, esp. with the Democratic Republic of Congo (DRC) and Rwanda, but less so at the Ugandan-Kenyan border with Tororo, Busia, and Mbale as market hubs.

Figure 2: Finger millet wholesale prices in Uganda between 2009–2013, USD/mt



Source: own calculations, based on price data from Ratin Net

Consumption: As shown in Table 20, average finger millet consumption per adult equivalent in Uganda is 28.86 kg per year (approximately 15 Kg per capita based on per capita/AE ratio of 2). High per capita consumption is found in the Capital Kampala (26.2 kg) and in the main production area in the country. There is a rural bias in consumption with 31 kg/ year compared to 18.75 kg/year for urban areas, but this bias is far less pronounced than for Sorghum. The same holds true for consumption in rural areas close and far from the finger millet areas. In summary, the consumption pattern for finger millet is more balanced across the country and, thus, stands in contrast with the uneven distribution of consumption for sorghum, with peak consumption in rural sorghum producing areas and almost none in the rest of the country.

Table 20: Consumption patterns for finger millet by sub-region (kg/AE//year)

Sub region	Total	Rural	Rural (Millet area)	Rural (non-Millet area)	Urban	Urban close to Millet area	Urban far from millet area
	Mean	Mean	Mean	Mean	Mean	Mean	Mean
National	**28.86**	**31.08**	**33.09**	**27.66**	**18.75**	**13.96**	**20.06**
Kampala	26.21				26.21		26.21
Central 1	7.93	8.95	21.65	5.86	1.97	0.00	1.99
Central 2	7.41	7.90	4.20	9.85	3.93	3.43	4.23
East Central	29.92	31.63	41.93	18.37	15.26	17.36	13.80
Eastern	55.56	59.76	67.03	37.28	9.48	10.52	8.07
Mid-Northern	45.59	46.93	51.88	28.62	32.52	44.57	18.31
North-East	1.48	1.57	1.57		0.00	0.00	
West Nile	11.82	12.76	12.76		4.40	4.65	0.00
Mid-Western	39.99	43.20	49.10	41.22	7.46	22.75	6.70
South-Western	57.69	59.16	46.31	10.26	34.87	34.01	35.94

Source: ICRISAT 2012

Richer households have a strong affinity for finger millet products (component in baby food, porridge). Income elasticity is positive (in contract to negative elasticity for Sorghum). On a national level, upper income households consume 31 kg/AE/year and low income households somewhat less at 27 kg/AE/year. The difference between low and upper income households is particularly high in Kampala (5.4 kg versus 30 kg) and in rural areas that are far from the major finger millet areas (e.g. Central 1, East Central, West Nile).

Consumption levels in production areas are less influenced by income with some regions show a positive (e.g. Mid Northern, South Western) and other regions (Eastern, Mid Western) even a negative trends with rising income[4].

[4] Food consumption figures are subject to a certain degree of inaccuracy and may show unusual or contradictory pattern in the data set.

Table 21: Consumption of finger millet by income group (kg/AE/year)

Income Group	National	Kam-pala	Central 1	Central 2	East Central	Eastern	Mid-Northern	North-East	West-Nile	Mid-Western	South Western
Consumpt ../AE (kg/y)	15.90	0.00	1.27	6.19	9.11	29.16	31.54	29.42	9.40	7.56	29.21
Low	27.2	5.37	6.66	7.48	18.41	53.31	38.89	1.73	5.84	70.17	49.03
Middle	28.43	12.03	6.68	7.66	30.04	61.77	37.74	0.66	13.57	29.24	56.99
Upper	31.33	30.47	9.35	7.35	45.09	51.92	86.1	0.58	16.83	27.32	61.02

Source: ICRISAT 2012

Table 22 shows the national finger millet consumption by region and sub region based on the unit consumption figures from Table 22 and population figures from UBOS (2012) at district level (respective adult equivalent). Initial calculation of aggregated consumption at 360,000 mt exceeds annual production of 276.935 mt by around 25% exceeds and, therefore has been adjusted accordingly by a common factor to match production (incl. external trade) while preserving the general pattern. Despite high urban and income preferences, 80% of Finger Millet is consumed in rural areas. Major urban consumption comes from the Central region with a higher level of urbanization and population density within Uganda. Kampala alone with its high AE intake of 26 kg per year accounts for 18,000 mt a year.

Table 22: Aggregate consumption and production by region and sub-region

	Production ('000 mt)	Production (Adult equivalent in kg)	Consumption ('000 mt)			Consumption (AE in kg)
			Total	Urban	Rural	Total
Region						
Central	13,735	2.97	37,650	22,897	14,753	8.14
Eastern	106,336	23.83	70,563	10,184	60,379	15.81
Northern	79,078	19.64	61,413	7,471	53,943	15.25
Western	77,786	18.08	106,459	8,028	98,431	24.74
Total	276,935	15.90	276,085	48,579	227,506	15.85
Sub Region						
Kampala	0	0.00	18,034	18,034	0	19.71
Central 1	2,380	1.27	9,629	2,348	7,281	5.12
Central 2	11,355	6.19	9,987	2,515	7,472	5.45
East Central	16,267	9.11	27,176	6,469	20,707	15.22
Eastern	49,043	29.16	43,187	3,715	39,473	25.68
Mid-Northern	56,803	31.54	58,007	7,265	50,742	32.21
North-East	48,513	29.42	200	0	200	0.12
West Nile	14,788	9.40	3,406	206	3,200	2.17
Mid-Western	16,734	7.56	63,179	1,579	61,600	28.54
South-Western	61,052	29.21	43,280	6,448	36,831	20.71
Total	276,935	15.90	276,085	48,579	227,506	15.85

Source: ICRISAT 2012, own calculations

Domestic Trade: The extent to which finger millet is traded within Uganda is described in Table 23. Around 45% of finger millet production from the surplus regions is in excess of local consumption and therefore traded with other sub-regions. In the deficit sub regions, around 47.6 % of consumption is sourced from other sub-regions while 52% comes from local supply. Assuming all production in the deficit regions stay in the region, the share of national production that is traded across other sub regions accounts for 30.58%. On the other hand, around 30.37% of national consumption has its origin from markets in other sub regions. In summary, as a result of a stronger divide between major production and consumption markets, Finger millet is traded more heavily than sorghum which remains largely a local crop produced and consumed within its local boundaries.

Table 23: Sub-regional trade matrix for finger millet

Sub Region	Destination of local production		Origin of local consumption	
	Consumed in the sub region	Traded with other sub regions	From the sub region	From other sub regions
Surplus Sub Regions	**54.16**	**45.84**		
Northeast	0.41	99.59		
South Western	70.89	29.11		
Eastern	88.06	11.94	%	
West Nile	23.03	76.97		
Central 2	87.95	12.05		
Deficit Sub Regions			**52.4**	**47.6**
Mid-Western			26.49	73.51
Kampala			0.00	100.00
East Central	%		59.86	40.14
Central 1			24.72	75.28
Mid Northern			97.92	2.08
Total Uganda	* Production Trade Share =30.58%		** Consumption Trade Share = 30.4%	

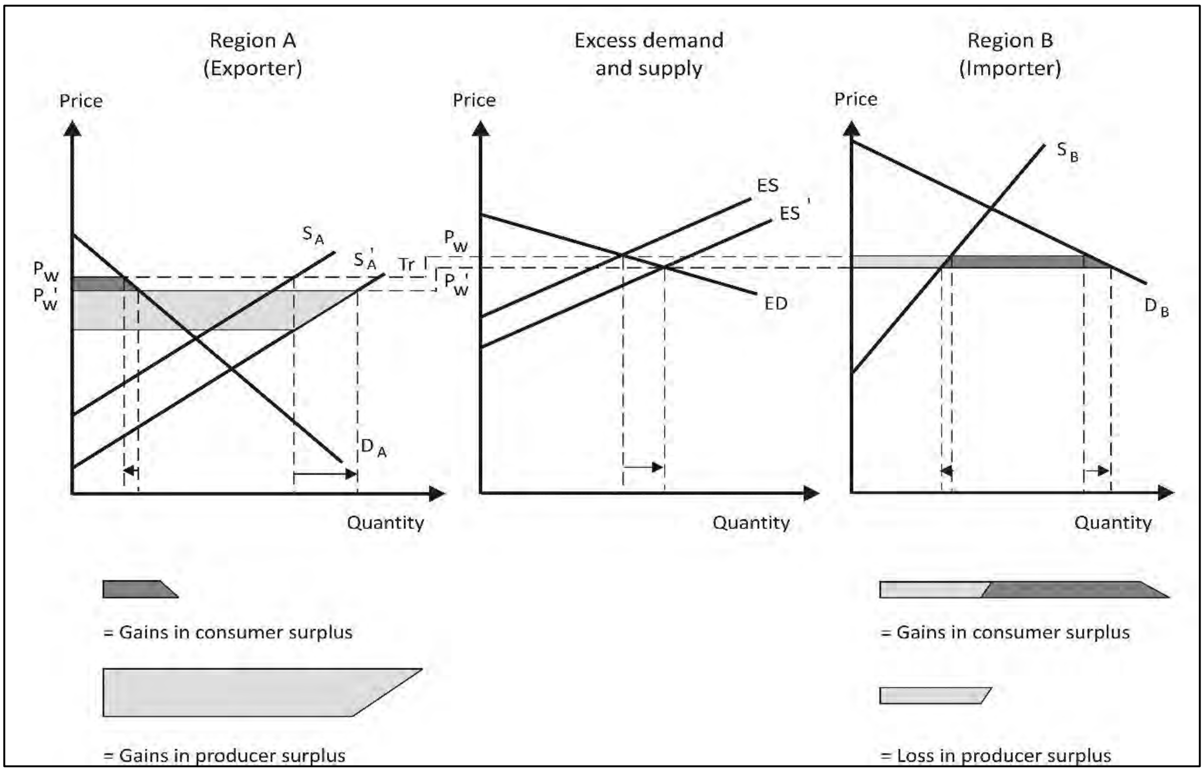
* Share of production that is traded with other sub regions;** Share of consumption that comes from other sub regions. Source: Own calculations

5. Research Impact Assessment: Analytical Framework and Data Elicitation

5.1. Methodological Framework

The economic effects from the introduction and use of improved varieties are commonly assessed through a cost-benefit analysis or economic surplus approach. The specific characteristics of the Ugandan markets with connected regional markets and price spill-overs suggest the application of an economic surplus framework similar to that of Davis, Oran, and Ryan (1987) and Alston et al. (1995) used in research evaluation. The impact analysis is carried out within the framework of a partial equilibrium multi-regional model where the economic gains are measured in terms of an increase in producer surplus (PS), consumer surplus (CS) and, in case government interventions are present, in terms of government surplus (GS), see Figure 3. Supply and demand curves are specified for different regions and shifted over time through research induced shifts on the supply side and other shift factors from e.g. exogenous growth. The analytical framework of the market model and the underlying algebra can be thoroughly studied in Alston et al. (1995) and other publications.

Figure 3: Two- market partial equilibrium model with price spill-over



Source: Modified, after Davis et al. (1987, p. 12)

The major specifications to be applied to the Ugandan markets for sorghum and finger millet can be summarised as follows:

- Linear demand and supply functions define a single commodity market framework with no linkages to other commodity markets via cross-price elasticities.
- Trading activities are basically restricted to the different regional markets within the country, while cross-border trade with neighbouring will be factored in for certain market scenarios and changes the set-up between a closed economy and an open market economy.
- Regional markets are fully interlinked via price spill-over effects. Sorghum and finger millet are traded in some quantities over long distances between producer and consumer markets. Thus, research induced changes in regional production and prices may affect prices and quantities in other regions.
- The dynamic elements of agricultural research are accounted for: the specific time profiles for technology generation and adoption, variable prices across regional markets, and multiple periods to aggregate annual economic gains over the simulation period and regions.

A standard software package for such a research impact study using the economic surplus concept is the 'DREAM' model. DREAM, or **D**ynamic **R**esearch **E**valuation for **M**anagement, is a stand-alone and menu-driven software package for evaluating the economic impacts of agricultural research and development (R&D). DREAM has been applied to the evaluation of individual projects in a national context as well as to entire commodity sectors at a sub-continental or continental scale. And while it was designed primarily to evaluate options for R&D that is yet to be undertaken (ex-ante assessments), DREAM has also been successfully applied to analysing the effect of past research (ex-post assessments). One of the major advantages is the flexible way of defining the market framework for the model builder. Markets can be specified with no restrictions on the number of markets and for any level: as regional markets for a country-level study or as national markets for an international study. It gives the analyst a great degree of freedom in deciding about the appropriate level of accuracy necessary to capture the spatial heterogeneity in technology adoption and profitability.

5.2. Eight-Stage Process for an Impact Assessment Workshop.

Organising an impact assessment workshop requires careful planning and strict time management. Expert-based data elicitation for a commodity or a project should be conducted within 2-3 full working days, not longer, as experts have a busy schedule and concentration in group work starts fading after 2 days. The composition of the expert group varies with the type of undertaking. For a crop breeding program a group of 5-8 experts suffice with probably 1-2 socio-economists, and the rest breeders and agronomists. To ensure good quality of information the workshop facilitator/impact analyst should build-in some cross-checks and validation procedures and join in the different working group in rotational manner. The key challenges are controlling the overly optimistic perspective of the experts with regard to varietal performance and the abstract and hypothetical nature of projecting the future market situation and performance of a variety that usually leads to a slow start, heavy discussions and doubts about successful completion of the tasks ahead.

Below is a short description of an eight-stage data elicitation process that deals with these challenges and has proven operational for such type of short brainstorming workshop.

1. Hand-outs and presentation

Prior to the workshop, the facilitator/analyst prepares hand-out material and a presentation in the office. The hand-outs contain all necessary commodity information such as prices, production, area cultivated and yields at the lowest administrative level possible, results from adoption and profitability studies and seed production. From experience the hand-outs are heavily used at any stage during group work. An administrative country map with district/sub-region names is important for defining homogenous impact zones and grouping and selecting districts. A presentation should be given at the beginning of the workshop introducing the workshop program, the set-up for group work, methodological background, and the hand-out material.

2. List of improved varieties

The list of varieties to be included depends on the scope of study, whether ex-post or ex-ante, institutional specific or countrywide, variety specific open-pollinating OPV or hybrids. In our case of a countrywide a combined ex-post/ex-ante perspective, the variety list is comprehensive and covers all major varieties (first generation, later generation and varieties still under development and testing.

3. **Impact area boundaries**

The impact area defines the locations and share of national production that will be subject to assessing the varietal performance and modelling the economic implications and market changes. Any production outside the impact areas are not omitted but treated in a different way, usually as a residual market in an impact model without presence of research-induced supply shifts. Depending on a commodity’s spread of production and presence of improved varieties across regions it may be necessary to declare all areas as impact region. When production is more clustered and improved varieties confined to certain areas, the impact zone can be limited and thus production in the impact zone becomes a fraction of national production. It is important to note that around 75% -90% of the impact zones’ production should be covered by selecting districts (or other lower-level units) and their compounded production volumes. The selection of districts is straight forward if the hand-out material contains a list of districts ranked in sequence of production or area planted.

4. **Homogeneous impact zonation**

Once the impact area is defined, the next step is to further structure the area into homogeneous impact zones HIZ with the idea to simply the assessment process by reducing the number of location specific impact parameters, such as adoption rate and profitability. The workshop in Uganda shows that experts are quite free in chosen the right approach for zonation. The Finger millet group decided for a zonation based on the administrative structure (North, West, East, Central region), but did the varietal assessment at the district level. The sorghum group choose the sub-regional level as zonation and assessment base. The facilitator/analyst should give the group(s) a free hand. Regardless of the assessment base or zonation, impact parameters can be converted in most instances into the appropriate model and market structure for the DREAM model.

5. Current adoption rates.

Probably the most difficult task is to manage and provide guidelines on assessing current and future adoption rates. Empirical evidence and systematic monitoring of varietal composition for major food crops is rare in national agricultural statistics. The bulk of information comes from adoption studies commissioned by research institutions, but reported adoption rates are not representative and usually confined to small sampling area. In the absence of sufficient hard evidence, seed production figures from the private and public seed sector can be helpful in providing an initial best-guess. That's the way the workshop was done in Ethiopia for Sorghum.

Clarification of the proper meaning of 'adoption rate' is necessary because the term is used in different way, sometimes as the percentage of HH using an improved variety, or share in area cultivated. In an impact study 'adoption rate' should always refer to the share of production as the method of impact assessment operates within a model based market framework with prices and quantities as parameters.

It is useful to define in the first instance a cumulative adoption rate for all improved varieties combined and for each impact zone and then proceed with the individual varieties. In many cases the sum of the individual adoption rates exceeds the prior set cumulative rate by a large margin. This way the cumulative acts a cross-check and benchmark for necessary downward adjustments in the individual adoption rates

6. Future adoption rates

If the planning horizon in the ex-ante study is too long and spans over 20-30 years, experts may find it hard to comprehend the circumstances and feel uneasy in providing an informed judgement about the spread of improved varieties for such a distant future. Therefore, it is advisable to shorten the look forward to 10 years in a first step which comes closer to what breeders and agronomists are familiar with as planning horizon. The experts should discuss the pros and cons, bottlenecks and pushing factors that drive or inhibit adoption rates and conclude the discussion with defining the cumulative adoption rate by zone in 10 years' time. The next steps are those as described under step 5. Once this task is completed, the core adoption information is ready and consists of current and future cumulative and individual adoption rates as shown in Table 24.

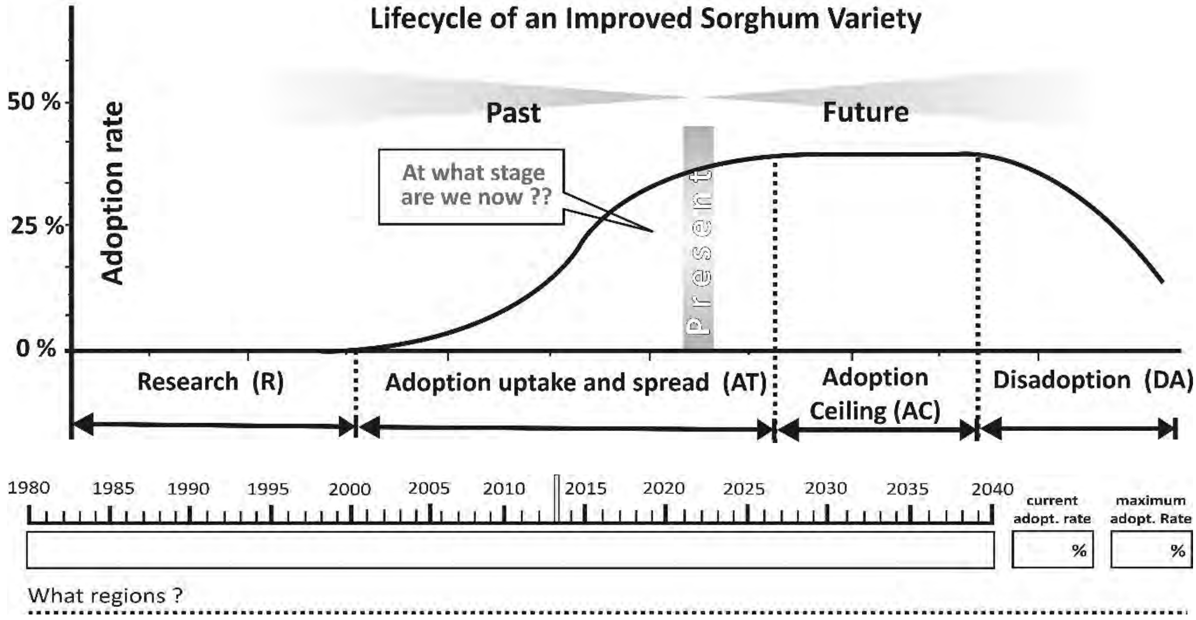
Table 24: Data sheet for current and future adoption rates

current adoption rates						
			Variety			
Zone (sub-region)	Cumulative rate (target)	Sum of Individual rates	Seso1	Seso 3	Sekedo	SRS 30 08/1
Teso	18	18	5	6	3	4
Karamoja	14	14	3	3	2	6
future adoption rates (10 years ahead)						
Teso	25	25	7	7	5	6
Karamoja	20	21	5	3	4	9

Source: own table.

The final step is to elicit the variety's remaining adoption parameters alongside the lifecycle of a variety as shown in Figure 4. These are: 1) year of release, number of years for adoption uptake (AT), 2) number of years at the maximum adoption level (AC), and eventually 3) beginning and speed of dis-adoption. In some cases, depending on the age of the variety, adoption rate in 10 years' time may not fall into the ceiling period (AC). Then the maximum adoption rate needs to be assessed in addition to the rate in 10 years.

Figure 4: Adoption information by variety



Source: own diagram.

7. Incremental profitability of improved over local varieties

Profitability is the second shift parameter that's drives the supply curve to the right making national production more cost efficient from better varieties. Local and improved varieties have a distinct expenditure and revenue structure that is analysed in a partial budget. The task of the experts is to develop partial crop budgets for local and improved varieties and calculate the differences on the revenue and cost side in absolute and relative terms.

Table 25 showcases a fictive example from Uganda with 'Edeidei' as the representative local variety that serves as benchmark to measure and compare the profitability of all improved varieties in that region (Teso). The level of accuracy applied to cost items and developing a partial budget that averages the profitability of the local variety mix in a given region needs to be discussed prior to start. As sorghum and finger millet are labour intensive crops enough attention should be given to the proper assessment and costing of family and hired labour use. Caution is necessary when it comes to yield. What should be measured is the potential yield at the farmers' field under normal production circumstances and not yields that have been attained on-station or in on-farm trials.

Another question arises with regard to agronomic practices and input intensity. They can be different between local and improved varieties as farmers may apply more modern inputs and labour to improved varieties. In a simple way the effects of agronomic practices on yield and profitability can be incorporated as model scenarios by defining a range of yield and costs effects, or experts can distinguish between input systems while developing the partial budgets.

Table 25: Partial budget to measure and compare profitability of improved varieties

Teso *		Local variety	Improved variety		Percentage increase over local variety	
	Unit	Edeidei	Seso 1	Epuripur	Seso 1	Epuripur
Yield	kg/ha	1,000	1,900	1,700	DREAM model '% revenue shifts'	
Price	USD/mt	250	260	350		
Revenues	USD/ha	250	494	595	**97.6**	**138.0**
Labour costs	USD/ha	120	140	180	DREAM model % 'cost shifts'	
Other costs	USD/ha	40	60	110		
Total costs	USD/ha	160	200	290	**25.0**	**81.3**
Gross margin	USD/ha	90	294	305		

*fictive numbers Source: own table

Assessment of adoption rates and profitability can run in parallel when even possible in order to safe time. Experts need be to divided and assigned to two different working groups. Dividing groups by variety is not advisable as it may inflict an assessment bias among varieties.

There is a methodological issue if prices for local and improved varieties differ. Improved varieties can achieve higher or lower market prices if they show a better quality (e.g. for brewing) or are inferior for human consumption (e.g. bad taste or colour). So, yields and/or prices act in the same way by driving revenues. The 'DREAM model' does not incorporate price differentials between both variety groups and asks only for percentage changes in yields and costs. Ignoring price differentials in the 'DREAM' model would underestimate or overestimate research gains. Therefore, instead of percentage yield changes we feed in the 'DREAM' model percentage revenue changes.

8. Research costs

Budgeting research costs has no limits in choosing tailor-made approach that suits the assessment case at hand and differs in almost every respects with other ways of doing it. Costs budgeting can be done at the workshop or assigned by the facilitator/analysts to the experts to be prepared prior or after the workshop. With a county-level exercise like this that takes account of the entire breeding program from the start to the distant future, only a simplified budget approach seems workable that ignores the complexity in the funding structure (e.g. multitude of donors and micro projects) and the time consuming task of reading out historic research budgets form the records.

The approach used in this study is a simple spreadsheet that accounts for the costs of the breeding program at an annual base, see Table 26. It includes the core budget from public funding and a donor component that supplements the budget in carrying out specific research projects. Costs figures are readily available from project funding proposals and the institutions budget department. The annual budget is a blend of real core budget figures plus a theoretical budget that reflects the scale of donor funding to carry out research at full scale.

Table 26: Annual research budget for sorghum and finger millet

Cost item	USD/year
1. Casual Labour	28,800
2.Salaries-Scientist	45,000
(I breeder. 0.1 Socio Economist, 0.4 agronomist, 0.5 entomolgy, 0.4 pathology, 0.1)	
3. Technicians	16,800
Human resource costs	90,600
4. Field and laboratory supplies	24,000
5. Office supplies	5,000
6. Vehicle	8,000
7. Vehicle maintenance/operation	3,000
Sub-total	40,000
8. Domestic Travel	16,000
9. International Travel	12,000
9. Meeting and training costs	15,000
Sub-total travel/training	43,000
10. Communications	5,000
11. Equipment	2,550
12. Statutory Variety Release	500
13. Overheads	10,000
Total	**191,650**
Source: data from the workshop	

The research budget for sorghum and finger millet which was set up by the workshop participants amounts to 200,000 USD/year based on the assumption that staff, equipment and maintenance costs are fairly similar for each crop breeding program. In a next step, the annual budget is then converted to any previous years by using the annual consumer price index provided by the IMF as deflator.

Table 27: Deflated research costs based on historic inflation rates (CPI), in USD

Year	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**
Inflation rate	14.00	18.70	9.40	14.20	7.30	6.80	6.60	7.98	5.01	5.68	-2.02
Deflated research costs	191,650	168,114	141,629	129,460	113,363	105,650	98,923	92,799	85,938	81,838	77,437
Year	**2001**	**2000**	**1999**	**1998**	**1997**	**1996**	**1995**	**1994**	**1993**	**1992**	**1991**
Inflation rate	4.50	5.84	0.21	5.83	7.73	7.52	6.79	5.85	29.97	42.25	20.82
Deflated research costs	79,037	75,633	71,457	71,306	67,375	62,541	58,169	54,472	51,462	39,595	27,835
Year	**1990**	**1989**	**1988**	**1987**	**1986**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**
Inflation rate	45.40	130.80	166.70	215.40	143.80	100.00	16.71	150.00	100.00	100.00	99.20
Deflated research costs	23,039	23,039	23,039	23,039	23,039	23,039	23,039	23,039	23,039	23,039	23,039

Source: http://www.indexmundi.com/uganda/inflation_rate_%28consumer_prices%29.html, based on data from the International Monetary Fund - 2011 World Economic Outlook

Table 27 shows inflation rates and the annual deflated research budget for Uganda between 1980 and 2012. Between 1980 and 1990 the country experienced a period of hyperinflation with rates above 100% annually which would have eroded the budget and brought down close to zero. Therefore, the budget during that period was kept flat at around 23,000 USD/year.

Each variety in the list is then allocated an equal share from the annual budget. Costs that incurred in years with no reported research activities are partially attributed to the following research period with the justification that those years serve as preparation and baseline research for the next program stage.

This approach takes account of what is known from the impact literature as the notion of '**probability of research success'**. The probability of research success takes note of the possible failure of generating useful outputs with consequent sunk costs and reduced potential impacts. Mathematically, it enters the impact model as a discounting factor in the product of adoption rates and yield shifts. In this study, all research costs are accounted for, in the budget in Table 26 regardless of the varietal success. This implies that costs incurred in developing varieties that never made it to the market are fully accounted for as sunk costs and attributed to the varieties that were being released and propagated.

6. Impact Analysis for Sorghum

6.1. Defining the Varieties, Impact Zones and Performance Parameters

The Sorghum experts at the workshop in Soroti, Uganda developed a homogenous impact zonation that consists of 5 sub-regions as outlined in Table 28. In a next step the districts are selected mainly based on production volume and Uganda's agro-ecological diversity.

Table 28: Sub-regions as homogenous impact zones for sorghum

Teso sub-region	Karamoja sub-region	Northern sub-region (excl. Karamoja)	West Nile sub-region	South-West Highland sub-region
Districts	Districts	Districts	Districts	Districts
Amuria	Kaabong	Amuru	Arua	Kabale
Bukedea	Kotido	Gulu	Nyadri	Ntungamo
Kaberamaido	Moroto	Kitgum	Yumbe	
Katakwi	Nakapirit	Lira		
Kumi		Pader		
Ngora				
Serere				
Soroti				

Source: own table

Table 29: Key Indicators of sorghum target sub-regions

	Population (Proj.2012)	Number of HHs	Population (AE)	Rural AE	Urban AE	Cereal Production in Season 2008/09 (mt)		
						Sorghum	Finger Millet	Maize
Teso	1,847,800	329,964	920,732	615,049	305,683	114,817	63,427	221,447
Karamoja	926,100	178,096	467,823	397,650	70,173	108,195	6,725	15,787
Northern	1,457,900	280,365	736,464	625,994	110,470	83,802	35,390	59,395
West Nile	1,521,500	292,596	768,592	653,303	115,289	19,970	12,325	69,583
South-West Highlands	1,232,700	241,706	625,027	551,899	73,128	44,762	20,216	76,156
Subtotal	6,986,000	1,322,728	3,518,638	2,843,895	674,743	371,546	138,083	442,368
% share of national level	20.5	19.1	20.2	23.1	13.2	85.4	49.9	18.7

Source: own calculations AE= Adult Equivalent

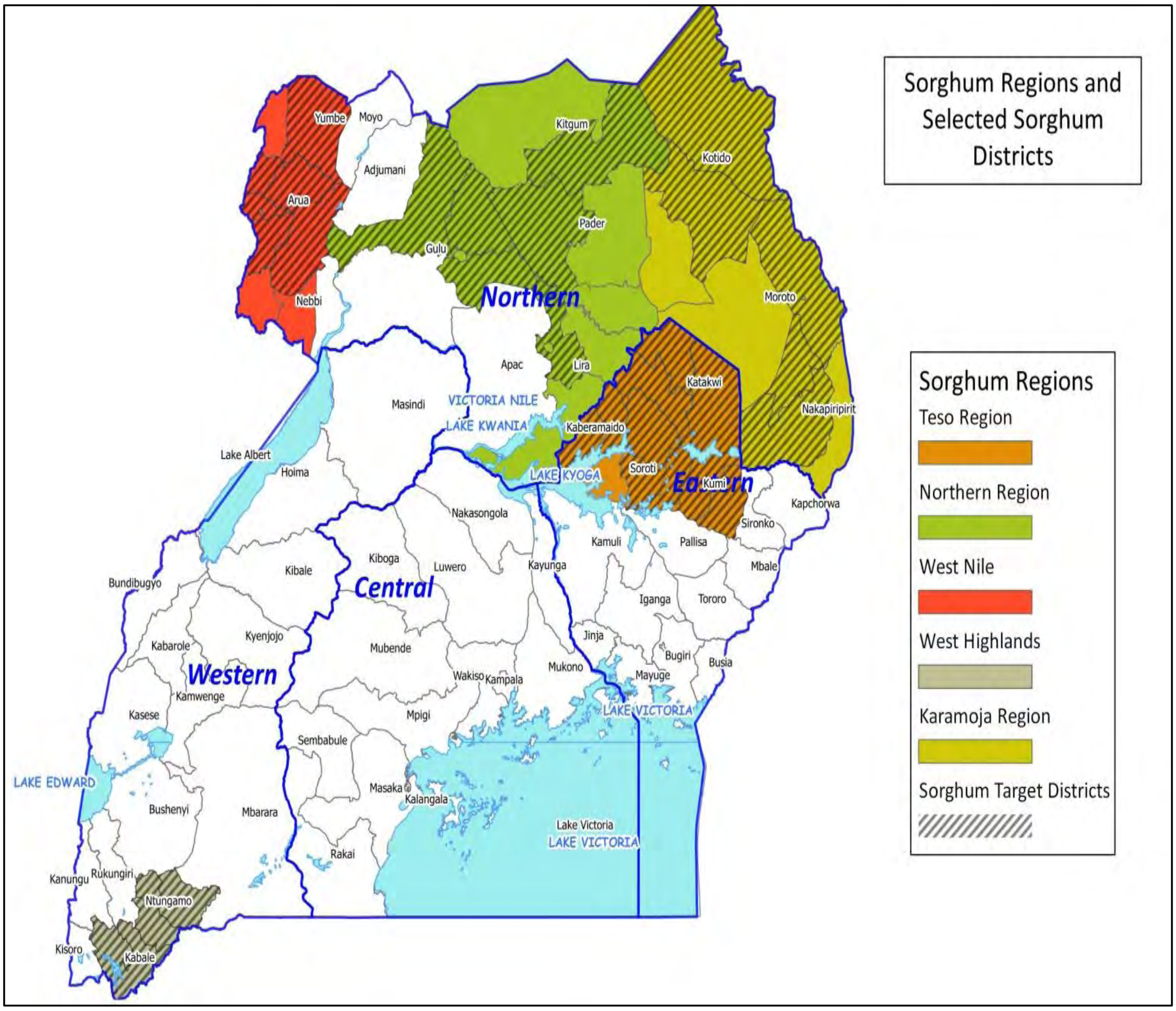
Table 29 provides a demographic and sector overview of the regions and aggregated over the 22 districts. In terms of production, about 85 % of national sorghum production is covered. It also comprises around 50 % of finger millet production. The maize share is low, only 20 % of national production is grown in these districts a consequence of severe drought that is not suitable for many local maize varieties. The consumption share is 76 % (Table 30) as sorghum is to a large extent consumed locally in the producing areas.

Table 30: Production and consumption of sorghum in the target sub-regions

	Consumption (mt) Rural	Consumption (mt) Urban	Consumption (mt) Total	Production (ha)	Production * (mt)	Surplus/ Deficit (mt)
Teso	96,154	5,563	101,718	78,910	114,817	13,099
Karamoja	71,812	421	72,232	116,582	108,195	35,963
Northern	101,002	5,634	106,636	82,805	83,802	-22,834
West Nile	54,287	4,711	58,997	16,450	19,970	-39,027
South-West Highlands	8,594	130	8,724	28,660	44,762	36,038
Subtotal	331,850	16,458	348,308	323,407	371,546	**23,238**
% share of national level	78.2	48.1	75.9	81	85.4	

*(2008/09). Source own calculations.

Map 2: Sorghum regions and districts



Source: own map, based on administrative layers from http://www.diva-gis.org/

List of improved sorghum varieties for assessment.

Sorghum experts at the workshop developed a list of sorghum varieties that includes all relevant varieties from the start of the Ugandan breeding program until now (Table 31). Relevant varieties are those that have been adopted at a commercially relevant level and with proper seed multiplication and maintenance in place. A few varieties (e.g. Serena) were dropped from the list as they were not considered as commercially important enough. The institution in charge of breeding of dryland cereals is the National Semi-Arid Resources Research Institute (NaSARRI, Serere). The NARO's Serere Research Institute actively engages in plant breeding for crop varieties suitable for semi-arid areas and is thus the appropriate source of foundation seed for Sorghum. NaSARRI together with Makerere University College of Agricultural and Environmental Sciences are the leading institutions in Uganda as private breeders are not particularly engaged in Sorghum and Finger Millet.

Epuripur had been released in 1995 by Serere Agricultural and Animal Production Research Institute (SAARI). Different spelling versions exits in the literature: Epurpur, Epuripur, or Epuripuri. Its development was through pure line selection from a cross 2kx 17/B/1 made in the 1970s Seed multiplication (EBIYAU, J. et al. 2005). Epuripur has proved to be adaptable to local conditions. Farmers can easily exploit the advantages of Epuripur as it is early maturing drought resistant and high yielding (two to three times compared to local varieties). Epuripur is also used by the animal and chicken feed industries in Uganda who use off types of the grain separated during the sorting. The sorghum grains have high level of proteins required in the feed industry. The grains are high in sugar and starch content, making it suitable for food and a substitute in the brewing industry. In terms of physical appearance, the local variety is small with brown seeds, while the Epuripur sorghum is white with big seeds.

Epuripur sorghum variety was found to possess excellent brewing qualities. In order to rapidly grow Epuripur in Uganda, SAARI, NGOs together with seed companies like FICA and AFRO- KAI Ltd. and the Nile Breweries Limited (NBL) established a partnership in 2002 with embarked on the multiplication of Epuripur foundation seed, contracting Epuripur farmers/groups, and supervision of farming operations and marketing of the crop to Nile Breweries Limited.

Sekedo is a dwarf variety (100 cm) with brown-red seeds. It has been developed in Serere district under the National Agricultural Research Organisation (NARO) and released in 1995 together with Epuripur. It is tolerant to stem borers and moderately resistant to shoot fly. It is recommended for food and feeds. It matures in 100 days with good management, a farmer can harvest up to 4 - 5 tons per ha. Sekedo sorghum is drought resistant and can be used in all parts of Uganda. Sekedo sorghum is being promoted in the semi - arid region of Karamoja. This region faces particular food shortages and farmers there are also struggling with changing rainfall patterns. Uganda National Farmers federation promotes Sekedo alongside other water efficient and drought resistant crop varieties.

More recently in 2011, NaSARRI released three more sorghum varieties (information from NaSARRI Web Page).

Table 31: List of improved sorghum varieties

Variety name	Start of research	Year of release	Breeding institution	Positive traits	Negative traits	Use
Old improved varieties						
EPURIPUR	1980	1995	NaSARRI	early maturing,drought tolerant, high yielding	Highly susceptible to bird damage	brewing, food consumption, livestock feed
SEKEDO	1980	1995	NaSARRI	early maturing,drought tolerant, high yielding	high tannin levels, susceptible to midge damage	food consumption, livestock feed
New Improved varieties						
SESO 1	1998	2011	NaSARRI	early maturing,drought tolerant, high yielding	Highly susceptible to bird damage	brewing, food consumption, livestock feed
SESO 2	1998	2011	NaSARRI	early maturing,drought tolerant, high yielding	Highly susceptible to bird damage	brewing, food consumption, livestock feed
SESO 3	1998	2011	NaSARRI	early maturing,drought tolerant, high yielding	high tannin levels	food consumption, livestock feed
Varieties under development and testing						
GA 010/010	2009	2016	NaSARRI	high yielding, drought and striga tolerance, mid-early maturing	susceptible to midge	food consumption, forage
SRS 30 08/1	2009	2016	NaSARRI	high yielding, drought and striga tolerance, early maturing	susceptible to midge	food consumption
GE 23/1	2009	2016	NaSARRI	high yielding, drought and striga resistant, earling maturing	susceptible to midge	food consumption
SRS 347 08/4	2009	2016	NaSARRI	high yielding, drought and striga resistant, earling maturing	susceptible to midge	food consumption
SRS 11 08/3	2009	2016	NaSARRI	high yielding, drought and striga resistant, earling maturing	susceptible to midge	food consumption
Local varieties for benchmarking						
EDEIDEI				early maturing, long shelf life	low yields	food consumption and animal feed
EKIRIKIR				mid-early maturing, long shelf life	low yields	brewing and food consumption
ABIR				long shelf life, high yielding, resistant to stem borers	late maturity, very tall/difficult to harvest	food consumption, livestock feed,
GODOO				long shelf life, high yielding, resistant to stem borers	late maturity, very tall/difficult to harvest	food consumption

Source: own table, based on workshop results

SESO 1 is white seeded. It is high yielding with a potential of 1760 -2205 kg/ha. It is tolerant to Striga weed and the sorghum shoot fly pest. Seso 1 has low tannin content (0.01%), making it have good (67.1%) brewing qualities, making it suitable also for Lager Beer production It is drought tolerant and matures within 90 days).

SESO 2 is white seeded. It is high yielding (1736 -2137) Kg/Ha, tolerant to Striga weed and sorghum shoot fly pest. It has low tannin content (0.01%) making it to have good (69.6%)

brewing qualities. It is therefore suitable for Lager Beer production. It is also drought tolerant and matures within 100 days.

SESO 3 is a brown seeded variety. It is high yielding (2188 -2569) Kg/Ha, resistant to sorghum shoot fly pest and striga weed. It has higher tannin content making it suitable for food (atap) and local brewing. It is early maturing (within 85 days) and tolerant to drought.

Adoption and profitability estimates

Table 32 summarizes the experts' assessment of the current and future adoption levels on aggregate and by individual variety. In the absence of exact data from national agricultural statistics experts examined the current volume in seed production and combined it with their field experience from the major sorghum growing area. They arrived at the conclusion that the production share from improved varieties in the Teso and Northern sub-region stands already high at 40 % but is lower proportion in the Karamoja and Western sub-region. The two most widespread varieties are Epuripur and Sekedo but experts forecast a decline within the next year and a partial replacement by Seso 1-3 and the 5 varieties currently under development. Experts are cautious about the varieties under development and expect a slow start and low rates for the first 10 years.

Table 32: Current and future adoption rates by variety and sub-region

		Seso 1	Seso 2	Seso 3	Epuri-puri	Sekedo	GA 10/ 010	SRS 30 08/1	SRS 34708/	SRS 1108/3	GE 23/1
	Cumulative adoption rate	Current adoption rate in % of production (year 2013)									
Teso	44.0	10.0	2.0	8.0	14.0	10.0	0.0	0.0	0.0	0.0	0.0
Karamoja	12.0	0.0	0.0	2.0	1.0	9.0	0.0	0.0	0.0	0.0	0.0
Northern	45.0	10.0	3.0	9.0	18.0	5.0	0.0	0.0	0.0	0.0	0.0
West Nile	5.0	1.0	0.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0
	Cumulative adoption rate	Future adoption rate in % of production (year 2023)									
Teso	60.0	15.0	5.0	12.0	6.0	7.0	3.0	3.0	3.0	3.0	3.0
Karamoja	31.0	5.0	1.0	7.0	1.0	7.0	2.0	2.0	2.0	2.0	2.0
Northern	61.0	15.0	5.0	12.0	10.0	4.0	3.0	3.0	3.0	3.0	3.0
West Nile	10.0	2.0	0.0	1.0	0.0	2.0	1.0	1.0	1.0	1.0	1.0

Source: own calculations from workshop data

On aggregated level, the share of improved varieties is forecast to rise further from 40 % to 60 % based on the following assumptions:

- Improved drought tolerance and seed availability, strong market demand from the Nile Breweries
- Improved security and area expansion in the region, ambitious sorghum breeding program by Agricultural Research Institutes (NaBWIN-ZARDI) coupled with good extension services and strong farmers groups.
- Changes in lifestyle from pastoralism to crop production in the sorghum regions
- Greater importance of sorghum in the national food security strategy

- Emergence of a seed company operating in the West Nile region and presence of zonal Agricultural Research Abi –ZARDI

Yields and profitability

Profitability comparisons between local and improved varieties are presented in Table 33. Yield differences between local and improved varieties are significant. Inquiring about the reasons, experts point at the genetic factor rather than at different agronomic practices in the field that makes it possible to harvest 2 tons/ha of sorghum even in a low-input system. Production costs are slightly higher for improved varieties due to higher seed costs and more hired labour. Better yields turn negative gross margins found in local varieties (except in the West Nile region) into positive margins between 100 and 400 USD/ha depending on the variety and region.

Table 33: Yields and profitability of improved and local sorghum varieties by sub-region

Region	local variety		Improved varieties									
			Seso1	Seso2	Seso3	EPUR-IPURI	Sekedo	GA 010/010	SRS 30 08/1	SRS 34708/	SRS11 08/3	GE 23/1
mt/ha			Yields									
Teso	Edeidei 1,037.8		1,977	1,977	1,977	2,076	2,470	2,076	2,076	2,076	2,076	2,076
Karamoja	Ekirikir 864.9		1,112	1,112	1,112	1,112	1,236	1,112	1,112	1,112	1,112	1,112
Northern	Abir 988.4		1,730	1,730	1,730	1,298	2,018	1,298	1,298	1,298	1,298	1,298
West Nile	Godoo 741.3		1,223	1,223	1,223	1,112	1,236	1,112	1,112	1,112	1,112	1,112
Profitability: revenues and costs in USD/ha												
Teso	Revenue	119	494	494	494	519	618	519	519	519	519	519
	Costs	279	342	342	342	369	375	369	369	369	369	369
Karamoja	Revenue	303	389	389	389	389	432	389	389	389	389	389
	Costs	301	334	334	334	346	334	346	346	346	346	346
Northern	Revenue	297	519	519	519	389	605	389	389	389	389	389
	Costs	265	287	287	287	320	297	320	320	320	320	320
West Nile	Revenue	556	917	917	917	834	927	834	834	834	834	834
	Costs	307	421	421	421	400	400	400	400	400	400	400

Source: own calculations from workshop data

DREAM model set-up

The market structure in the dream model is captured in Table 34. Markets are the four impact sub-regions Teso, Karamoja, Northern and West Nile sub-region. The South- West Highlands were initially considered as impact region but dropped later after discussion and conclusion that it remains basically under local varieties for the next 10 years. However, the South-West Highlands were kept as stand-alone market in the 'DREAM' but without research induced supply shifts. All unaccounted sorghum production from the impact and non-impact sub-regions is subsumed under 'Rest of Uganda'. Two separate markets account for cross-border trade assuming a structural trade deficit of around 50,000 mt/year which is composed of 55,000 mt/year in imports and 5,000 mt/year in exports. Market prices are calculated as 2-year average prices from the RATIN NET's weekly price data. No own-price elasticity coefficients for sorghum are found in the literature. Therefore, coefficients are taken from an Ethiopian study (Schipmann 2012) assuming similar responsiveness to prices in Uganda. Exogenous supply and demand growth are set at zero as no long-term trend in production is visible.

Table 34: 'DREAM' model configuration

Region	Supply (2008/09)	Demand	Surplus / Deficit	Price level	Elasticities		Discount rate %	Exogen. growth %
	(mt)	(mt)	(mt)	USD/mt	Supply	Demand		Supply /demand
Teso	114,817	101,718	13,099	320.00	0.50	-0.66	5.00	0.0
Karamoja	108,195	72,232	35,963	266.43	0.50	-0.66	5.00	0.0
Northern	83,802	106,636	-22,834	247.85	0.50	-0.66	5.00	0.0
West Nile	19,970	58,997	-39,027	312.10	0.50	-0.66	5.00	0.0
South-West Highlands	44,762	8,724	36,038	347.14	0.50	-0.66	5.00	0.0
Rest of Uganda	36,792	110,030	-73,238	437.96	0.50	-0.66	5.00	0.0
Total Uganda	408,338	458,338	-50,000					
RoW Imports	55,000		55,000	278.00	1.00		5.00	0.0
Row Exports		5,000	-5,000	257.00		1.00	5.00	0.0
Total Uganda &Trade	463,338	463,338	0					

Source: own calculations.

6.2. Baseline Model Results for Sorghum

The economic impact from improved sorghum varieties accounts for around USD 125 Mio. over the entire period from first release in 1996 until 2030. On an annual base, this translates into USD 3.6 Mio. Less than one-third of the benefits goes to consumers in terms of lower prices and increased consumption, while sorghum growers capture the main share (USD 76 Mio, USD 2.3 Mio./year) due to the superior profitability of the improved varieties. Table 35 summarizes the economic surplus and the Internal Rate of Return IRR by variety. The IRRs vary within a range of 28.3% and 59.8. Seso 1, Epuripur, Sekedo and the 'new' varieties show similar IRRs despite distinct levels of research costs, yield gains and adoption level cycles. Seso 2 is the least attractive variety with an IRR of 28.3% due its low adoption rate and rather pessimistic adoption outlook. As a matured variety being on the market since 1996, Sekedo shows the highest IRR based on satisfactory yield performance.

Examination of the flow of benefits by region (Table 36) shows a clear trend towards the major sorghum producing Teso and Northern regions which is driven by significant surplus gains for producers. The Teso sub-region stands out as the biggest beneficiary as most of the improved varieties are suited to the Teso region, perform well and enjoy positive adoption prospects. Other sorghum areas follow by a large margin.as a result of lower adoption rates.

Sorghum growers of local varieties (non-adopters) are estimated to incur net losses in the Southern Highlands, Rest of Uganda, and Karamoja) at a magnitude of USD 10 Mio and above as a result of price pressure coming from the major adopting regions and their expansion in production and cross-regional trade. The South –West Highlands suffer most with a total loss of USD 4 Mio. as a consequence of no adoption, low market prices and low consumption.

Table 35: Economic surplus by sorghum variety

Base Run	Economic Surplus ('000 USD)			('000 USD)		
Varieties	PS	CS	TS	Research Costs	TS - Costs	IRR %
Seso 1	18,261	11,886	30,146	292	29,854	46.7
Seso 2	5,849	3,848	9,696	292	9,404	28.3
Seso 3	14,903	9,793	24,696	292	24,404	35.5
Epuripur	6,741	4,099	10,840	78	10,762	51.0
Sekedo	13,839	8,836	22,674	87	22,587	59.8
Any variety under development	3,410	2,090	5,500	218	5,282	42.8
All five varieties under development combined	17,051	10,452	27,502	1,090	26,412	42.8
Total Uganda	76,642	48,913	125,555	2,132	123,423	
Economic surplus/year	2,254	1,439	3,693		3,630	
Source: own calculations						

Table 36: Economic surplus for sorghum by region

Base Run	Economic Surplus ('000 USD)				('000 USD)	
Regions	PS	CS	TS	% of TS	Research Costs	TS - Costs
Teso	70,926	10,853	81,779	65.1	2,132	79,647
Karamoja	-2,529	7,714	5,184	4.1	0	5,184
Northern	17,860	11,391	29,251	23.3	0	29,251
West Nile	-961	6,295	5,334	4.2	0	5,334
Rest of Uganda	-3,905	11,731	7,826	6.2	0	7,826
South-West Highlands	-4,749	930	-3,819	-3.0	0	-3,819
Total Uganda	76,642	48,913	125,555	100.0	2,132	123,423
Source: own calculations						

How much of the impact is ex-post and how much is expected for the future until the year 2030 can be studied from Table 37. 20% (USD 25 Mio.) of the total research benefits fall into the period from 1996 until 2013, while the remaining gains of USD 100 Mio. fall into the future. The release of the 5 new varieties in 2116 has the potential to add USD 27 Mio. and over USD 50 Mio. can be generated with strong adoption performance (10-15 %) in the Teso and Karamoja sub-regions from Seso 1+3. So far, past research gains came exclusively from Sekedo variety (USD 17 Mio.) and Epuripur (USD 7.8 Mio).

These results underpin the long-term nature of the breeding program for dryland cereals in generating returns to investments as the varietal development and use by farmers takes considerable time. With 80 % (over USD 100 Mio.) of the economic potentials lie ahead, that is over USD 5 Mio. a year for the next 17 years, all concerned institutions in the Sorghum sector should ensure varieties can develop their full potentials in terms of widespread use and yield superiority.

Table 37: Past and future impact from sorghum

	Economic Surplus ('000 USD)								
by Region	Past Surplus	Past Surplus in % of Total	Future Surplus	Total Surplus	**by Variety**	Past Surplus	Past Surplus in % of Total	Future Surplus	Total Surplus
Teso	17,026	**20.8**	64,753	81,779	Seso 1	174	**0.6**	29,972	30,146
Karamoja	1,801	**34.7**	3,383	5,184	Seso 2	57	**0.6**	9,640	9,696
Northern	4,412	**15.1**	24,839	29,251	Seso 3	143	**0.6**	24,553	24,696
West Nile	1,080	**20.2**	4,254	5,334	Epuripur	7,834	**72.3**	3,006	10,840
Rest of Uganda	1,551	**19.8**	6,275	7,826	Sekedo	16,903	**74.5**	5,771	22,674
Southern Highlands	-759	**19.9**	-3,060	- 3,819	New Varieties	-	**0.0**	27,502	27,502
Total Uganda	25,111	20.0	100,445	125,555	Total Uganda	25,111	20.0	100,445	125,555
TS / year	1,477		5,909	3,693					
Source: own calculations									

6.3. Modelling Scenarios and Results for Sorghum

A set of sensitivity analyses/scenarios are carried out to test the robustness of model results with regard to certain impact parameters and value ranges. This way part of the uncertainty surrounded in the experts' assumptions and assessment can be treated and simulated. In addition, model scenarios can incorporate different assumptions regarding the market environment in which a commodity is produced and traded and conduct a comparative analysis based on their economic and distributional consequences. Here two sets of scenarios are developed which correspond directly to ICRISAT's areas of interventions (Table 38).

One set of scenarios tests different adoption and yield levels that are attainable from the genetic potential of improved varieties, better agronomic practices and promotion of improved varieties. The second set comprises market and trade scenarios for the domestic markets and trade with neighbouring countries which are related and part of ICRISAT's IMOD strategy and impact chains.

Table 38: Linking ICRISAT's areas of interventions with model scenarios

ICRISAT	Breeding & Agronomy		IMOD Strategy (Inclusive Market Oriented Development)		
Research Outcome	Development of superior germplasm	Exploit genetic yield potential	Up-scale spread of improved varieties across locations	Improve market linkages and efficiency	Improve demand from foreign markets
Promoting activities	draught & disease resistance, high yielding, specialised Var.	Agronomic best-practise and modern inputs	e.g. seed multiplication and quality	Linking poor farmers with markets, product innovations.	Specialised varieties with high foreign demand (for brewing)
DREAM model scenarios					
Scenario type	Base Run (0)	Adoption and yields		Markets and trade	
Model parameters		Variation in the yield effects	Variation in the future adoption rates	Variation in domestic price elasticity	Variation of price elasticity in markets for cross-border trade

Source: own table

Markets and trade scenarios

Four different market scenarios are tested in addition to the status-quo (Table 39). Each scenario is defined by a set of price elasticity parameters for the domestic market and for cross-border trade.

- The status quo (scenario 0) for the base run is characterized by relatively low price elasticity of demand (η_p) which reflects the inferiority of sorghum by consumers and low responsiveness of sorghum production (ε_p) to price changes. Trade elasticities are defined at value 1,-1, approx. two times the value of (ε_p) or (η_p).
- Scenario 1 depicts a situation with a deteriorating market situation: sorghum becomes even more inferior to consumers (η_p at -0.2), e.g. quality problem, contamination, alternative cereals cheaper and farmers become less responsive to changing sorghum prices (e.g. difficult access to markets and inputs) (ε_p= 0.2).
- Scenario 2 portrays an improved market situation: preference for sorghum products strengthen (η_p at -1.5) and production becomes more price responsive (ε_p= 1.5)., e.g. from a shift in relative cereal prices in favour of sorghum, better market linkages of farmers, higher share in market sales and less home consumption.
- Scenario 3 assumes the status-quo in the domestic market but takes account of enhanced cross-border trade, e.g. between Uganda and its neighbouring countries such as Ruanda, South Sudan, and Kenya. Underlying reasons can be extreme market situation in the trading countries, improvement in physical and regulatory trading environment, or specialised varieties with high foreign demand. Import (ε_{im}) and export elasticity (η_{ex}) are set at 10, resp. -10.

- Scenario 4 combines enhanced cross-border trade (scenario 3) with an improved domestic market (scenario 2), an ideal open market situation with highly integrated domestic and foreign markets.

Table 39: Configuration of price elasticity parameters for the different scenarios

	Trade regime	Status Quo market framework (0)	Low domestic market integration (1)	High domestic market integration (2)	Liberalized cross-border trade (3)	Liberalized cross-border & domestic trade (4)
Domestic Market	(ε_p)	0.5	0.2	1.5	0.5	1.5
	(η_p)	-0.66	-0.2	-1.5	-0.66	-1.5
Foreign Markets	(ε_{im})	1	1	1	10	10
	(η_{ex})	-1	-1	-1	-10	-10

Source: own table:

Scenario model results

Inspection of modelling results from Table 40 shows that changes in the market framework has little effect on the overall welfare. The difference in economic surplus between the least (trade 1) and most favourable scenario (trade 2) is only around 9 %. Interesting to note is the price dynamic in the domestic market and its effects on consumer surplus in combination with liberalized cross-border trade that seem to offset some of the negative consequences of cross-border trade in the 'Trade 1' scenario.

Table 40: Market & trade scenarios for sorghum: economic surplus

	Base Run	Low	High	Trade 1	Trade 2	
Economic Surplus (in '000 USD)	Status Quo market framework	Low domestic market integration	High domestic market integration	Liberalized cross-border trade	Liberalized cross-border & domestic trade	Variability in %*
Total Surplus	125,555	128,886	133,845	122,964	131,917	8.8
Producer Surplus	76,642	80,751	70,096	98,984	87,508	41.2
Consumer Surplus	48,913	48,135	63,750	23,980	44,409	165.8

* highest-lowest)/lowest value Source: own calculations

The effects on the consumer side are mostly price driven. In a closed economy case with no or little cross border trade and in markets with a low price elasticity, domestic prices drop sharply from a research induced supply shift, and is benefitting consumers particularly by lower market prices. On the other hand, an open market economy with regular cross-border trade and price responsive domestic markets help reduce price volatility and stabilize prices at a higher level as imports and exports set in and ease market pressure. The price stabilisation effects from cross-border trade and integrated domestic markets should not be underestimated in its long-term positive influence on sector development and technology adoption. It can ease up the intrinsic trade-offs between technology-driven expansion in production and enormous pressure on market prices that comes along with low-capacity and disintegrated local markets. Farmers who experience depressed prices from time to time may be discouraged to take risks in opting for improved varieties and high expenditures on modern inputs.

In contract to total benefits the distributional effects of the markets& trade scenarios between producers and consumers are much more pronounced showing the highest volatility on the consumer side (166 %), and much lower (41 %) on the producer side. Consumers' welfare seems to be particularly affected by a combination of adjustments in domestic production and imports that cause changes in the supply of sorghum at affordable prices (from 463,000 mt to 513,000 mt) see Table 43.

However, the distributional consequences in the case of sorghum should not be overrated and taken not as serious as with high-value cash crops where producers and consumers are distinct entities. As 60 – 70% of sorghum falls under home consumption the distinction between consumer and producers is somewhat arbitrary.

Inspection of the scenario differences with regard to volume of production and consumption (Table 41) shows only small changes despite the fact that some scenarios ('High' and 'Trade 2') run on high price elasticity values. An obvious result is that 'High' and 'Trade 2' scenario cause markets to expand from 460,000 mt (no research) to 525,000 ('high') and 514,000 mt ('trade 2') but the expansion in market size is small compared to the status-quo market framework. It is reasonable to conclude that the variation in producer and consumer surplus across scenarios is large driven by price effects rather than volume effects.

Table 41: Market & trade scenarios for sorghum: quantitative effects and market size

(ø per year) in '000 mt	No Research	Base Run	Low	High	Trade 1	Trade 2
		Status Quo market framework	Low domestic market integration	High domestic market integration	Liberalized cross-border trade	Liberalized cross-border & domestic trade
Market Size	463.3	501.4	495.7	525.2	498.1	513.9
Production	408.3	419.1	413.3	441.0	422.7	443.0
Consumption	458.3	466.8	461.3	488.6	462.4	476.7
Import	55.0	52.8	53.3	53.3	46.1	40.7
Export	5.0	5.2	5.3	5.7	6.4	7.0
Ex-Im	-50.0	-47.7	-48.0	-47.6	-39.7	-33.7

Source: own calculations

Table 42 summarises the scenario results on a regional base. An obvious finding is that the major production regions (Teso and Northern) remain largely unaffected with low variation between 7.8 and 8.4% while minor production regions including the net consumer regions differ at a much larger scale (above 100%). The reason is, as explained above, that minor production areas have a higher relative share in consumption where the high variability in consumer surplus affects the overall variability in a given region.

Table 42: Market& trade Scenario: Welfare effects by regions

Economic Surplus (TS) in '000 USD	Base Run	Low	High	Trade 1	Trade 2	Variability in %*
Teso	81,779	85,439	87,304	82,640	88,166	**7.8**
Karamoja	5,184	5,207	4,178	7,105	5,584	70.1
Northern	29,251	29,060	30,409	28,060	29,530	**8.4**
West Nile	5,334	5,261	6,627	3,204	4,957	106.8
Rest of Uganda	7,826	7,696	10,229	3,834	7,117	166.8
Southern Highlands	-3,819	-3,777	-4,900	-1,879	-3,438	160.8
Total Uganda	125,555	128,886	133,845	122,964	131,917	

* highest-lowest)/lowest value Source: own calculations

Adoption and yield scenarios

Adoption rates and yields are the two key impact factors that determine the size of the research induced supply shift and thus the magnitude of the welfare gains. In the elicitation process, adoption rates and yield effects are subject to a multitude of different assumptions on which future trends in those variables are based on. In the absence of quantitative forecasting methods (lack of adoption time series), the best way to capture the surrounding uncertainties is to conduct sensitivities analyses and test the robustness of the impact results for a range of likely values for adoption rate and yield effects. Because of the rather conservative baseline values, only the upside value range was tested with +20% & 40% above baseline for the maximum adoption rate and yields from improved varieties.

Table 43: Adoption and yield scenarios: economic surplus by variety

'000 USD	Scenario					
	Base Run	A. Rate +20%	A. Rate +40%	Yield Incr. +20%	Yield Incr. +40%	Spread in %*
Total Surplus	125,555	156,271	182,693	163,293	196,494	56.5
Producer Surplus	76,642	95,614	111,878	99,879	120,266	56.9
Consumer Surplus	48,913	60,657	70,815	63,414	76,228	55.8
	Internal Rate of Return by Variety					
Seso 1	46.7	48.8	50.0	48.9	51.3	9.9
Seso 2	28.3	32.9	34.2	33.1	34.6	22.3
Seso 3	35.5	39.1	40.6	39.5	41.1	15.8
Epuripur	51.0	54.1	55.8	54.9	57.2	12.2
Sekedo	59.8	62.9	64.6	63.2	65.2	9.0
New	42.8	46.9	49.3	47.9	51.0	19.2

*highest-lowest)/lowest value Source: own calculations

Table 43 summarizes the major results. Higher adoption rates and yield effects simply amplify the impact dynamic without changing much the distribution pattern between consumers and producers, or between regions (Table 44). Thus, it stands in sharp contrast to the effects from different markets and trade environments. An increase in the adoption level or yield level of 40% over the baseline generate welfare gains of over 50% and raises the IRR for the sorghum varieties by 10% to 23%. Table 44 shows the equal spread of the gains across regions, regardless of market size or type of market.

Table 44: Adoption and yield scenarios: economic surplus by sub-region

Economic Surplus (TS) in '000 USD	Scenario					
	Base Run	A. Rate +20%	A. Rate +40%	Yield Incr. +20%	Yield Incr. +40%	Spread in %*
Teso	81,779	103,383	120,885	107,435	128,811	57.5
Karamoja	5,184	6,081	7,106	6,828	8,592	65.7
Northern	29,251	35,259	41,208	36,874	44,402	51.8
West Nile	5,334	6,571	7,673	6,950	8,419	57.8
Rest of Uganda	7,826	9,707	11,334	10,149	12,203	55.9
Southern Highlands	-3,819	-4,730	-5,514	-4,943	-5,933	55.3
Total Uganda	125,555	156,271	182,693	163,293	196,494	

*highest-lowest)/lowest value Source: own calculations

7. Impact Analysis for Finger Millet

7.1. Defining the Varieties, Impact Zones and Performance Parameters

Finger Millets experts at the workshop decided to differentiate homogeneous production for assessing the varietal performance according to a four-region scheme that is identical to the first-level administrative structure for Uganda. This scheme was considered as appropriate as it basically reflects the regional focus in finger millet breeding and the suitability of the varieties. 25 districts, 1 from the Central, region, 7 districts in the Eastern and the Western region each, and 10 districts in the northern region were chosen based on two features: the importance of finger Millet production and relevance with regarding to improved varieties at the current stage and potential in the future for significant adoption (Table 45). The selected districts make up 24% of Uganda's population. The same percentage holds true in terms of adult equivalent Table 46). Urbanization is lower than national average, which implies rural AE is lightly higher and urban AE (16%) is considerably lower than national average. All districts combined cover 84% of national finger millet production, high enough to capture the ecological diversity and economic impact potential.

Table 45: Sub-regions as homogenous impact zones for finger millet

Central Region	Eastern Region	Northern Region	Western Region
Districts	Districts	Districts	Districts
Nakasongola	Soroti Tororo Pallisa Kamuli Butaleja Bukedea Kaliro	Amuru Arua Pader Dokolo Apac Kitgum Kotido Gulu Lira Oyam	Ntungamo Rukungiri Kanungu Bushenyi Ibanda Kyenjojo Kiruhura

Source: own table

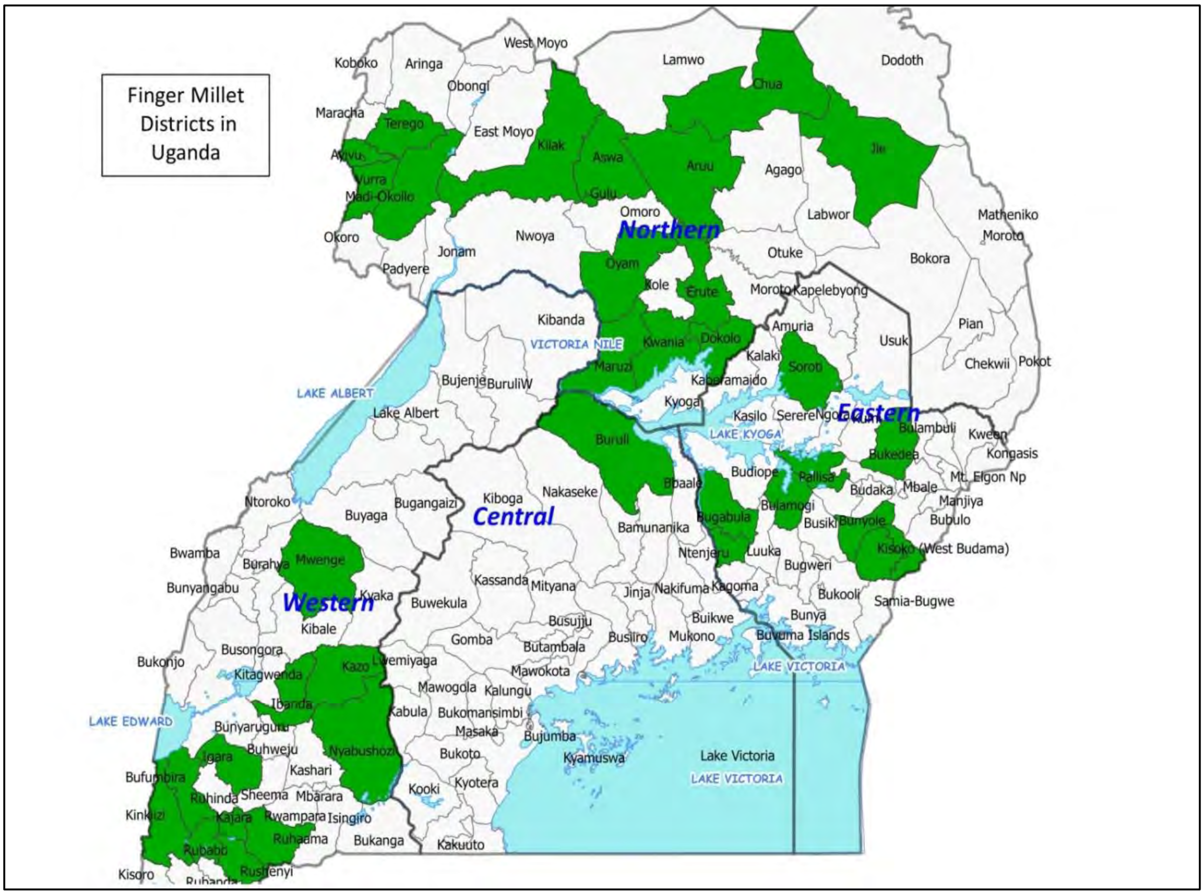
Table 46: Key Indicators of the finger millet sub-regions

Region	Population (Proj. 2012)	Population (Adult Equivalent)	Rural Adult Equivalent	Urban Adult Equivalent	Cereal Production in Season 2008/09 (mt)		
					Sorghum	Finger Millet	Maize
Central	156,500	83,094	46,948	36,146	0	9,674	251,050
Eastern	2,297,300	1,144,712	764,667	380,044	82,389	90,621	120,723
Northern	3,379,200	1,707,016	1,450,963	256,052	120,016	70,263	121,708
Western	2,244,800	1,138,202	1,005,032	133,170	30,275	62,642	499,856
Subtotal	8,077,800	4,073,023	3,267,611	805,412	232,680	233,200	993,337
% share of national level	23.67	23.38	26.56	15.73	53.51	84.21	42.06

Source: Source: Own calculations, based on data from ICRISAT (2012)

Apart from finger millet, the districts cover 50% of the Sorghum and 42% of the national maize production. Finger millet production accounts for 233,000 mt, out of 277,000 mt for the entire sector (Table 47). Production by AE is 3.6 times higher and consumption is 1.8 times higher than national level. Despite high per capita (AE) consumption, only 42% are consumed in the districts as a result of a low population density. The surplus of 116,000 mt is traded with consumers from other part of Uganda.

Map 3: Finger Millet Districts in Uganda



Source: own map, based on administrative layers from http://www.diva-gis.org/

Table 47: Production and Consumption Balance in the Finger Millet Districts

Region	Production (mt)	Production (AE in kg)	Consumption (mt)			Consumption (AE in kg)	Surplus / Deficit mt
			Total	Urban	Rural	Total	
Central	9,674	116.42	242	93	148	2.91	9,432
Eastern	90,621	79.16	28,658	2,951	25,707	25.04	61,963
Northern	70,263	41.16	49,110	6,223	42,887	28.77	21,153
Western	62,642	55.04	38,573	3,213	35,360	33.89	24,069
Subtotal	233,200	57.25	116,583	12,480	104,103	28.62	116,617
% share of national level	84.21	360.17	42.23	25.69	45.76	180.61	

Source: Own calculations, based on data from ICRISAT (2012)

List of improved finger millet varieties for assessment

Local varieties occupy 90 % of cultivation. However, new varieties are increasing recently, with high yielding capacity and resistance against Pyricularia grisae, etc. Five varieties released from Serere Agric. Animal Research Institute (SAARI) are Engenyi (1969), Gulu E (1970), Serere 1 (1985), PESE 1 and PESE 2 (1995), all of which mature in 100 days, and PESE varieties have a yielding capacity of 2,000–3,500 kg/ha. Recently, a very early variety Seremi 2 which can mature in 70–90 days was released.

Table 48: List of Improved finger millet varieties and their characteristics

Variety	Start of research	Year of Release	Breeding institution	Use	Positive traits	Regional coverage
			Old varieties			
Engenyi	1965	1969	NaSARRI	Food, Brewing	early maturing, tolerant to drought, blast and lodging	country wide but most common in Teso region
Gulu E	1966	1970	NaSARRI	Food, Brewing	high yielding, tolerant to blast	country wide but most common in the Northern region
Serere 1	1966	1970	NaSARRI	Food, Brewing	resistant to blast	common in the Teso region
Pese 1	1978	1982	NaSARRI	Food, Brewing	high yielding, responsive to inputs	country wide
			New varieties			
Seremi 1	1998	2002	NaSARRI	Food, Brewing	early maturing, drought tolerant	localised in Eastern and Northern Uganda
Seremi 2	1998	2002	NaSARRI	Food, Brewing, Confectionary	very early maturing, most drought tolerant, tolerant to blast, favourable seed colour	country wide
Seremi 3	1998	2002	NaSARRI	Food, Brewing	high yielding, good aroma and taste	localised in Eastern and Northern Uganda
			Varieties under development			
Sec 915	2007	2013	NaSARRI	Food, Brewing	tolerant to blast, high yielding, medium maturity	
FMS-02-383	2007	2013	NaSARRI	Food, Brewing, Confectionary	high yielding, tolerant to blast and lodging	
FMS-02-53	2007	2013	NaSARRI	Food, Brewing, Confectionary	high yielding, tolerant to blast and lodging	

Source: own table

Current and future adoption rates for finger millet

Table 49 summarizes the experts' assessment of the current and future adoption level. In the absence of exact data from national agricultural statistics experts examined the current volume in seed production and combined it with their field experience from the major millet growing area. They estimated that currently around 12 % of finger millet production in the Northern region comes from improved varieties with Pese 1 and Seremi 2 as the predominant varieties. The current adoption rate in the Eastern and Western region has been assessed at 6.6% and 4.5%. The experts' predict for the next 10 years a positive trend and forecast a more than twofold rise in the adoption level across all major regions. Much of the increase they attributed to release of the three new varieties and further spread of Pese 1 and Seremi 2.

Table 49: Current and future adoption rates of improved finger millet varieties

Variety		Engeny	Gulu E	Serere 1	Pese 1	Seremi 1	Seremi 2	Seremi 3	Sec 915	FMS-02-383	FMS-02-53
Region	Cumulative adoption rate	Current adoption rate in % of production (year 2013)									
Northern	**12.09**	0.00	1.39	0.00	4.38	0.00	5.23	0.61	0.48	0.00	0.00
Eastern	**6.61**	0.75	0.39	0.09	2.49	0.09	2.04	0.42	0.33	0.00	0.00
Western	**4.45**	0.00	0.00	0.00	1.00	0.00	3.45	0.00	0.00	0.00	0.00
Central	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cumulative adoption rate	Future adoption rate in % of production (year 2023)									
Northern	**26.72**	0.00	2.07	0.22	3.73	0.22	4.88	0.77	4.94	4.94	4.94
Eastern	**20.56**	0.33	0.74	0.18	2.32	0.11	3.32	0.73	4.50	4.17	4.17
Western	**15.08**	0.00	0.00	0.00	1.42	0.00	2.95	0.79	3.31	3.31	3.31
Central	**4.00**						1.00		1.00	1.00	1.00

Source: own calculations from workshop data

Profitability

Profitability comparisons between local and improved finger millet varieties are presented in Table 50. Yield increase is assumed identical to revenue increase with no price differences between local and improved varieties. Also the profitability was discussed for the Eastern and Western region and agreed to be fairly similar across all varieties. Yields of local varieties are low, between 600-700 kg/ha only. First and second generation improved varieties have better yield and yield performance. Yield levels of improved varieties are significant higher than for local varieties and increase further with the younger generations. All three varieties under development are expected to outperform all others by a large margin at yield levels between 1,700 – 1,900 kg/ha.

Table 50: Yields and profitability of improved and local finger millet varieties by sub-region

Region	local variety	Improved varieties									
		Engenyi	Gulu E	Serere 1	Pese 1	Seremi 1	Seremi 2	Seremi 3	Sec 915	FMS-02-383	FMS-02-53
mt/ha		Yields									
Northern	700	850	950	900	1,300	1,020	1,100	1,220	1,700	1,900	1,700
Eastern	600	750	850	800	1,200	920	1,000	1,120	1,600	1,800	1,600
Western	600	750	850	800	1,200	920	1,000	1,120	1,600	1,800	1,600
Central	600	750	850	800	1,200	920	1,000	1,120	1,600	1,800	1,600
Profitability: revenues and costs in USD/ha											

Northern	Revenue	969	1,176	1,315	1,245	1,799	1,411	1,522	1,688	2,352	2,629	2,352
	Costs	367	388	402	395	451	412	423	440	507	535	507
Eastern	Revenue	890	1,112	1,260	1,186	1,779	1,364	1,483	1,661	2,372	2,669	2,372
	Costs	367	392	408	400	465	419	432	452	530	563	530
Western	Revenue	890	1,112	1,260	1,186	1,779	1,364	1,483	1,661	2,372	2,669	2,372
	Costs	367	392	408	400	465	419	432	452	530	563	530
Central	Revenue	890	1,112	1,260	1,186	1,779	1,364	1,483	1,661	2,372	2,669	2,372
	Costs	367	392	408	400	465	419	432	452	530	563	530

Source: own calculations from workshop data

Research costs

The same representative research budget (USD 191,650) as for Sorghum is applied to Finger Millet and then discounted in the same way as explained under the research cost section for sorghum. However, research costs attributed to individual varieties vary with the length and timing during the breeding stage.

DREAM model set-up for finger millet

The market structure in the 'DREAM' model (Table 51) consists of 8 partial markets: the four impact regions with its districts, the 'Rest of Uganda' market that subsumes residual supply and demand, and the two trade markets RoW Imports and RoW Exports. The capital Kampala is treated as a separate market due to its high consumption share and interest in how much of the research benefits go into the Capital's consumers.

Table 51: 'DREAM' Model Market Configuration

Markets in the DREAM model	Supply	Demand	Surplus / Deficit	Price level	Elasticity		Discount rate %	Exogenous growth %	
	mt	mt	mt	USD/mt	S	D		S	D
Northern	70,263	49,110	21,153	327.6	1.1	-1.1	5	0	0
Eastern	90,621	28,658	61,963	408.4	1.1	-1.1	5	0	0
Western	62,642	38,573	24,069	538.9	1.1	-1.1	5	0	0
Central excl. Kampala	9,674	242	9,432	554.5	1.1	-1.1	5	0	0
Rest of Uganda (RoU) excl. Kampala	43,735	141,468	-97,733	477.0	1.1	-1.1	5	0	0
Kampala	0	18,034	-18,034	559.8	1.1	-1.1	5	0	0
Sub Total	276,935	276,085	850						
RoW Imports	250		250	320	2.2				
Row Exports		1,100	-1,100	600.0		2.2			
Total	277,185	277,185	0						

Source: own calculations

Market prices: Prices for the DREAM model are taken from ICRISAT (2012) consumer report at sub region level and then transposed to the region level as price weighted by the sub-regional production share. The average national price is set for the RoU market that spans across all regions. Prices for cross border trade are not from an empirical source[5] but chosen to fit domestic prices. Export prices are set above the highest domestic price (Kampala) and the import price set below the lowest domestic price (Northern Region). Otherwise it would be more profitable to sell or buy from the domestic market.

Price Elasticity: In the absence of empirical coefficients for Finger Millet in Uganda, the own price elasticity for finger millet demand is taken from the ICRISAT demand survey for Ethiopia (Schipmann 2012, ICRISAT, 2012) at η_p = -1-1. The same value is chosen for the supply elasticity at ε_p = +1.1. Higher η_p & ε_p compared to sorghum is a reasonable assumption as finger millet is perceived as a more price responsive market crop compared to sorghum with its strong connotation as subsistence crop and low elasticity. Export supply and import demand elasticity is set as two times the value of its corresponding domestic elasticities at (+-) 2.2. Foreign export demand and import supply are defined as extremely elastic with a value of (+-) 100.

Exogenous growth: There is no clear production trend over the last 10 years that supports positive or negative exogenous growth rate. As with finger millet demand, population growth above 3% level indicate higher future demand, but no long-term demand data are available that allow to determine the magnitude of demand growth as other factors such as income elasticity and cross-price elasticity are relevant too.

7.2. Baseline Model Results for Finger Millet

Examination of the baseline results in Table 52 shows a diverse performance of the 10 finger millet varieties under examination. In terms of Internal Rate of Return (IRR) the 1st generation and part of the 2nd generation varieties perform poorly, with 3 varieties having IRR below 15%. ICRISAT scientists at the ESA Regional Office report difficulties during the early stage of finger millet breeding in Uganda which they claim to be caused by poor quality and inappropriate parental breeding lines that were not particularly suitable to local conditions and very simple breeding technologies.

With better suited parental material introduced into the National program afterwards and significant advances in breeding technologies such as genetic markers, the 2nd generation Finger Millet varieties released in 1998 constitute a significant advance. Especially ‘Pese 1’ and ‘Seremi 2’ are the best performing varieties up to date with IRR of 96.5 % and 107 %. All 3 varieties under development that are expected to be released soon over the next few years are promising with an IRR range of 80 % – 90 %, based on the optimistic assumptions the workshop experts with regard to future yield gains and adoption uptake.

Over the entire 64 years (1965 – 2030) the finger millet breeding program generates economic returns of USD 2.5 Mio. on an annual base and with only USD 25,550 of research costs (inflation adjusted). In aggregated terms, the total returns amount to USD 163 Mio. and research costs USD 2.5 Mio.

[5] Trade data for Finger Millet in Uganda from FAOSAT are not consistent as a result of the erratic nature cross border trade and few data price data points.

Table 52: Baseline results for finger millet by variety

	Economic Surplus ('000 USD)			('000 USD)		
	PS	CS	TS	Research Costs	TS - Costs	**IRR %**
Old Varieties						
Engeny	291	322	613	123	491	**16.0**
Gulu E	976	1,493	2,470	123	2,347	**30.6**
Serere 1	142	189	331	123	208	**10.9**
New Varieties						
Pese 1	9,203	11,542	20,745	123	20,622	**96.5**
Seremi 1	146	211	356	135	222	**14.7**
Seremi 2	7,109	7,643	14,752	135	14,618	**107.3**
Seremi 3	2,063	2,111	4,174	135	4,039	**39.9**
Varieties under development						
Sec 915	17,829	19,091	36,921	247	36,673	**79.2**
FMS 02 383	22,126	23,638	45,764	247	45,517	**88.0**
FMS 02 53	18,125	19,405	37,530	247	37,283	**83.3**
Total Uganda	**78,009**	**85,646**	**163,655**	**1,635**	**162,019**	
Economic Surplus/Year	1,279	1,404	2,683	26.81	2,656	

Source: own calculations

Returns to research are fairly equally spread among the three major production regions in the North, East and West with each region generates around USD 40 Mio. over time (Table 53). The returns for the Central region are negative as it is basically a non- adoption region and confronted with lower market prices that spill-over from the production increase in the other regions. The Capital Kampala with an annual consumption of 18,000 mt captures USD 5.5 Mio as consumers pay lower prices in the market.

Table 53: Baseline results for finger millet by markets

Region	Economic Surplus ('000 USD)			('000 USD)		% of Total Surplus by Region
	PS	CS	TS	Research Costs	TS - Costs	
Northern	25,837	15,289	41,126		39,491	25.1
Eastern	39,535	8,900	48,434		48,434	29.6
Western	27,200	11,944	39,144		39,144	23.9
Central excl. Kampala	-1,267	74	-1,193		-1,193	-0.7
Rest of Uganda (RoU) excl. Kampala	-13,295	43,857	30,562		30,562	18.7
Kampala	0	5,581	5,581		5,581	3.4
Total Uganda	78,009	85,646	163,655	1,635	162,019	100

Source: own calculations

How much impact has been achieved in the past and how much is expected in the future can be studied from Table 54. Out of the USD 163 Mio.in total surplus only a disappointing

14 % (USD 23 Mio, USD 0.5 Mio. annually) has been realized since 1965 until now due to the poor performance of the 1st and 2nd generation varieties. The old varieties are about to disappear completely and replaced by the 2nd generation and the new varieties. The prospects for the future are bright as the new promising varieties enter favourable market conditions and attractive prices. Model results forecast returns of USD 140 Mio. for the next 17 years between 2013 and 2030 which translates into USD 8.2 Mio. per year if the new varieties perform well as assumed by the experts. It is up to the concerned institutions, such as NARS, extension services and seed companies to provide the necessary support that so that the potentials in the new varieties can be fully exploited.

Table 54: Baseline results for finger millet: past and future impact

by Region	Economic Surplus ('000 USD)				by Variety	Economic Surplus ('000 USD)			
	Past Surplus	Past Surplus in % of Total	Future Surplus	Total Surplus		Past Surplus	Past Surplus in % of Total	Future Surplus	Total Surplus
Northern	7,925	**19.3**	33,201	41,126	Engeny	594	**96.9**	19	613
Eastern	5,932	**12.2**	42,502	48,434	Gulu E	2,344	**94.9**	126	2,470
Western	4,763	**12.2**	34,381	39,144	Serere 1	312	**94.3**	19	331
Central	-428	**35.8**	-766	-1,193	Pese 1	8,785	**42.3**	11,960	20,745
RoUganda	4,528	**14.8**	26,034	30,562	Seremi 1	190	**53.4**	166	356
Kampala	832	**14.9**	4,749	5,581	Seremi 2	9,408	**63.8**	5,345	14,752
					Seremi 3	1,512	**36.2**	2,662	4,174
					Sec 915	117	**0.3**	36,804	36,921
					FMS 02 383	161	**0.4**	45,603	45,764
					FMS 02 53	132	**0.4**	37,398	37,530
Total Uganda	23,553	14.4	140,102	163,655	Total Uganda	23,553	14.4	140,102	163,655
Annual	491		8,241	2,557					

* excl. Kampala Source: own calculations

7.3. Modelling Scenarios and Results for Finger Millet

Sensitivity analyses for Finger Millet are carried out in the same fashion as it was done for Sorghum: on the one hand to test different market& trade behaviour and on the other hand to raise yield effects and adoption rate above the initial levels. Scenarios are configured by modifying the parameter values of the own-price elasticity in the domestic and foreign markets, see Table 55. In addition, the 'liberalized cross-border trade' raises the initial volume in cross border trade while preserving the initial net trade surplus at 850 mt. The effect is that, because of linear S&D functions and point elasticity in the 'DREAM' model, trade volumes react more vividly to research induced supply shifts.

Table 55: Model Configuration for Sensitivity Analyses in Markets & Trade

	Trade regime	Status Quo market (0)	Low domestic market integration (1)	High domestic market integration (2)	Liberalized cross-border trade (3)	
	Parameters	Base Run	Low domestic Price Elasticity	High domestic Price Elasticity	High cross border trade elasticity and	Higher volume in cross-border trade
Domestic Market	(ε_p)	1.1	0.2	2.5	1.1	
	(η_p)	-1.1	-0.2	-2.5	-1.1	
Foreign Markets	(ε_{im})	2.2	2.2	2.2	10	10,000 mt (im)
	(η_{ex})	-2.2	-2.2	-2.2	-10	10,850 mt ex)(

Source: own calculations

Results from sensitivity analyses in finger millet

Table 56 highlights the major results for the markets & trade part. Closer inspection reveals a similar pattern with the results for Sorghum. Total economic surplus remains unaffected regardless of how domestic markets and foreign trade are specified. On the other hand the distributional consequences for producers and consumers are obvious and range between +-30 % across all scenarios. The ‘cross border trade’ scenario stands out above all others as it shows the highest distributional effects in favour of producers. Cross border trade dampens price variation and a sharp fall in domestic prices by adjusting exports and imports in line with the price differentials between domestic and external markets. Thus, higher prices in the domestic markets favour the local producers but reduce the benefits to consumers who pay more for finger millet in the market place.

Table 56: Market & trade scenarios for finger millet by surplus and region

Economic Surplus (in ‘000 USD)	Status Quo market (0)	Low domestic market integration (1)	High domestic market integration (2)	Liberalized cross-border trade (3)	Variability in %
Total Surplus	163,655	161,261	166,379	163,845	3.17
Producer Surplus	78,009	77,993	79,534	100,299	28.60
Consumer Surplus	85,646	83,268	86,844	63,546	36.66
by Region					
Northern	41,126	40,789	41,842	42,879	5.12
Eastern	48,434	48,393	49,649	53,518	10.59
Western	39,144	38,261	39,139	41,129	7.49
Central excl. Kampala	-1,193	-1,140	-1,191	-455	162.53
Rest of Uganda (RoU) excl. Kampala	30,562	29,522	31,294	22,631	38.28
Kampala	5,581	5,436	5,645	4,143	36.23
Total Uganda	163,655	161,261	166,379	163,845	3.17

*highest-lowest)/lowest value Source: own calculations

Another interesting observation from Table 56 is the fact that smaller markets like the Central region inflict the higher variations. Large markets tend to be more resilient -in relative terms- with regard to external shocks and changes in market supplies from neighbouring and foreign markets.

The percentage increase in yields and adoption rates of 40 % allocates the additional economics surplus in fairly equal proportions among consumers and producers, as can be studied from Table 57. If adoption profiles and yield effects vary across the varieties and important varieties have a particular regional focus, the stream of research gains can become distorted across regions and varieties.

Table 57: Adoption and yield scenarios: results by variety

	Base Run	Adoption Rate +40% above Baseline	Yield Increase +40% above Baseline	Spread in %*
Total Surplus	163,655	229,207	242,336	48.1
Producer Surplus	78,009	109,485	115,613	48.2
Consumer Surplus	85,646	119,722	126,723	48.0
	Internal Rate of Return by Variety			
Engeny	16.0	19.0	23.3	45.6
Gulu E	30.6	35.7	36.3	18.6
Serere 1	10.9	13.9	14.1	29.4
Pese 1	96.5	108.0	110.1	14.1
Seremi 1	14.7	22.0	20.0	36.1
Seremi 2	107.3	120.5	123.4	15.0
Seremi 3	39.9	44.9	46.3	16.0
Sec 915	79.2	86.8	88.1	11.2
FMS 02 383	88.0	96.3	97.6	10.9
FMS 02 53	83.3	91.3	92.8	11.4

*highest-lowest)/lowest value Source: own calculations

8. Poverty and Improved Sorghum and Finger Millet Varieties

Breeding program in dryland cereals that are conducted by ICRISAT and its NARS partners in ESA countries are aimed at providing resource poor farmers in remote areas with better agronomic practices and high performing varieties that help increase and stabilize agricultural income. Poverty comes along with Sorghum and Finger Millet as both crops are grown to a large extent in dry and semi-dry areas with a high prevalence of poverty and underdevelopment. This section gives fresh and quantitative evidence to the notion of sorghum and to a lesser extend Finger Millet as a 'poor man's crop and assess how successful and inclusive the Sorghum and Finger Millet breeding programs were in generating economic benefits for the rural and urban 'poor'. The analysis cannot come up with advanced conclusions regarding the scale of poverty eradication from those improved varieties, but allows a general assessment whether the Ugandan breeding programs are neutral or have a 'poor' or' non-poor' bias in the flow of research benefits.

8.1. Prevalence of Poverty in Uganda

Based on the 2009/10 survey data, 24.5 % of Ugandans are poor, corresponding to nearly 7.5 million persons in 1.2 million households. Table 60 provides more detailed statistics, broken down by region and rural-urban status. The incidence of poverty remains higher in rural areas than in urban areas. The poor in the rural areas represent 27.2 percent of the population but only 9.1 percent in the urban areas. The rural areas with 85 percent of the population constitute 94.4 percent of national poverty. On the other hand, the urban areas represent 15 percent of the population and constitute 5.6 percent of national poverty. These results suggest that the majority of the poor are in rural areas, about 7.1 million out of the 7.5 million poor Ugandans.

National poverty varies significantly by region. The incidence of poverty remains highest in the Northern region and least in the Central region. On average, poverty incidence in Northern region (46.2%) remains higher than the national average (24.5%).

To evaluate poverty trends, results of the UNHS IV 2009/10 with those of UNHS III 2005/06 (Table 58) reveal that the percentage of the people living in poverty (P0) declined from 31.1 % in 2005/06 to 24.5 %. The reduction in poverty was accomplished at a similar pace in the rural and urban region as well as across all regions. Significant progress in fighting poverty has been achieved in the Northern Region, down from 60.7 % in 2009/10 to 46.2 % in 2005/06. The map 4 provides a detailed picture of poverty at a sub-county level and visualizes the strong South-North poverty divide within Uganda. The map also incorporates the main sorghum and finger millet districts that were chosen for the impact analysis.

According to Mukwaya, P. et.al. (2011), there is a direct link between poverty and being engaged in small holder farming as the main source of income. Results presented in Table 59 shows a decline in poverty prevalence in recent years for households whose main source of income is from agriculture (from 34.7 % in 2005/06 to 28.6 % in 2009/10). However, for the three main principal sources of income for Ugandan households, it is those households that engage in agriculture that are the poorest. This is confirmed by the depth and severity of poverty measures – poor agricultural households are shown to be poorer than households below the poverty line who obtain their income from wage employment or non-agricultural enterprises. Agriculture, as the principal source of income for rural households in Uganda, is not as effective in boosting the welfare levels those engaged in the sector above the poverty line as does engagement in wage employment or non-agricultural enterprises, types of work generally pursued in urban areas.

Table 58: Poverty measures in the UNHS III, 2005/06 and UNHS IV 2009/10

Location	Pop. share	Poverty estimate UNHS IV 2009/10			Contribution to:	Poverty estimate UNHS III, 2005/06			Contribution to:
		P0[6]	P1[7]	P2[8]	P0	P0	P1	P2	P0
National	100	24.5	6.8	2.8	100	31.1	8.8	3.5	100
Residence									
Rural	85	***27.2***	7.6	3.1	94	***34.2***	9.7	3.9	93.2
Urban	15	***9.1***	1.8	0.6	5.6	***13.7***	3.5	1.4	6.8
Region									
Central	26.5	10.7	2.4	0.8	12	16.4	3.6	1.3	15.4
Eastern	29.6	24.3	5.8	2.1	29	35.9	9.1	3.5	29
Northern	20	46.2	15.5	7.3	38	60.7	20.7	9.2	38.5
Western	24	21.8	5.4	2	21	20.5	5.1	1.8	17

Source: UBOS, 2007; UBOS, 2010

Table 59: Poverty measures by main source of income, 2005/06 and 2009/10

	Poverty headcount (p0) in %		Depth of poverty (p1)		Severity of poverty (p2)	
	2005/06	2009/10	2005/06	2009/10	2005/06	2009/10
Agriculture	34.7	28.6	0.094	0.077	0.037	0.03
Wage employment	23.3	17.1	0.064	0.043	0.025	0.017
Non-agricultural enterprise	20.4	22.1	0.053	0.066	0.021	0.031

Source: UBOS, 2010

[6] The P0 indicator is "headcount": the percentage of individuals estimated to be living in households with real private consumption per adult equivalent below the poverty line for their region. Thus a P0 of 24.5 implies that 24.5 percent of Ugandans are estimated to live in households which spend less than what is necessary to meet their caloric requirements and to afford them a mark-up for non-food needs. The headcount shows how broad poverty is, although not necessarily how deep.

[7] The P1 indicator is the "poverty gap". This is the sum over all individuals of the shortfall of their real private consumption per adult equivalent from the poverty line, divided by the poverty line. One way to interpret the P1 is that it gives the per capita cost of eradicating poverty, as a percentage of the poverty line, if money could be targeted perfectly.

[8] The P2 indicator is the "squared poverty gap". This is the sum over all individuals of the square of the shortfall of their real private consumption per adult equivalent and the poverty line divided by the poverty line. The reason to square the shortfall is to give greater weight to those who are living far below the line. In brief, whereas P0 measures how widespread poverty is, P1 measures how poor the poor are and, by giving more weight to the poorest, P2 gives an indication of how severe poverty is.

8.2. Poverty in the Sorghum and Finger Millet Sector

An accurate account of poverty can be best achieved by incorporating estimations from the producer and consumer side in combination. However, most impact studies, if at all, take poverty estimates from consumer analyses that are derived from the data base of national Household Budget Surveys (HBS) commonly found in ESA countries. Less abundant are poverty data in crop production, esp. for the less important dryland cereals. In rare cases, national agricultural surveys take notice of the income and/or consumption levels and differentiate by crop type.

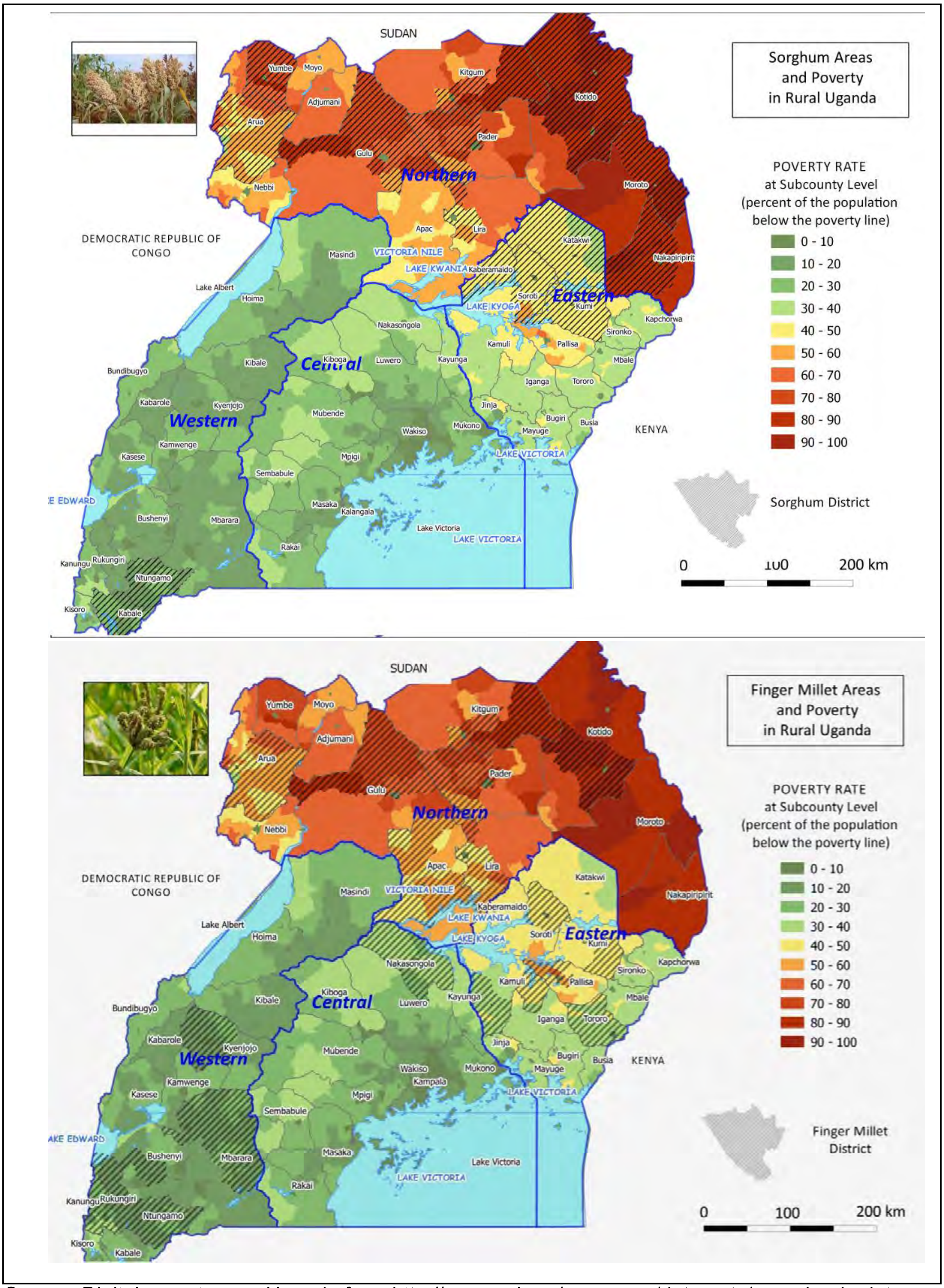
For the above mentioned reason, this analysis takes a simplified approach for the production side and uses district-level rural poverty rates from the Uganda National Household Survey (UNHS, 2005) which is published at 'www.scribd.com/openmicrodata'. These poverty rates serve as proxy for the 'poor' and 'non-poor' shares in sorghum and finger millet production in the resp. districts, but admittedly ignore the 'poverty bias' of dryland cereals versus other cereals as preferred crops as well as yield differences and marketing conditions that persist among producers with different resource endowments.

For the consumption side, ICRISAT (*ICRISAT, 2012*) analysed consumption patterns for Uganda by income groups based on the Uganda National Household Survey (UNHS) 2009/2010 and calculated the 1) annual consumption in kg per adult equivalent by different income groups and 2) share of each income group in the sorghum and finger millet sub-sample. Both combined allows calculating the absolute and proportionate consumption by income group, by sub region including rural-urban divide which can be, in a next step, converted to any other regional grouping used in the analysis. In contrast to previous calculations, it is not possible to differentiate further into sorghum and non-sorghum areas as the data set is incomplete in that regard.

In a next step, income groups (low, middle and high) are assigned to the 'poor' and 'non-poor' category as defined in a different section of the report by breaking up the 'middle income' group into poor (40%) and non-poor (60%) while the low income group was assumed to be 'poor' and the high income group to be 'non-poor'. This way, the general poverty pattern in ICRISAT's 2012 analysis is preserved. Table 62 provides an overview of the poverty rates for both crops.

Table 60 summarizes the poverty rates for sorghum and finger millet that are derived from the set of data described above. In case of sorghum, there is a strong correlation between sorghum areas and rural poverty as sorghum is predominantly grown and consumed in the poverty hotspots in the Northern and Eastern regions (Map 4). Therefore, poverty rates in sorghum are very high. Table 60 shows that 63.5 % of national production come from poor farmers, in consumption the rate is even higher at 77%. Variations in poverty rates within the sorghum growing areas is significant with the Northern region shows the highest percentage of 76 % and the Western region the lowest at 31.4 %. A similar picture prevails on the consumption side, but with the Eastern Region exceeds the Northern region by some margin.

Map 4: Poverty Map for Uganda incl. Major Sorghum and Finger Millet Areas



Source: Digital poverty map Uganda from http://www.wri.org/resources/data-sets/uganda-gis-data

In contrast, finger millet has a much weaker connotation with poverty. At national level, the poverty rate in production is 48.5 % and among consumers approximately 44%. The main reasons are that 1) finger millet production is more evenly spread within Uganda, with a considerable proportion grown in the more prosperous Central and Western Regions, and 2) the positive income elasticity for finger millet which translates into high per capita consumption among the middle and high income classes.

Table 60: Poverty rates in sorghum and finger millet production & consumption

Region	Poverty rates in production			Poverty rates in consumption		
	Total Production (mt)	Production by poor farmers (mt)	Poverty rate in %	Total Consumption (mt)	Consumption by poor households (mt)	Poverty rate in %
Sorghum						
CENTRAL	2,677	808	30.2	4,570	1,347	29.5
Eastern	129,800	73,177	56.4	135,903	117,976	86.8
Northern	239,656	182,328	76.1	264,157	203,844	77.2
Western	62,715	19,715	31.4	53,708	29,024	54.0
Total	434,848	276,028	63.5	458,338	352,192	76.8
Finger Millet						
CENTRAL	13,735	3,607	26.3	37,766	6,967	18.4
Eastern	106,336	55,339	52.0	70,781	35,924	50.8
Northern	79,078	52,310	66.2	61,602	29,173	47.4
Western	77,786	23,140	29.7	106,786	48,895	45.8
Total	276,935	134,396	48.5	276,935	120,958	43.7

Source: own calculations

8.3. Targeting Poverty in the Breeding Programs

A straight way forward to define the extent to which the two breeding programs are targeting the 'poor' in Uganda is to compare the share of poverty in the production and consumption of the crop outlined in Table 60 with the share of research gains from the improved varieties that is allocated to the 'poor'. Comparison is done in a pairwise fashion, the poverty share in production with the share in producer surplus and consumption with consumer surplus. A breeding program can then be labelled as 'poverty neutral' if both shares are similar and 'poverty friendly' if the shares from the research gains going to the 'poor' is considerably higher than the poverty share in the sector.

There are basically two factors that determine the poverty focus of a research program. The first factor is the regional distribution. If research gains have a regional bias towards richer regions like Central and Western regions then the program's impact tends to underrepresent the 'poor' compared to the sector average. The second factor is the distribution of the research gains between producers and consumers. The poverty rates in production and consumption are different for both crops. For example, if a large part of research gains in the sorghum program goes to consumers then the program's poverty share tends to rise because the poverty share in consumption (76.8%) is higher than in production (63.5%).

Table 61 depicts the poverty rates transposed to the region/market structure in the DREAM model. These figures constitute the poverty benchmarks for calculating and comparing the poverty rates from the model results.

Table 61: Poverty rates in the DREAM' model structure

	Sorghum					
	Poverty rate in production			Poverty rate in consumption		
	Total Production (mt)	Production by poor farmers (mT)	Poverty rate in %	Total Consumption (mt)	Consumption by poor HH (mt)	Poverty rate in %
Teso	114,817	66,252	**57.7**	101,718	90,928	**89.4**
Karamoja	108,195	92,254	**85.3**	72,232	65,963	**91.3**
Norther	83,802	61,372	**73.2**	106,636	88,021	**82.5**
West Nile	19,970	11,475	**57.5**	58,997	29,743	**50.4**
South-Western Highlands	44,762	14,767	**33.0**	8,724	1,353	**15.5**
Rest of Uganda	36,792	17,383	**47.2**	110,030	76,185	**69.2**
	Finger Millet					
Northern	70,263	46,557	**66.3**	49,110	23,220	**47.1**
Eastern	90,621	48,050	**53.0**	28,658	15,231	**53.0**
Western	62,642	18,794	**30.0**	38,573	11,919	**30.8**
Central excl. Kampala	9,674	2,355	**24.3**	242	78	**32.1**
Rest of Uganda (RoU) excl. Kampala	43,735	18,641	**42.6**	141,468	69,332	**48.9**
Kampala	0	0	**0.0**	18,884	904	**5.0**
Sub Total	276,935	134,396	**48.5**	276,935	120,958	**43.7**

Source: own calculations

Model results

Table 62 summarizes the findings from the DREAM model and the delineation of the economic surplus estimates into 'poor' and 'non-poor'. Some caution in the interpretation of the results should be exercised in light of the simplistic nature and market mechanism in the DREAM model. However, there seems to be a general observation that poverty rates are very robust across all possible scenarios which holds true for Sorghum and Finger Millet alike despite their distinct function with regard to poverty. In other words, the policy environment such as domestic market integration, intensified cross border trade as well as productivity factors such as higher adoption rates and yield differentials have little bearing on the poverty rates, not in absolute but in relative terms. It raises the economic welfare for the 'poor' but not much beyond the general sector and regional average.

The impact from the Sorghum breeding program in Uganda over the years can be stated as '**poverty neutral'**. Between 67 - 69 % of the total economic surplus is captured by the 'poor' depending on the scenario. The share of producer surplus that goes to the 'poor' (61.7 – 62.5 %) lies slightly below the initial level of around 63.5 %. This can be attributed to the large share of producer surplus generated in the Teso region that has a below average poverty rate of 57.7 %. The welfare gains for farmers alone are approx. 187.7 USD per metric ton, and 181.7 USD for the poor farmers (base run) and increase considerably with the adoption rates and yields +40% scenarios. The gains to consumers per metric ton are 50 % lower ‘across all scenarios, 106.7 USD/mt in the base run.

Table 62: Poverty targeting of the Sorghum and Finger Millet breeding programs

Poverty indicators*	Unit	No research	Base Run	Low market integration	High market integration	Liberalized cross-border trade	Adoption rate +40%	Yield +40%
Sorghum								
Poor TS	'000 USD		85,474	87,266	92,273	88,638	123,983	133,631
Poverty Rate TS	%		**68.1**	**67.7**	**68.9**	**67.2**	**67.9**	**68.0**
Poor PS	'000 USD		47,885	50,278	43,278	54,509	69,563	75,051
Poverty Rate PS	%	**63.5**	**62.5**	**62.3**	**61.7**	**62.3**	**62.2**	**62.4**
Poor CS	'000 USD		37,589	36,989	48,995	34,129	54,420	58,580
Poverty Rate CS	%	**76.8**	**76.8**	**76.8**	**76.9**	**76.9**	**76.8**	**76.8**
Farmers' perspective (Producer surplus in USD per mt production)								
All Farmers	USD/ mt		187.7	197.8	171.7	214.3	274.0	294.5
Poor farmers	USD/ mt		181.7	190.8	164.2	206.9	264.0	284.8
Consumers' perspective (Consumer surplus in USD per mt consumption)								
All Consumers	USD/ mt		106.7	105.0	139.1	96.9	154.5	166.3
Poor Consumers	USD/ mt		106.7	105.0	139.1	96.9	154.5	166.3
Finger Millet								
Poor TS	'000 USD		77,600	76,664	79,015	78,805	108,672	115,175
Poverty Rate TS	%		**47.4**	**47.5**	**47.5**	**48.1**	**47.4**	**47.5**
Poor PS	'000 USD		40,268	40,376	41,150	51,108	56,482	59,932
Poverty Rate PS	%	**48.5**	**51.6**	**51.8**	**51.7**	**51.0**	**51.6**	**51.8**
Poor CS	'000 USD		37,332	36,289	37,865	27,698	52,190	55,243
Poverty Rate CS	%	**43.7**	**43.6**	**43.6**	**43.6**	**43.6**	**43.6**	**43.6**
Farmers' perspective (PS in USD per mt production)								
All Farmers	USD/ mt		281.7	281.6	287.2	362.2	395.3	417.5
Poor farmers	USD/ mt		299.6	300.4	306.2	380.3	420.3	445.9
Consumers' perspective (CS in USD per mt consumption)								
All Consumers	USD/ mt		309.3	300.7	313.6	229.5	432.3	457.6
Poor Consumers	USD/ mt		308.6	300.0	313.0	229.0	431.5	456.7

* TS: total surplus, PS: producer surplus, CS: consumer surplus
Source: own calculations

As with sorghum, the finger millet breeding program can be labelled as ‘**poverty neutral’,** though with above-average targeting of poor farmers at a rate of 51 – 51.8 % compared to

48.5 % as sector average. Finger Millet varieties generate much higher return for farmers per metric tons, between 281 – 417 USD/ mt, and for consumers between 229 – 457 USD/mt but finger millet price/mt is more than double the price for sorghum. Thus returns per ton as percentage to the market value appear to be similar for both crops.

A possible conclusion can be that a ‘poverty focused’ breeding program obviously requires more dramatic steps towards one-sided interventions into the poverty regions with high performing varieties and rapid and widespread uptake. Fair to say, this poverty focus is hard to achieve when the poverty incidence for a crop like sorghum is as high as 63.5 % on the production side and 76.8 % on the consumption side. Not to mention the trade-offs between striving for maximum research impacts in a breeding program and sacrificing some impact for the sake of an exclusively ‘pro-poor’ breeding program that is operating in a low-performance production environment.

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